JEPPIAAR INSTITUTE OF TECHNOLOGY
“Self-Belief| Self Discipline | Self Respect”

QUESTION BANK

REGULATION : 2013

YEAR : III

SEMESTER : 05

BATCH : 2016-2020

DEPARTMENT
OF
ELECTRICAL &ELECTRONICS
ENGINEERING

BLOOM’S TAXONOMY

Definition:

Bloom’s taxonomy is a classification system used to define and distinguish different levels of human cognition like thinking, learning and understanding.

Objectives:

- To classify educational learning objectives into levels of complexity and specification. The classification covers the learning objectives in cognitive, affective and sensory domains.
- To structure curriculum learning objectives, assessments and activities.

Levels in Bloom’s Taxonomy:

- **BTL 1** – **Remember** - The learner recalls, restate and remember the learned information.

- **BTL 2** – **Understand** - The learner embraces the meaning of the information by interpreting and translating what has been learned.

- **BTL 3** – **Apply** - The learner makes use of the information in a context similar to the one in which it was learned.

- **BTL 4** – **Analyze** - The learner breaks the learned information into its parts to understand the information better.

- **BTL 5** – **Evaluate** - The learner makes decisions based on in-depth reflection, criticism and assessment.

- **BTL 6** – **Create** - The learner creates new ideas and information using what has been previously learned.

TABLE OF CONTENT

SYLLABUS

EE6501 **POWER SYSTEM ANALYSIS** **L T P C**

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OBJECTIVES:

- To model the power system under steady state operating condition.
- To apply numerical methods to solve the power flow problem.
- To model and analyze the system under faulted conditions.
- To model and analyze the transient behaviour of power system when it is subjected to a fault.

UNIT I INTRODUCTION 9

Need for system planning and operational studies – basic components of a power system.- Introduction to restructuring - Single line diagram – per phase and per unit analysis – Generator - transformer –transmission line and load representation for different power system studies.- Primitive network -construction of Y-bus using inspection and singular transformation methods – z-bus.

UNIT II POWER FLOW ANALYSIS 9

Importance of power flow analysis in planning and operation of power systems - statement of power flow problem - classification of buses - development of power flow model in complex variables form -iterative solution using Gauss-Seidel method - Q-limit check for voltage controlled buses – power flow model in polar form - iterative solution using Newton-Raphson method .

UNIT III FAULT ANALYSIS – BALANCED FAULTS 9

Importance of short circuit analysis - assumptions in fault analysis - analysis using Thevenin's theorem- Z-bus building algorithm - fault analysis using Z-bus – computations of short circuit capacity, post fault voltage and currents.

UNIT IV FAULT ANALYSIS – UNBALANCED FAULTS 9

Introduction to symmetrical components – sequence impedances – sequence circuits of synchronous machine, transformer and transmission lines - sequence networks analysis of single line to ground,line to line and double line to ground faults using Thevenin's theorem and Z-bus matrix.

UNIT V STABILITY ANALYSIS 9

Importance of stability analysis in power system planning and operation - classification of power system stability - angle and voltage stability – Single Machine Infinite Bus (SMIB) system:Development of swing equation - equal area criterion - determination of critical clearing angle and time– solution of swing equation by modified Euler method and Runge-Kutta fourth order method.

TOTAL : 45 PERIODS

OUTCOMES:

Ability to understand and analyze power system operation, stability, control and protection.

TEXT BOOKS:

1. Nagrath I.J. and Kothari D.P., 'Modern Power System Analysis', Tata McGraw-Hill, Fourth Edition,2011.
2. John J. Grainger and W.D. Stevenson Jr., 'Power System Analysis', Tata McGraw-Hill, Sixth reprint, 2010.
3. P. Venkatesh, B.V. Manikandan, S. Charles Raja, A. Srinivasan, ' Electrical Power Systems-Analysis, Security and Deregulation', PHI Learning Private Limited, New Delhi, 2012.

REFERENCES:

1. Hadi Saadat, 'Power System Analysis', Tata McGraw Hill Education Pvt. Ltd., New Delhi, 21st reprint, 2010.55
2. Kundur P., 'Power System Stability and Control, Tata McGraw Hill Education Pvt. Ltd., New Delhi,10th reprint, 2010.
3. Pai M A, 'Computer Techniques in Power System Analysis', Tata Mc Graw-Hill Publishing Company Ltd., New Delhi, Second Edition, 2007.
4. J. Duncan Glover, Mulukutla S. Sarma, Thomas J. Overbye, ' Power System Analysis & Design',Cengage Learning, Fifth Edition, 2012.
5. Olle. I. Elgerd, 'Electric Energy Systems Theory – An Introduction', Tata McGraw Hill PublishingCompany Limited, New Delhi, Second Edition, 2012.
6. C.A.Gross, "Power System Analysis," Wiley India, 2011.

Subject Code: EE6501 **Year/Sem: III/05**

Subject Name: Power System Analysis **Subject Handler: Ms. S.Sarumathi**

UNIT I – INTRODUCTION	
Need for system planning and operational studies – basic components of a power system.-Introduction to restructuring - Single line diagram – per phase and per unit analysis – Generator - transformer – transmission line and load representation for different power system studies.- Primitive network - construction of Y-bus using inspection and singular transformation methods – z-bus.	
PART *A	
Q.No.	**Questions**
1.	**State the requirements of planning the operation of a power system.** BTL2 Planning the operation of a power system requires load studies, fault calculations, the design of means for protecting the system against lightning and switching surges and against short circuits, and studies of the stability of the system.
2.	**Define steady state operating condition. (Nov/Dec 2012)** BTL1 A power system is said to be in a steady state operating condition, if all the measured (or calculated) physical quantities describing the operating condition of the system can be considered constant for the purpose of analysis.
3.	**How are the base values chosen in per unit representation of a power system?** BTL3 **Selection of base MVA**: First a base MVA is chosen. The small MVA is used in all parts of the system. It may be the largest MVA of a section, or total MVA of the system or any value like 10,100,1000 MVA etc. **Selection of base KV**: The rated voltage of the largest section may be taken as base KV. The base voltages of remaining section are assigned depends on turn ratio of the transformer.
4.	**Define per unit value. Write the equation for base impedance with respect to three phase system. (Nov/Dec 2015,17)** BTL2 The per unit value of any quantity is defined as the ratio of the actual value of the quantity to the base value expressed as a decimal. The base value is an arbitrary chosen value of the quantity. Per unit value = Actual value / Base value Base impedance / phase, $Z_b = (kV_b)^2 / MVA_b$
5.	**Write the equation for converting the p.u. impedance expressed in one base to another base. (Nov/Dec 2017)** BTL1 $Zpu,new= Zpu,old \times (kVb,old / kVb,new)^2 \times (MVAb,new / MVAb,old)$

6.	**List out the components of power system. (Nov/Dec 2014)** BTL1 The components of power system are • Generators • Power transformers • Transmission lines • Substation transformers • Distribution transformers • Loads
7.	**Why are base values required in power system?** BTL2 The components or various sections of power system may operate at different voltage and power levels. It will be convenient for analysis of power system if the voltage, power, current and impedance ratings of components of power system are expressed with reference to a common value called base value. Hence for analysis purpose a base value is chosen for voltage, power, current and impedance ratings of the components are expressed as a percent or per unit of the base value.
8.	**Define single line diagram. Give it advantages. (Nov/Dec 2011,15)** BTL1 A single line diagram is diagrammatic representation of power system in which the components are represented by their symbols and the interconnection between them are shown by a straight line (even though the system is three phase system).The ratings and the impedances of the components are also marked on the single line diagram.
9.	**State the term bus admittance matrix.** BTL1 The matrix consisting of the self and mutual admittances of the network of a power system is called bus admittance matrix.
10.	**Define bus.** BTL1 The meeting points of various components in a power system are called a bus. The bus is a conductor made of copper or aluminum having negligible resistance. The buses are considered as points of constant voltage in a power system.
11.	**Bring out the applications of Y-bus matrix.** BTL1 • Load flow analysis • Optimal load flow analysis • Stability analysis.
12.	**List out the applications of Z-bus matrix.** BTL1 Short Circuit Analysis (symmetrical and unsymmetrical fault analysis).
13.	**State the purpose of using single line diagram.** BTL2 The purpose of the single line diagram is to supply in concise form of the significant information about the system.
14.	**Define impedance and reactance diagram.** BTL2 The impedance diagram is the equivalent circuit of power system in which the various components of power system are represented by their approximate or simplified equivalent circuits. The impedance diagram is used for load flow studies. The reactance diagram is the simplified equivalent circuit of power system in which the various components of power system are represented by their reactances. The reactance diagram can be obtained from impedance diagram if all the resistive components are neglected. The reactance diagram is used for fault calculations.
15.	**Bring out the approximations made in impedance diagram.(Nov/Dec 2016)** BTL4 The following approximations are made while forming impedance diagram • The natural reactance are neglected. • The shunt branches in equivalent circuit of induction motor are neglected

16.	**Define bus impedance matrix.** BTL1 The matrix consisting of driving point impedances and transfer impedances Of the network of a power system is called bus impedance matrix.
17.	**Write the four ways of adding impedance to an existing system so as to modify bus impedance matrix.** BTL1 1. Adding a branch of impedance Z_b from a new bus-p to the reference bus. 2. Adding a branch of impedance Z_b from a new bus-p to an existing bus-q. 3. Adding a branch of impedance Z_b from an existing bus-q to the reference bus. 4. Adding a branch of impedance Z_b between two existing buses h and q.
18.	**A generator rated at 30 MVA, 11 kV has a reactance of 20%. Calculate it's per unit reactance for a base of 50 MVA and 10 kV.** BTL3 New p.u.reactance of generator, Xpu,new= Xpu,old x (kVb,old / kVb,new)^2 x (MVAb,new / MVAb,old) Here, $X_{pu,old}$ =20%=0.2p.u. , $MVA_{b,old}$=30MVA, $MVA_{b,new}$=50MVA, $kV_{b,old}$ =11KV, $kV_{b,new}$ =50MVA New p.u.reactance of generator = 0.2 x (11/10)^2 x (50/30) =0.403 p.u.
19.	**List the approximations made in impedance diagram.(Or) What are the factors that need to be omitted for an impedance diagram to reduce it to a reactance diagram?** BTL1 1. The neutral reactance are neglected. 2. Shunt branches in the equivalent circuits of transformer are neglected. 3. The resistances are neglected. 4. All static loads and induction motors are neglected. 5. The capacitances of the transmission lines are neglected.
20.	**Name the diagonal and off-diagonal elements of bus admittance matrix. (Nov/Dec 2013)** BTL1 Diagonal elements of bus admittance matrix are called self admittances of the buses and off-onal elements are called mutual admittances of the buses.
21.	**List the two advantages of per-unit Computation.(Nov/Dec 2016)** BTL2 1. Manufacturers usually specify the impedance of a device or machine in per unit 2. The p.u. values of widely different rating machines lie within a narrow range, even though the ohmic values have a very large range. 3. The p.u. impedance of circuit element connected by transformers expressed on a proper base will be same if it is referred to either side of a transformer. 4. The p.u. impedance of a three phase transformer is independent of the type of winding connection.
22.	**Bring out the need for per unit value.(Nov/Dec 2014)** BTL2 1. The p.u. systems are ideal for the computerized analysis and simulation of complex power system problems. 2. Circuit parameters tend to fall in relatively narrow numerical ranges making erroneous data easy to spot.
23.	**Define Primitive impedance matrix.** BTL1 The matrix which contain information about transmission line is called as primitive impedance matrix.
24.	**Why bus admittance matrix is preferred in load flow?** BTL2 - Easy to formulate Ybus matrix - No need of taking inverse

- Computation time is less
- Symmetric matrix

25. **How are the loads represented in reactance or impedance diagram?** BTL2 **(Nov/Dec 2011,16)**

Load is represented by a constant power representation, both the specified MW (P) and MVAR (Q) are taken to account.

PART * B

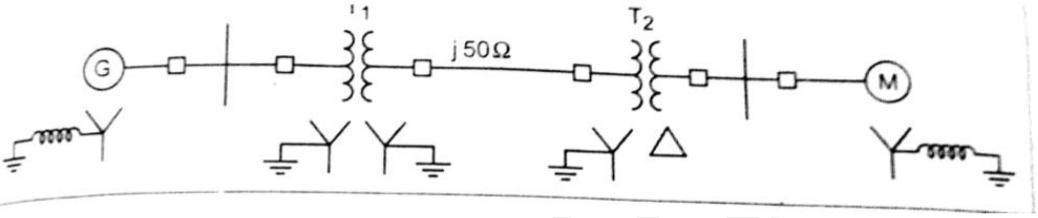
1. **Draw the reactance diagram for the power system shown in Fig. Neglect resistance and use a base of 100 MVA, 220 kV in 50 Ω line. The ratings of the generator, motor and transformer are given below. (May/June 2007) (13 M)** BTL3

Generator: 40 MVA, 25 kV, X" = 20%

Synchronous motor : 50 MVA, 11 kV, X" = 30%

Y – Y Transformer : 40 M VA, 33/220 kV, X = 15%

Y -Delta 30 MVA, 11/220 kV, (delta /Y), X = 15%



Answer: Page S.3- M.Jeraldin Ahila

Z_{actual} and $Z_{p.u.}$for the transmission line: (2 M)

$$Z_{BASE} = \frac{(KV_{LL})^2}{MVA_{3\Phi}}\ (ohms)$$

$$A_{BASE} = \frac{MVA_{3\Phi}}{\sqrt{3}\ x\ KV_{LL}\ x\ 1000}\ (amps)$$

$$Z_{PU} = \frac{Z\ (In\ ohms)}{Z_{BASE}}$$

Z_{PU} = j0.1033 p.u.

$KV_{b\ new}$ for the transformer T1: (2 M)

$$Z_{PU} = Z_{PU\ Given}\ x\ \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2\ x\ \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

Z_{PU} = j0.375 p.u.

$Z_{p.u.new}$ for the transformer T2 : (2 M)

$$Z_{PU} = Z_{PU\ Given}\ x\ \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2\ x\ \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

Z_{PU} = j0.5 p.u.

$Z_{p.u.new}$ for the Generator G1 : (4 M)

Z_{PU} = j0.287p.u

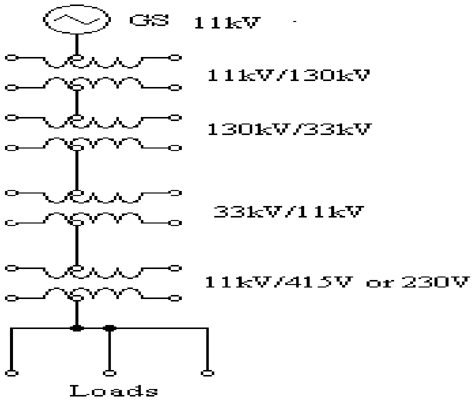
Impedance diagram: (3 M)

2.

Draw the structure of an electrical power system and describe the components of the system with typical values. (Nov/Dec 2014) (13 M) BTL1

Answer: Page 1.2 - M.Jeraldin Ahila

Single line diagram of power system: (5 M)



Generation, transmission and distribution parts: (8 M)

Generation

1. Conversion of one form of energy into another form of energy into electrical energy.
2. Generated from resources like wind waves, fossil fuel-hydro thermal and nuclear power station

Transmission

1. Large blocks of power to bulk power station or very big consumers
2. Primary transmission and secondary transmission

Distribution system

1. Primary distribution-voltage is stepped down to 11 KV or 6.6 KV using step down transformers.
2. Secondary distribution-The voltage is stepped down to 400 V or 230 V using step down transformers.

3.

Explain the modeling of generator, load, transmission line and transformer for power flow, short circuit and stability studies.(13 M) BTL2

Answer: Page 1.10-1.18- M.Jeraldin Ahila

Develop the thevenin and norton equivalent circuit of generator: (2 M)

1. Equivalent circuit of the generator voltage source in series with the thevenin equivalent impedance.
2. Norton form of equivalent circuit is current source in parallel with the admittance

Develop the short line, medium line and long line model for the transmission line:(2 M)

Short line-resistance and inductance are assumed to be lumped

Develop the transformer model for unity turns ratio and non unity turns ratio: (2 M)

Transformer are modeled by a series resistance

short circuit analyse: (3 M)

1. Circuit model for steady state, subtransient and transient current.
2. Circuit model for computing subtransient and transient current in motor
3. Model of transmission line, transformer and load through reactance.

Consider the assumption for transient stability and develop the model: 4 (M)

1. Sometimes, the load change may not be gradual.
2. There may be sudden change of load, switching operation, loss of generation or fault.
3. These types of severe disturbances make the system to fall out of step.

4. This type of stability is called transient stability.

4.

Explain the step by step procedures to be followed to find the per-unit impedance and reactance diagram of a power system. (13 M) BTL1

Answer: Page 2.34 - M.Jeraldin Ahila

Choose a common MVA base : (3 M)

z = actual impedance(Ω) and Z = base impedance (Ω)

Choose an appropriate base KV: (2 M)

Per unit impedance in each section: (2 M)

1. Select a base power kVA_b or MVA_b .
2. Select a base voltage kV_b.
3. The voltage conversion is achieved by means of transformer (formula).

Assumptions: (2 M)

1. Single phase transformer considered to be ideal
2. Magnetization reactance and neutral grounding impedance are neglected
3. Generators represented as voltage source
4. Shunt capacitance are neglected
5. Shunt capacitance are neglected

Impedance diagram : (2M)

z = actual impedance(Ω) and Z = base impedance (Ω)

Reactance Diagram: (2 M)

Drawn from impedance diagram by neglecting all resistances

5.

Write short notes on:

(i)Single line diagram (4M) BTL1

Answer: Page 2.13 - M.Jeraldin Ahila

Significant information about the system

Symbolic representation of the system.

(ii)Change of base (4M) BTL1

Answer: Page 2.4- M.Jeraldin Ahila

- Calculate per unit impedance
- New base value

$$Z_{PU} = Z_{PU\,Given}\ x \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2 x \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

iii) Reactance of synchronous machines: (5M) BTL2

Answer: Page 8.7- M.Jeraldin Ahila

- Demagnetizing flux equation for direct axis synchronous reactance
- Circuit model of synchronous machine.

6.

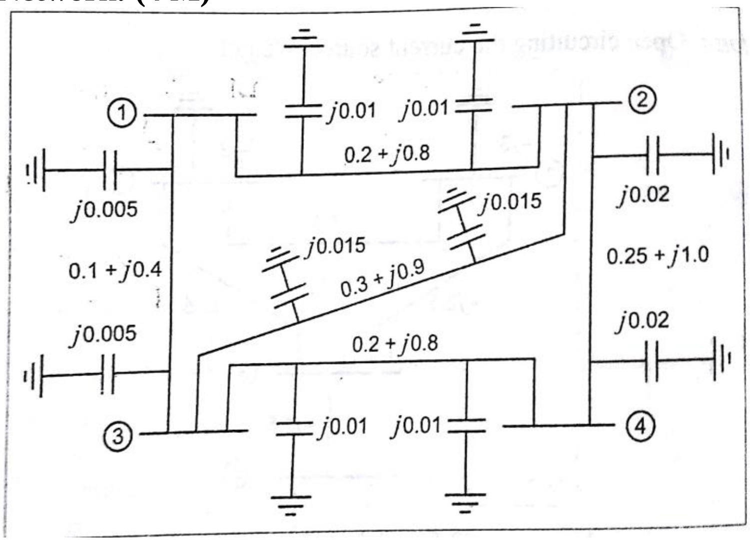
The parameters of a 4-bus system are as under:

Bus code	**Line impedance (pu)**	**Charging admittance (pu)**
1-2	**0.2 + j 0.8**	**j 0.02**
2-3	**0.3 + j 0.9**	**j 0.03**
2-4	**0.25 +j 1.0**	**j 0.04**
3-4	**0.2 + j 0.8**	**j 0.02**
1-3	**0.1 + j0.4**	**j 0.01**

Draw the network and find bus admittance matrix. (Nov/Dec 2011,16) (13 M) BTL3

Answer: Page 1.10- Notes

- **Network: (4 M)**



- **Elements of Y-BUS matrix : (5 M)**
- **Formulate the bus admittance matrix: (4M)**

$$\begin{bmatrix} 0.882-j3.514 & -0.294+j1.176 & -0.588+j2.353 & 0 \\ -0.294+j1.176 & 0.862-j3.072 & -0.333+j1 & -0.235+j0.941 \\ -0.588+j2.353 & -0.333+j1 & 1.215-j4.499 & -0.294+j1.176 \\ 0 & -0.235+j0.941 & -0.294+j1.176 & 0.529-j2.088 \end{bmatrix}$$

7.

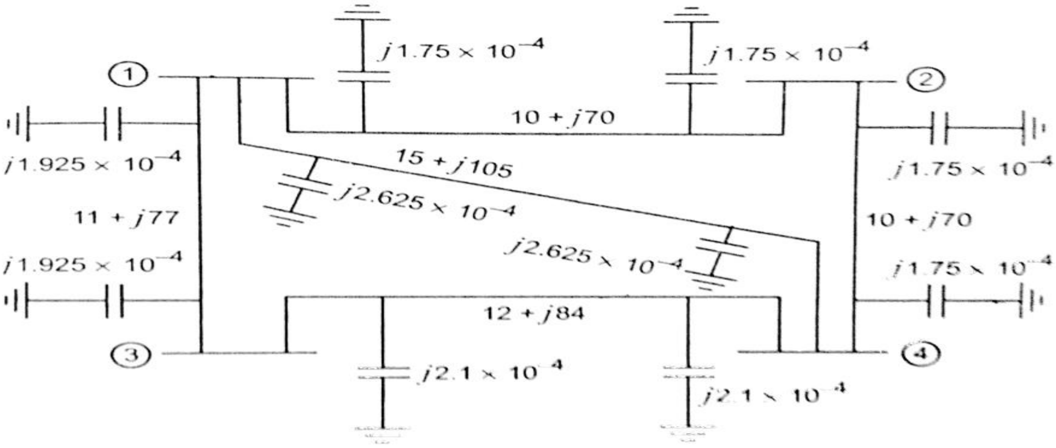
Find the bus admittances matrix for the system shown below. Use the values of 220 KV and 100 MVA as base quantities. Express all impedances and admittance in per unit, it is given that all the lines are characterized by a series impedances of 0.1+j0.7 ohm/km and shunt admittance of j0.35 ×10-5 mho/km. lines are rated at 220 KV. (13M) BTL3

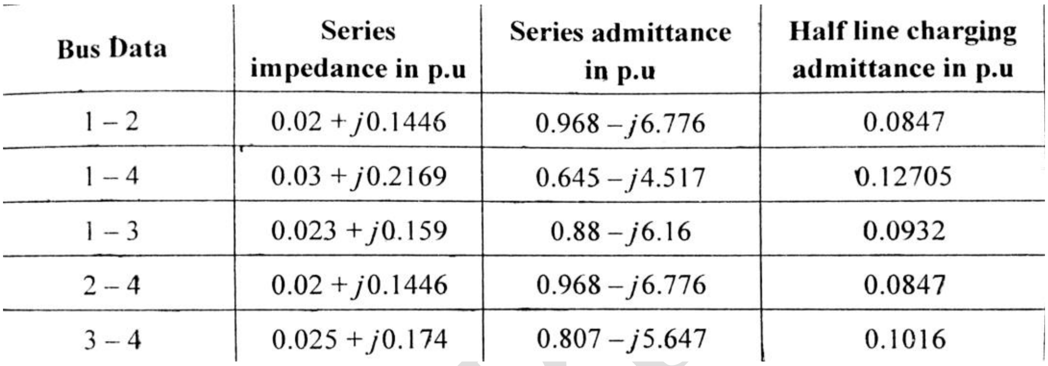
Element no	**Self**		**Mutual**	
	Bus code	**Impedance**	**Bus code**	**Impedance**
1	**1-2**	**0.5**	**1-2**	**0.1**
2	**1-3**	**0.6**		
3	**3-4**	**0.4**		
4	**2-4**	**0.3**		

Answer: Page 3.26 and 3.28- M.Jeraldin Ahila

- **Series impedance,shunt admittance,Half line charging admittance,base impedance: (4 M)**

- **Network and bus data tabulation : (5 M)**



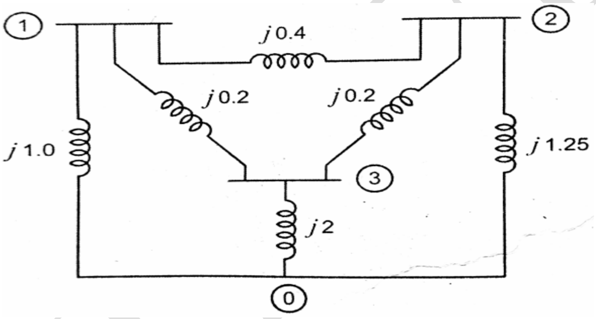


Bus Data	Series impedance in p.u	Series admittance in p.u	Half line charging admittance in p.u
1 – 2	$0.02 + j0.1446$	$0.968 - j6.776$	0.0847
1 – 4	$0.03 + j0.2169$	$0.645 - j4.517$	0.12705
1 – 3	$0.023 + j0.159$	$0.88 - j6.16$	0.0932
2 – 4	$0.02 + j0.1446$	$0.968 - j6.776$	0.0847
3 – 4	$0.025 + j0.174$	$0.807 - j5.647$	0.1016

- **Primitive admittance matrix : (4 M)**

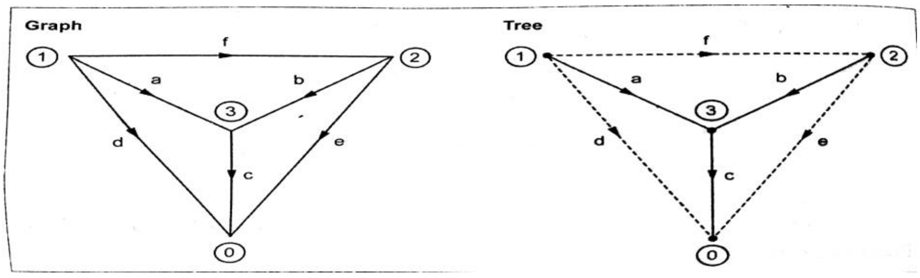
8.

Determine Primitive admittance for the network shown in Fig. Where the impedance labeled in p.u. (Nov/Dec 2007) (13 M) BTL3



Answer: Page S.14 - M.Jeraldin Ahila

- **Graph and tree diagram :(4 M)**



- **Bus incidence matrix: (3 M)**

$$\text{Bus incidence matrix } [A] = \begin{array}{c|cccccc} & a & b & c & d & e & f \\ \hline 1 & 1 & 0 & 0 & 1 & 0 & 1 \\ 2 & 0 & 1 & 0 & 0 & 1 & -1 \\ 3 & -1 & -1 & 1 & 0 & 0 & 0 \end{array}$$

- **Find the primitive impedance matrix: (3 M)**

$$\text{Primitive impedance matrix } [Z_p] = \begin{array}{c|cccccc} & a & b & c & d & e & f \\ \hline a & j0.2 & 0 & 0 & 0 & 0 & 0 \\ b & 0 & j0.2 & 0 & 0 & 0 & 0 \\ c & 0 & 0 & j2 & 0 & 0 & 0 \\ d & 0 & 0 & 0 & j1.0 & 0 & 0 \\ e & 0 & 0 & 0 & 0 & j1.25 & 0 \\ f & 0 & 0 & 0 & 0 & 0 & j0.4 \end{array}$$

- **Find the bus admittance matrix using singular transformation method: (3 M)**

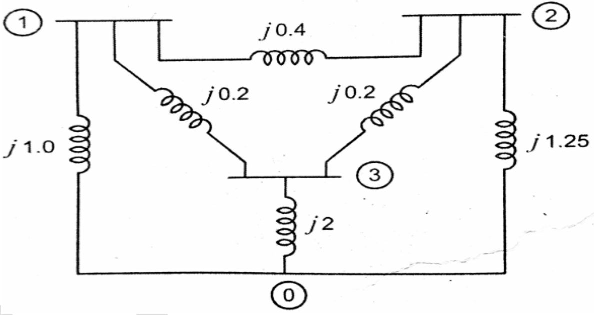
$$\begin{bmatrix} -j8.5 & j2.5 & j5 \\ j2.5 & -j8.3 & j5 \\ j5 & j5 & -j10.5 \end{bmatrix}.$$

9.

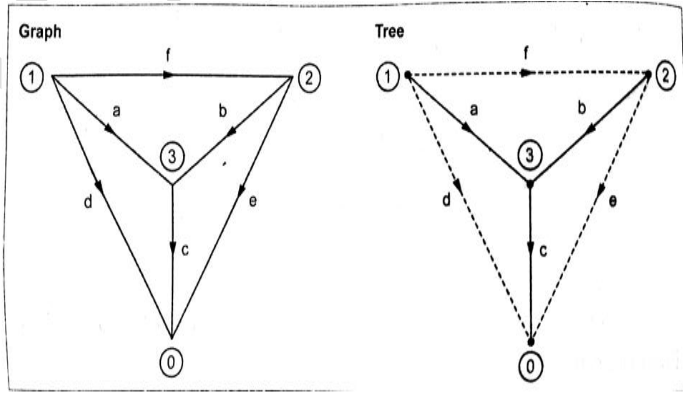
Explain the formation of YBUS by Singular transformation with one example. (Nov/Dec 2010) (13 M) BTL2

Answer: Page S.14 - M.Jeraldin Ahila

- **Consider one network: (2 M)**



- **Graph and tree diagram: (3 M)**



- **Bus incidence matrix: (3 M)**

$$\text{Bus incidence matrix } [A] = \begin{array}{c} \\ 1 \\ 2 \\ 3 \end{array} \begin{array}{c} \begin{array}{cccccc} a & b & c & d & e & f \end{array} \\ \left[\begin{array}{cccccc} 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & -1 \\ -1 & -1 & 1 & 0 & 0 & 0 \end{array}\right] \end{array}$$

- **Primitive impedance matrix: (2 M)**

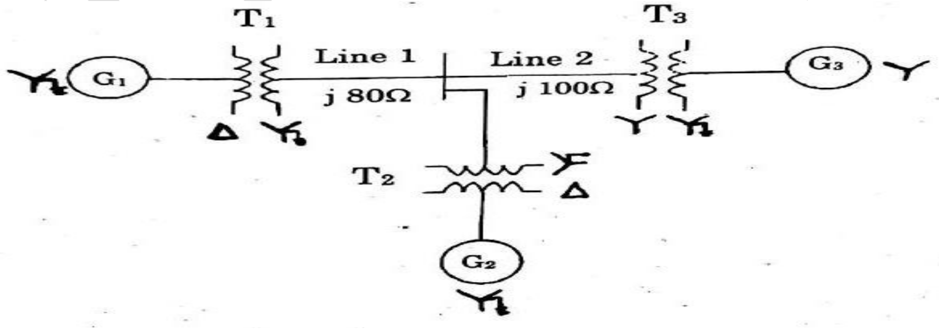
$$\text{Primitive impedance matrix } [Z_p] = \begin{array}{c|cccccc} & a & b & c & d & e & f \\ \hline a & j0.2 & 0 & 0 & 0 & 0 & 0 \\ b & 0 & j0.2 & 0 & 0 & 0 & 0 \\ c & 0 & 0 & j2 & 0 & 0 & 0 \\ d & 0 & 0 & 0 & j1.0 & 0 & 0 \\ e & 0 & 0 & 0 & 0 & j1.25 & 0 \\ f & 0 & 0 & 0 & 0 & 0 & j0.4 \end{array}$$

- **Bus admittance matrix using singular transformation method: (3 M)**

$$\begin{bmatrix} -j8.5 & j2.5 & j5 \\ j2.5 & -j8.3 & j5 \\ j5 & j5 & -j10.5 \end{bmatrix}.$$

10.

Draw the reactance diagram for the power system as shown in fig,Neglect resistance and use a base of 50 MVA and 13.8 KV on generator G1
G1:20 MVA ,13.8 KV,X" = 20 %
G1:30 MVA ,18.0 KV,X" = 20 %
G1:30 MVA ,20.0 KV,X" = 20 %
T1:25 MVA, 220/13.8 KV,X = 10 %
T2: 3 single phase unit each rated 10 MVA ,127/18 KV,X = 10 %
G1:35 MVA, 220/22 KV,X = 10 %. Determine the new values of per unit reactance of G1, G2, T1, T2, G3, T3, Transmission line 1 and 2.0.(Nov/Dec 2015) (13 M) BTL3



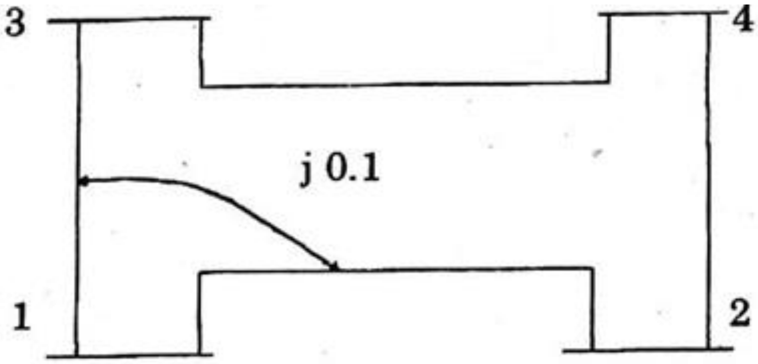
Answer: Page 2.30 -M.Jeraldin Ahila

- Consider the given MVA and KV as new values: (3 M)
- $Z_{\text{p.u. new}}$ for the G1,T1 and transmission line1 and 2. :(4 M)
- For transformer T2 calculate the voltage for 3 single phase units: (3 M)
- With that value, Find the $Z_{\text{p.u. new}}$ for the G2,T3 and G3: (3 M)

11.

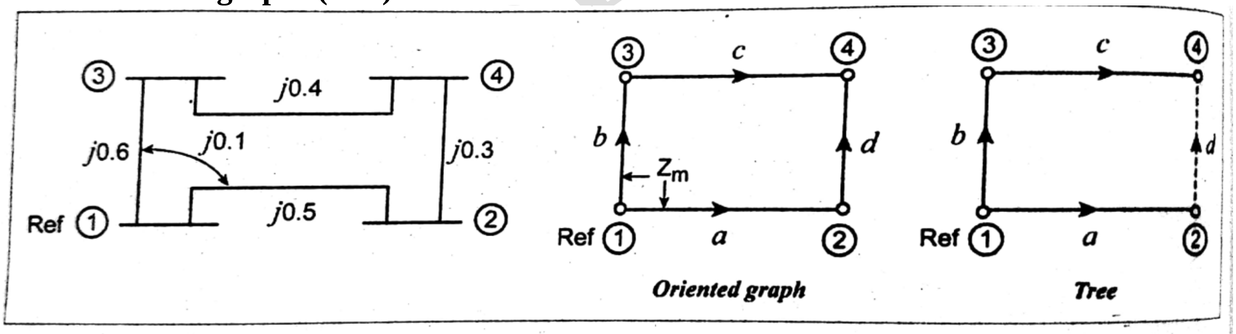
Form Y_{bus} of the test system as shown in figure below using singular transformation method. The impedance data is given in table below. Take 1 as the reference node. (Nov/Dec 2015) (13 M) BTL3

Element no	Self		Mutual	
	Bus code	Impedance	Bus code	Impedance
1	1-2	0.5	1-2	0.1
2	1-3	0.6		
3	3-4	0.4		
4	2-4	0.3		



Answer: Page 3.25 - M.Jeraldin Ahila

- **Oriented graph: (3 M)**



Oriented graph *Tree*

- **Incidence matrix: (4 M)**

$$\text{Incidence matrix } [\,A\,] = \begin{array}{c} \\ (2) \\ (3) \\ (4) \end{array} \begin{array}{c} \begin{array}{cccc} a & b & c & d \end{array} \\ \begin{bmatrix} -1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \\ 0 & 0 & -1 & -1 \end{bmatrix} \end{array}$$

- **Primitive impedance and admittance matrix: (3 M)**

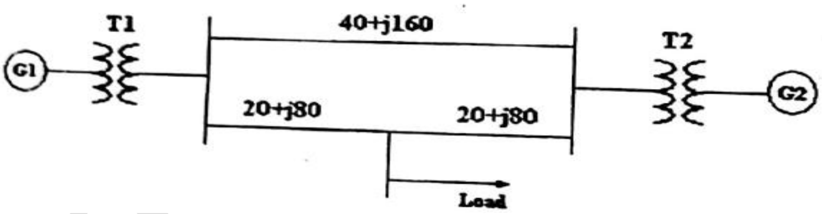
$$[Y_{Primittive}] = \begin{bmatrix} -j2.0689 & j0.3448 & 0 & 0 \\ j0.3448 & -j1.724 & 0 & 0 \\ 0 & 0 & -j2.5 & 0 \\ 0 & 0 & 0 & -j3.333 \end{bmatrix}$$

- **Y_{bus} : (3 M)**

$$Y_{bus} = \begin{bmatrix} -j5.4019 & j0.3448 & j3.333 \\ j0.3448 & -j4.224 & +j2.5 \\ j3.333 & j2.5 & -j5.833 \end{bmatrix}$$

12.

Prepare per phase schematic of the system as shown in fig and show all the impedance in per unit on a 100 MVA, 132 KV base in the transmission line circuit. The necessary data are given as follows
G1:50 MVA,12.2 KV, X=0.15 p.u
G2:20 MVA,13.8 KV, X=0.15 p.u
T1:80 MVA,12.2/161 KV, X=0.1 p.u
T2:40 MVA,13.8/161 KV, X=0.1 p.u
Load:50 MVA,0.8 pf lag operating at 154 KV. Determine the p.u impedance of the load. (Nov/Dec 2016) (13 M) BTL3



Answer: Page S.45- M.Jeraldin Ahila

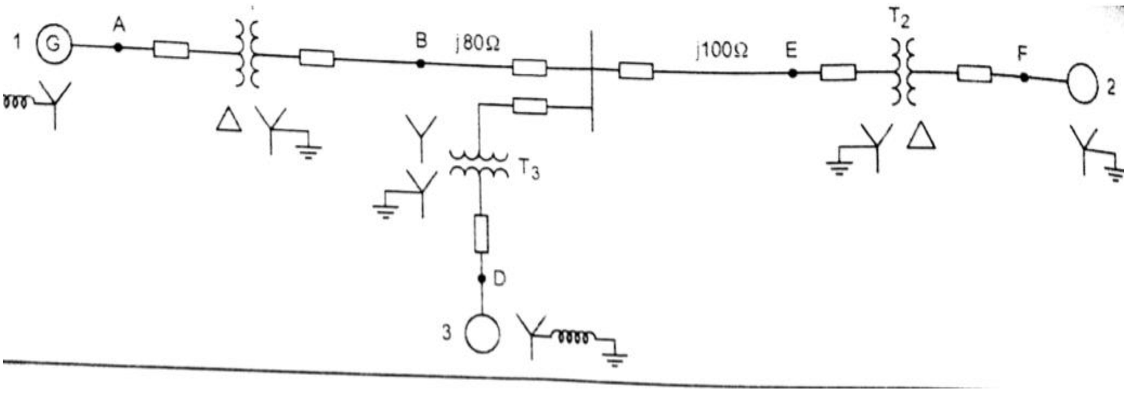
Find Z $_{p.u.new}$ for the transmission line : (3 M)
Find actual load impedance and base impedance for load: (2 M)
Find Z $_{p.u.new}$ for the T1,G1(LV side) : (4 M)

$$Z_{PU} = Z_{PU\ Given}\ x \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2 x \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

Find Z $_{p.u.new}$ for the T2,G2(HV side) : (2 M)
Draw the impedance diagram : (2 M)

13.

Describe the restructuring concept with their models in detail. (13 M) BTL2
Answer: Page 1.4- Notes
Restructure definition: (2 M)
Separate the function of generation, transmission and distribution.
Independent System Operator: (2M)
Maintain the instantaneous balance of the grid function.
Power Exchange: (2 M)

	Market place to sell and buy **Structure of Restructure market: (4 M)** **Restructure model: (3 M)** 1. Poolco Model 2. Bilateral contracts 3. Hybrid model
PART*C	
1.	**(i)The terminal voltage of a Y-connected load consisting of three equal impedances of $20\angle 30^0$ ohm is 4.4 KV line to line. The impedance of each of the three lines connecting the load to a bus station is $Z_L = 1.4\angle 75^0$ ohm Find the line to line voltage at the substation bus. (Nov/Dec 2007) (7M)** BTL5 **Answer: Page S.10 - M.Jeraldin Ahila** ➢ Diagram from the given data: (1 M) ➢ Load current: (2M) ➢ Current through line: (2M) ➢ Substation line voltage : (2M) **(ii)A single phase transformer is rated 110/440V,2.5 KVA. Leakage reactance measured from the low-voltage side is 0.06 ohm. Determine the leakage reactance in per unit. (Nov/Dec 2007) (8M)** BTL3 **Answer: Page S.11 M.Jeraldin Ahila** ➢ Diagram from the given data : (2M) ➢ Z_{actual} value : (2M) ➢ $Z_{p.u}$ value : (1M) ➢ Leakage reactance :(3 M)
2.	**The single line diagram of an unloaded power system as shown in figure. Reactances of the two sections of the transmission line are shown on the diagram. The generators and transformers are rated as follows.** **G1:20 MVA, 11 KV, X_d'' = 0.25 per unit** **G2:30 MVA, 18 KV, X_d'' = 0.25 per unit** **G1:30 MVA, 20 KV, X_d'' = 0.21 per unit** **T1: 25 MVA, 220Y/13.8 delta KV, X=0.15 per unit** **T2: single phase units, each rated 10 MVA, 127/18 KV, X=0.15 per unit.** **T3: 35 MVA, 220Y/22Y KV, X=0.15 per unit.** **Draw the impedance diagram with all reactances marked in p.u choose a base of MVA, KV in the circuit of generator 1. (Nov/Dec 2007) (15 M)** BTL3  **Answer: Page S.12- M.Jeraldin Ahila**

$Z_{p.u.new}$ for the Generator G1 : (2M)

$$Z_{PU} = Z_{PU\,Given}\ x \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2 x \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

Z_{PU} = j0.625p.u

Z_{actual} and $Z_{p.u.}$ for the transmission line: (2 M)

$$Z_{BASE} = \frac{(KV_{LL})^2}{MVA_{3\phi}}\ (ohms)$$

$$A_{BASE} = \frac{MVA_{3\phi}}{\sqrt{3}\ x\ KV_{LL}\ x\ 1000}\ (amps)$$

$$Z_{PU} = \frac{Z\ (In\ ohms)}{Z_{BASE}}$$

Z_{PU} = j0.13 and j0.163 p.u.

$Z_{p.u.new}$ for the transformer T1: (2 M)

$$Z_{PU} = Z_{PU\,Given}\ x \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2 x \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

Z_{PU} = j0.472 p.u.

$Z_{p.u.new}$ for the transformer T2: (2 M)

$$Z_{PU} = Z_{PU\,Given}\ x \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2 x \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

Z_{PU} = j0.393 p.u.

$Z_{p.u.new}$ for the transformer T3: (2 M)

$$Z_{PU} = Z_{PU\,Given}\ x \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2 x \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

Z_{PU} = j0.455 p.u.

$Z_{p.u.new}$ for the Generator G2 : (2M)

$$Z_{PU} = Z_{PU\,Given}\ x \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2 x \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

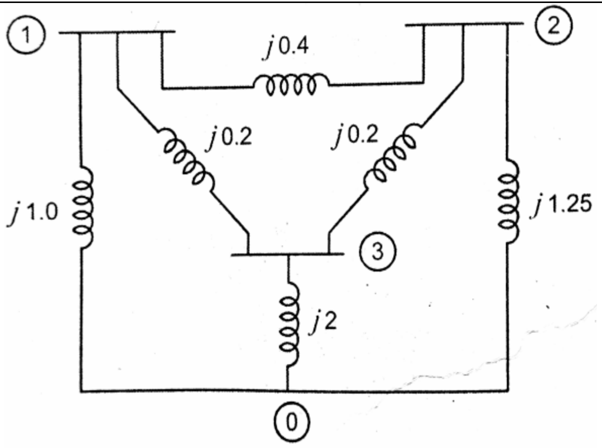
Z_{PU} = j0.656p.u

$Z_{p.u.new}$ for the Generator G3 : (3M)

$$Z_{PU} = Z_{PU\,Given}\ x \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2 x \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

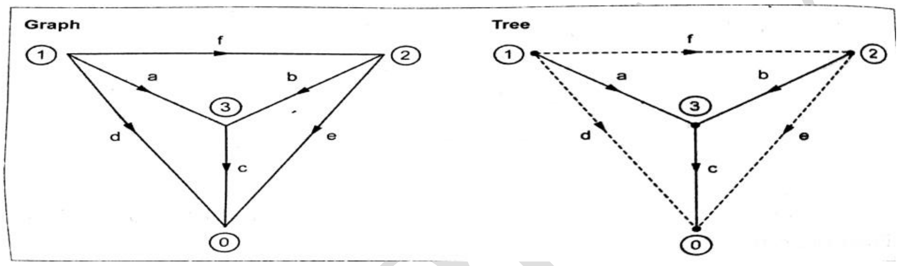
Z_{PU} = j0.455p.u

3. **Using Singular transformation, determine Ybus for the network as shown in fig. (Nov/Dec 2007) (15 M)** BTL3



Answer: Page S.14 - M.Jeraldin Ahila

- **Graph and tree diagram :(4M)**



- **Bus incidence matrix: (4M)**

$$\text{Bus incidence matrix}\,[\,A\,] = \begin{array}{c} \\ 1 \\ 2 \\ 3 \end{array}\begin{array}{cccccc} a & b & c & d & e & f \\ \end{array}$$

$$\begin{array}{c|cccccc} & a & b & c & d & e & f \\ \hline 1 & 1 & 0 & 0 & 1 & 0 & 1 \\ 2 & 0 & 1 & 0 & 0 & 1 & -1 \\ 3 & -1 & -1 & 1 & 0 & 0 & 0 \end{array}$$

- **Find the primitive impedance matrix: (4M)**

$$\text{Primitive impedance matrix}\,[Z_p] = \begin{array}{c|cccccc} & a & b & c & d & e & f \\ \hline a & j0.2 & 0 & 0 & 0 & 0 & 0 \\ b & 0 & j0.2 & 0 & 0 & 0 & 0 \\ c & 0 & 0 & j2 & 0 & 0 & 0 \\ d & 0 & 0 & 0 & j1.0 & 0 & 0 \\ e & 0 & 0 & 0 & 0 & j1.25 & 0 \\ f & 0 & 0 & 0 & 0 & 0 & j0.4 \end{array}$$

- **Find the bus admittance matrix using singular transformation method: (3 M)**

$$\begin{bmatrix} -j8.5 & j2.5 & j5 \\ j2.5 & -j8.3 & j5 \\ j5 & j5 & -j10.5 \end{bmatrix}$$

5.

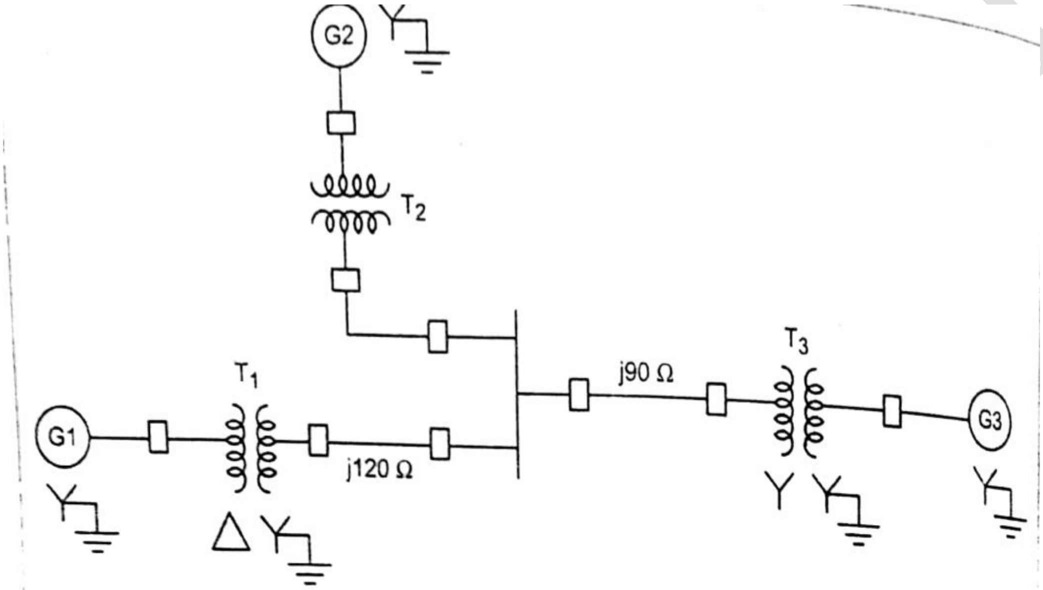
The single line diagram of a simple power system as shown in figure

Generator	**MVA**	**KV**	**Reactance in p.u**
1	**25**	**6.6**	**0.2**
2	**15**	**6.6**	**0.15**
3	**30**	**13.2**	**0.15**

T1:30 MVA, 6.9 delta/115YKV, X=10%
T2:15 MVA, 6.9delta/115YKV, X=10%
T3:Single phase unit, each rated 10 MVA, 6.9/69 KV, X=10%

Draw an impedance diagram and mark all values in p.u. choosing a base of 30 MVA,6.6 KV in the generator 1 circuit. (May/June 2009) (15 M) BTL3

Answer: Page S.37-M.Jeraldin Ahila



Z_{actual} and $Z_{p.u.}$for the transmission line: (2 M)

$$Z_{BASE} = \frac{(KV_{LL})^2}{MVA_{3\Phi}}\ (ohms)$$

$$A_{BASE} = \frac{MVA_{3\Phi}}{\sqrt{3}\ x\ KV_{LL}\ x\ 1000}\ (amps)$$

$$Z_{PU} = \frac{Z\ (In\ ohms)}{Z_{BASE}}$$

z_{PU} = j0.298 and j0.223 p.u.

$Z_{p.u.new}$ for the transformer T1: (2 M)

$$Z_{PU} = Z_{PU\ Given}\ x\ \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2\ x\ \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

z_{PU} = j0.109 p.u.

$Z_{p.u.new}$ for the transformer T2 : (2 M)

$$Z_{PU} = Z_{PU\ Given}\ x\ \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2\ x\ \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

z_{PU} = j0.218 p.u.

$Z_{p.u.new}$ for the transformer T3 : (2 M)

$$Z_{PU} = Z_{PU\ Given}\ x\ \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2\ x\ \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

z_{PU} = j0.218 p.u.

$Z_{p.u.new}$ for the Generator G1 : (2M)

$$Z_{PU} = Z_{PU\ Given}\ x\ \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2\ x\ \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

z_{PU} = j0.1p.u

$Z_{p.u.new}$ for the Generator G2 : (2M)

$$Z_{PU} = Z_{PU\ Given}\ x\ \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2\ x\ \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

z_{PU} = j0.3 p.u.

$Z_{p.u.new}$ for the Generator G3 : (1M)

$$Z_{PU} = Z_{PU\ Given}\ x\ \left(\frac{KV_{GIVEN}}{KV_{NEW}}\right)^2\ x\ \left(\frac{MVA_{NEW}}{MVA_{GIVEN}}\right)$$

z_{PU} = j0.183 p.u.

- **Impedance diagram: (2M)**

UNIT II – POWER FLOW ANALYSIS

Importance of power flow analysis in planning and operation of power systems - statement of power flow problem - classification of buses - development of power flow model in complex variables form - iterative solution using Gauss-Seidel method - Q-limit check for voltage controlled buses – power flow model in polar form - iterative solution using Newton-Raphson method .

PART * A

Q.No.	Questions
1.	**Define P-Q bus in power flow analysis.** BTL1 A bus is called PQ-bus or load bus when real and reactive components of power are specified for the bus. In a load bus the voltage is allowed to vary within permissible limits.
2.	**Bring out the need for power flow or load flow study. (Nov/Dec 2017)** BTL2 The load flow study of a power system is essential to decide the best operation of existing system and for planning the future expansion of the system. It is also essential for designing a new power system.
3.	**Give the advantages of N-R method.** BTL1 • The N-R method is faster, more reliable and the results are accurate. • Requires less number of iterations for convergence. • The number of iterations are independent of the size of the system(number of buses). • Suitable for large size system.
4.	**Give the disadvantages of N-R method.** BTL1 • The programming is more complex. • The memory requirement is more. • Computational time per iteration is higher due to large number of calculations per iteration.
5.	**Mention any three advantages of N-R method over G-S method.** BTL2 • The N-R method has quadratic convergence characteristic and so convergence faster than G-S method. • The number of iterations for convergence is independent of the size of the system in N-R method. • In N-R method the convergence is not affected by the choice of slack bus.
6.	**State the need for slack/swing bus in power system. (Nov/Dec 2016)** BTL2 The slack/swing bus is needed to account for transmission line losses. In a power system the total power generated will be equal to sum of power consumed by loads and losses. In a power system only the generated power and load power are specified for buses. The slack bus is assumed to generate the power required for losses. Since the losses are unknown the real and reactive power are not specified for slack bus. They are estimated through the solution of load flow equations.
7.	**List out the advantages of FDLF method.** BTL2 • FDLF method is faster, simple to program, more reliable and requires less memory than NR load flow method. • FDLF method requires more iterations than N-R method but requires less time per iterations.
8.	**Classify the types of buses. (OR) What are the three classes of buses of a power system used in power flow analysis? (Nov/Dec 2011)** BTL1 • Load bus or PQ-bus (P and Q are specified) • Generator bus or voltage controlled bus or PV bus (P and V are specified) • Slack bus or swing bus or reference bus (Voltage magnitude and angle are specified).

9.	**Why the load flow studies are important for planning the existing system as well as its future expansion?** BTL2 The load flow studies are very important for planning, economic scheduling, control and operations of existing systems as well as planning its future expansion depends upon knowing the effect of interconnections, new loads, new generating stations, or new transmission lines, etc., before they are installed.
10.	**Define power flow study or load flow study. (Nov/Dec 2014)** BTL2 The study of various methods of solution to power system network is referred to as load flow study. The solution provides the voltages at various buses, power flowing in various lines and line-losses
11.	**Bring out the information that is obtained from load flow study.(Nov/Dec 2015)** BTL2 • The magnitude and phase of bus voltages, real and reactive power flowing in each line and the line losses. • The load flow solution also gives the initial conditions of the system when the transient behavior of the system is to be studied.
12.	**List out the quantities to be specified and to be computed for each class during power flow solution.** BTL1 •Load bus or PQ-bus (P and Q are specified- Voltage magnitude and angle are to be obtained) •Generator bus or voltage controlled bus or PV bus (P and V are specified- Voltage angle and Q are to be obtained) •Slack bus or swing bus or reference bus (Voltage magnitude and angle are specified- P and Q are to be obtained)
13.	**Define swing bus (or slack bus).** BTL1 A bus is called swing bus (or slack bus) when the magnitude and phase of bus voltage are specified for it. The swing bus is the reference bus for load flow solution and it is required for accounting line losses. Usually one of the generator bus is selected as the swing bus.
14.	**List out the methods used for the iterative solution of non-linear algebraic equations.** BTL1 • Gauss-Seidal Load Flow Method(GSLF) • Newton-Raphson Load Flow Method(NRLF) • Fast-decoupled Load Flow Method(FDLF)
15.	**Define flat voltage start.** BTL2 In iterative methods of load flow solution, the initial voltages of all buses except slack bus are assumed as 1+j0 p.u. This is referred to as flat voltage start.
16.	**Define bus.** BTL1 The meeting point of various components in a power system is called as bus. At some of the buses power is being injected into the network, whereas at other buses it is being tapped by the system loads.
17.	**When the generator bus is treated as load bus? (Nov/Dec 2013,15)** BTL2 If the reactive power of a generator bus violates the specified limits then the generator bus is treated as load bus.
18.	**State out the technique is used to solve load flow problems using Z-bus.** BTL1 The formulation of load flow problem using Z_{bus} employs Diakoptics techniques which is actually the piecewise solution of the power system problem by using tearing off technique.
19.	**Define PQ bus.** BTL1 A bus is called PQ bus or load bus when real and reactive components of power are specified for the bus. In a load bus the voltage is allowed to vary within permissible limits.

20.	**List out the four quantities that are associated with each bus in a system.** BTL2 • Real Power • Reactive Power • Voltage magnitude • Phase angle of voltage
21.	**Define voltage controlled bus. (Nov/Dec 2014)**BTL1 The real power and voltage magnitudes are specified. The phase angle of the voltages and reactive power are to be determined. The limits on the value of reactive power are also specified.
22.	**Define Jacobian matrix. (Nov/Dec 2016)**BTL1 The Jacobian matrix gives the relationship between small changes in voltage angle and voltage magnitude with a small change in real and reactive power.
23.	**Define acceleration factor. (Nov/Dec 2012)**BTL1 In Gauss seidal method, the number of iterations required for convergence can be reduced if the correction in bus voltage computed at each iteration is multiplied by a factor greater than unity is called as acceleration factor.
24.	**State the data required for load flow study. (Nov/Dec 2012)** BTL2 • Network Configuration • Complex power demands • Real power • Reactive power • Voltage magnitude
25.	**Give the advantages of Gauss Seidel method.** BTL1 • Calculations are simple and programming task is less • Memory requirement is less • Useful for small size system
	PART * B
1.	**Derive load flow algorithm using Gauss – Seidel method with flow chart and discuss the advantages of the method. (Nov/Dec 2017) (13 M)** BTL1 **Answer: Page 6.11- M.Jeraldin Ahila** **Explain: (5M)** 1. Form Y-bus matrix (1M) 2. Initialize bus voltages (1M) 3. Set iteration count and bus number (1M) 4. Calculate Q and check for violation (1M) 5. Compute V and calculate the relevant quantities (1M) **Advantages: (3M)** 1. Calculations are simple and programming task is less 2. Memory requirement is less **3.** Useful for small size system **Flowchart: (5M)**

2.	**Draw the detailed flow chart and explain the algorithm of Newton-Raphson method when the system contains all type of buses. (Nov/Dec 2014,17) (13 M)** BTL1 **Answer: Page 6.39 - M.Jeraldin Ahila** **Explain: (6M)** 1. Formulate Y-bus matrix 2. Assume flat start for starting voltage equation 3. Calculate P and Q and check for Q-limit violation 4. Calculate change in P and Q value 5. Compute Jacobian matrix Obtain correction value and update until error minimize **Advantages: (3M)** 1. Faster more reliable and the results are accurate 2. Requires less number for iterations for convergence. 3. Number for iterations are independent of the size of the system. 4. Suitable for larger size systems **Flowchart: (4M)**
3.	**Explain clearly the algorithmic steps for solving load flow equation using Newton – Raphson method (polar form) when the system contains all types of buses. Assume that the generators at the P-V buses have adequate Q Limits. (13 M)** BTL1 **Answer: Page 6.39 - M.Jeraldin Ahila** **Explain:** 1. Formulate Y-bus matrix (2M) 2. Assume flat start for starting voltage equation (3M) 3. Calculate P and Q and check for Q-limit violation (3M) 4. Calculate change in P and Q value (2M) 5. Compute Jacobian matrix (1M) 6. Obtain correction value and update until error minimize (2M)
4.	**Compare Gauss-Seidel method and Newton-Raphson method of load flow studies. (Nov/Dec 2012) (13 M)** BTL2 **Answer: Page 6.48 - M.Jeraldin Ahila** **Explain:** 1. Rectangular and polar coordinates (3M) 2. Computation time per iteration (2M) 3. Linear and quadrature convergence (4M) **4.** Presence of series capacitor (4M)
5.	**The below mentioned shows a three bus power System.** **Bus 1 : Slack bus, $V= 1.05\angle 0^0$ p.u** **Bus 2: PV bus, V = 1.0 p.u. $P_g = 3$ p.u.** **Bus 3: PQ bus, $P_l = 4$ p.u., $Q_l = 2$ p.u.** **Carry out one iteration of load flow solution by Gauss Seidel method. Neglect limits on reactive power generation (Nov/Dec 2014,11) (13M)** BTL3 **Answer: Page 6.20 - M.Jeraldin Ahila** **Explain:** 1. Form Y_{bus} (3M) 2. Initialize bus voltages (3M)

<table>
<tr><td></td><td>
3. For generation bus calculate V_i (3M)
4. Calculate Q value for generator buses and check for the limit violation and calculate new voltage (2M)
5. Calculate slack bus power, line flow and transmission loss (2M)
</td></tr>
<tr><td>6.</td><td>
Write the advantages and disadvantages of Gauss-Seidel method and Newton-Raphson method. (13 M) BTL1
Answer: Page 6.47 and 6.48 - M.Jeraldin Ahila
Advantages and Disadvantages of Gauss Seidel Method: (6M)
Advantages
1. Faster more reliable and the results are accurate.
2. Requires less number for iterations for convergence.
3. Number for iterations are independent of the size of the system.
4. Suitable for larger size systems.
Disadvantages
1. Requires large number of iteration to reach convergence
2. Not suitable for larger systems
3. Convergence time increases with the size of the system.
Advantages and Disadvantages of Newton Raphson Method: (7M)
Advantages:
1. Faster more reliable and the results are accurate
2. Requires less number for iterations for convergence.
3. Number for iterations are independent of the size of the system.
4. Suitable for larger size systems
Disadvantages
1. Programming logic is more complex than Gauss seidel method
2. Memory Requirement is more.
3. Number of calculation required per iteration are higher than Gauss seidel method
</td></tr>
<tr><td>7.</td><td>
Derive the power flow equation in polar form. (13 M) BTL1
Answer: Page 6.5 - M.Jeraldin Ahila
Explain:
1. Two bus system (3M)
2. Net power Injected into bus (4M)
3. Net current entering into bus (3M)
4. Equate real and reactive parts and find the P and Q (3M)
</td></tr>
<tr><td>8.</td><td>
The system data for a load flow problem are given below. Determine bus voltages at the end of first iteration by gauss Seidel method. Take acceleration factor as 1.6 (Nov/Dec 2015) (13 M) BTL3
<table>
<tr><th>Bus code</th><th>Admittances(p.u)</th><th>Bus code</th><th>P_D in p.u</th><th>Q_D in p.u</th><th>V p.u</th></tr>
<tr><td>1-2</td><td>2-j8</td><td>1</td><td>-</td><td>-</td><td>1.06∠0⁰</td></tr>
<tr><td>1-3</td><td>1-j4</td><td>2</td><td>0.5</td><td>0.2</td><td>-</td></tr>
<tr><td>2-3</td><td>0.6-j2.6</td><td>3</td><td>0.4</td><td>0.3</td><td>-</td></tr>
</table>
Answer: Page 6.5 - M.Jeraldin Ahila
Explain:
</td></tr>
</table>

1. Form Y_{bus} (3M)
2. Initialize bus voltages (3M)
3. For generation bus calculate V_i (3M)
4. Calculate Q value for generator buses and check for the limit violation (2M)
5. Calculate the new voltage (2M)

9. **Explain why power flow studies are essential and vital parts of power system studies. (13 M)** BTL4

Answer: Page 6.1 - M.Jeraldin Ahila

Explain:

1. Meet increase load demand (3M)
2. Planning Economic scheduling and future expansion (3M)
3. Improving power factor and voltage level (4M)
4. Meet the balancing nature of generation and demand (3M)

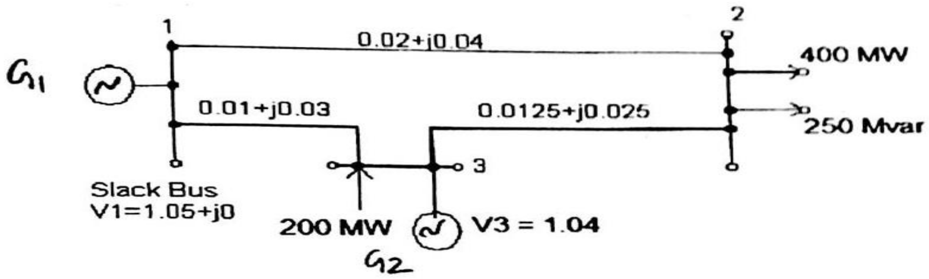
10. **For the sample system shown below. The generators are connected at all the four buses, while the loads are at buses 2 and 3. Values of real and reactive powers are listed in table. Bus 2 be a PV bus with V_2 = 1.04 p.u and bus 3 and bus 4 are PQ bus. Assuming a flat voltage start, find bus voltages and bus angles the end of first gauss seidal iterations. And consider the reactive power limit as $0.2<Q_2<1$. (Nov/Dec 2009) (13 M)** BTL3

Bus-code	**Admittances(p.u)**	**Bus**	**P_P(p.u)**	**Q_P(p.u)**	**V_P(p.u)**
1-2	**2-j6**	**1**	**-**	**-**	**$1.04\angle 0^0$**
1-3	**1-j3**	**2**	**0.5**	**-**	**1.04p.u**
2-3	**0.666-j2**	**3**	**-1.0**	**0.5**	**-**
3-4	**2-j6**	**4**	**0.3**	**-0.1**	**-**
2-4	**1-j3**			**-**	**-**

Answer: Page S.49 - M.Jeraldin Ahila

Explain:

1. Form Y_{bus} (3M)
2. Initialize bus voltages (3M)
3. Q2 for the PV bus (3M)
4. Calculate V2 (2M)
5. With the formula calculate the new value of voltages (2M)

11.	**Write a note on classification of buses. (Nov/Dec 2012) (13 M)** BTL1 **Answer: Page 6.2-6.4 - M.Jeraldin Ahila** **Explain:** 1. Slack bus or swing bus or reference bus (4M) 2. Generator bus or P-V bus or voltage controlled bus (4M) 3. Load bus or P-Q bus (4M) **4.** Combined feature (1M)
PART*C	
1.	**The below figure shows the one line diagram of a simple 3 bus power system with generators at buses 1 and 3. Line impedance are marked in p.u. on a 100 MVA base. Determine the bus voltages at the end of second iteration using Gauss-Seidel method.(Nov/Dec 2016) (15 M)** BTL3  **Answer: Page 2.4 - Notes** **Explain:** 1. Form Y_{bus} (3M) 2. Initialize bus voltages (2M) 3. Q value for the generator bus (3M) 4. Q_{limit} violation (2M) 5. V2 new Value (2M) 6. Using acceleration factor and calculate the new value of voltages (3M)
2.	**Starting from the power flow model obtain gauss seidal power flow model and explain the algorithmic steps for getting power flow solutions. (Nov/Dec 2009) (15 M)** BTL4 **Answer: Page 6.5 to 6.9 and 6.11 - M.Jeraldin Ahila** **Explain:** 1. Gauss seidal method including PV bus adjustment (2M) 2. Flat voltage start (1M) 3. Acceleration factor (1M) 4. Convergence check (1M) 5. Form Y-bus matrix (2M) 6. Initialize bus voltages (2M) 7. Set iteration count and bus number (2M) 8. Calculate Q and check for violation (2M) 9. Compute V and calculate the relevant quantities (2M)
3.	**Perform two iteration of Newton Raphson load flow method and determine the power flow solution for the given system. Take base MVA as 100. (15 M)** BTL5 **Line data:**

Line	**Bus**		**R(p.u.)**	**X(p.u.)**	**Half line charging admittance**
	From	**To**			**($Y_p/2$ p.u)**
1	**1**	**2**	**0.08939**	**0.5183**	**0.0636**

Bus data:

Bus	**P_L**	**Q_L**
1	**90**	**20**
2	**30**	**10**

Answer: Page 6.41 - M.Jeraldin Ahila
Explain:

1. Formulate Y-bus matrix (3M)
2. Assume flat start for starting voltage equation (2M)
3. Calculate P and Q and check for Q-limit violation (3M)
4. Calculate change in P and Q value (3M)
5. Compute Jacobian matrix and obtain correction value (4M)

UNIT III FAULT ANALYSIS – BALANCED FAULTS

Importance of short circuit analysis - assumptions in fault analysis - analysis using Thevenin's theorem-Z-bus building algorithm - fault analysis using Z-bus – computations of short circuit capacity, postfault voltage and currents

PART*A

Q.No.	Questions
1.	**Write the relative frequency of occurrence of various types of faults.(Nov/Dec 2013)** BTL1 S.No. / Type of Faults / Relative Frequency of Occurrence 1. Three phase fault – 5% 2. Double line to ground fault – 10% 3. Line to line fault – 15% 4. Single line to ground fault – 70%
2.	**Write out the assumptions made in short circuit studies of a large power system network.** BTL1 • Representing each machine by a constant voltage source behind proper reactances which may be X", X' or X. • Pre fault load currents are neglected. • Transformer taps are assumed to be nominal. • Shunt elements in the transformer model that account for magnetizing current and core loss are neglected. • A symmetric three phase power system is considered. • Shunt capacitance of the transmission line is ignored. • Series resistances of transmission lines are neglected. • The negative sequence impedance of alternators are assumed to be the same as their positive sequence impedance.$Z_1=Z_2$
3.	**List out the reactances used in the analysis of symmetrical faults on the synchronous machines as its equivalent reactance.** BTL1 • Sub transient reactance X_d'' • Transient reactance X_d' • Synchronous reactance X_d
4.	**Bring out the reason for transients during short circuit.** BTL2 The faults or short circuits are associated with sudden change in currents. Most of the components of the power system have inductive property which opposes any sudden change in currents so the faults (short circuit) are associated with transients.
5.	**Define short circuit interrupting MVA of a circuit breaker.** BTL1 The short circuit interrupting MVA of a circuit breaker is the volt-amperes (power) flowing

Table for Q.1:

S.No.	Type of Faults	Relative Frequency of Occurrence
1.	Three phase fault	5%
2.	Double line to ground fault	10%
3.	Line to line fault	15%
4.	Single line to ground fault	70%

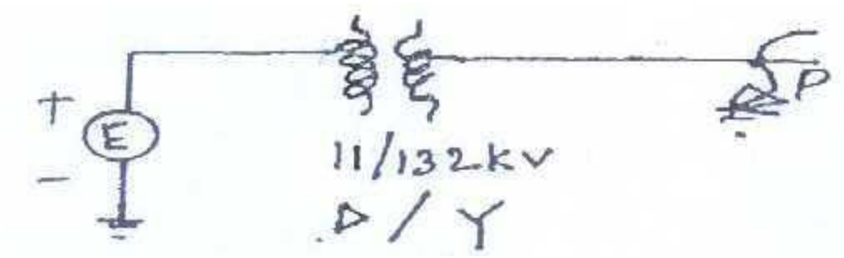
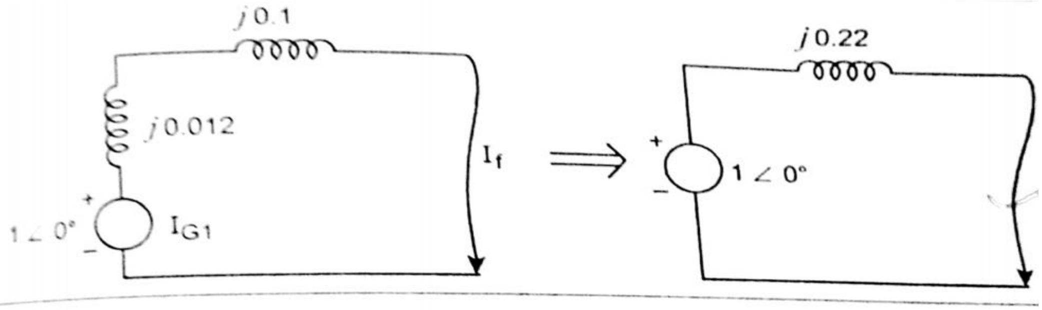
	through it at the moment of opening its contacts due to a fault Short circuit interrupting MVA =$\|V\|_{prefault}*\|I_{sc}\|*(MVA)_{base}$
6.	**Define short circuit capacity of power system (or) fault level of power system.** BTL1 Short circuit capacity or short circuit MVA or fault level at a bus is defined as the product of the magnitudes of the pre fault bus voltage and the post fault current.
7.	**Define doubling effect.** BTL1 If a symmetrical fault occurs when the voltage wave is going through zero then the maximum momentary short circuit current will be double the value of maximum symmetrical short circuit current. This effect is called doubling effect.
8.	**Define momentary current rating of circuit breaker. How it is estimated?** BTL1 The momentary current rating is the maximum current that may flow through a circuit breaker for a short duration. It is estimated by multiplying the symmetrical sub transient fault current by a factor of 1.6.
9.	**Define interrupting short circuit current rating of circuit breaker. How it is estimated?** BTL1 The interrupting short circuit current rating of the circuit breaker is the maximum current that may flow through it when its contact open due to fault. It is estimated by multiplying the transient short circuit current by a factor of 1.0 to 1.5.The value of the factor depends on the speed of the breaker.
10.	**List the various types of shunt faults.** BTL1 The various types of shunt faults are • Line to ground fault • Line to line fault • Double Line to ground fault • Three phase fault
11.	**Bring out the need for short circuit analysis.(Nov/Dec 2011,12,14,16)** BTL2 The short circuit studies are essential in order to design or develop the protective schemes for various parts of the system. The protective scheme consists of current and voltage sensing devices, protective relays and circuit breakers. The selection of these devices mainly depends on various currents that may flow in the fault conditions.
12.	**List the various types of shunt and series faults.** BTL1 • Line to ground fault • Line to line fault • Double Line to ground fault • Three phase fault • One open conductor fault • Two open conductor fault
13.	**List the symmetrical and unsymmetrical faults.** BTL1 The three phase fault is the only symmetrical fault. All other types of faults are unsymmetrical faults are unsymmetrical faults. The various unsymmetrical faults are • Line to ground fault • Line to line fault • Double Line to ground fault • One or two open conductor fault.

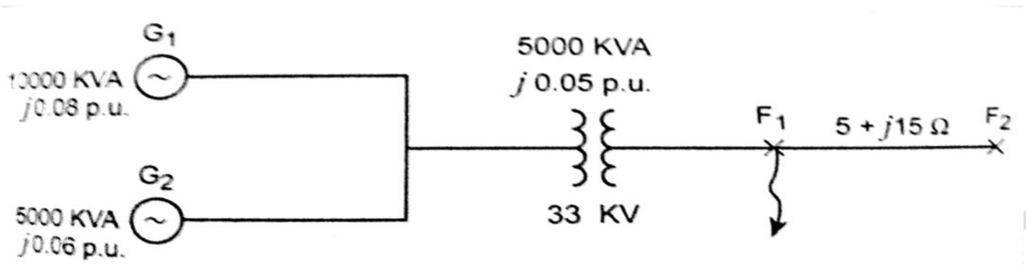
14.	**Name any two methods of reducing short circuit current.** BTL1 - By providing neutral reactance - By introducing a large value of shunt reactance between buses.
15.	**Define symmetrical fault. (Nov/Dec 2014,17)** BTL1 If the fault current is equal in all the phases, it is called as symmetrical fault. The fault conditions are analyzed on per phase basis using Thevenin theorem or using bus impedance matrix.
16.	**Write the significance of subtransient reactance and transient reactance in short circuit studies.** BTL2 The subtransient reactance can be used to estimate the initial value of fault current immediately on the occurrence of fault. The transient reactance can be used to estimate the transient state fault current.
17.	**Why faults occur in a power system?(Nov/Dec 2015)** BTL2 A fault in a circuit is any failure which interprets with the normal value of current, voltage and frequency. The faults may cause damage to the equipment, if it is allowed to persist for a long time. Lightning, Short circuit and losses of transmission lines are some of the reasons for the occurrence of fault in power system.
18.	**Bring out the use of short circuit capacity.** BTL4 Short circuit capacity is used to determine the dimension of a bus bar and the interrupting capacity of a circuit breaker
19.	**Define the term synchronous reactance.** BTL2 It is the ratio of induced emf and the steady state rms current. It is the sum of leakage reactance and the armature reaction reactance. $X_d = X_l + X_a$
20.	**Define transient reactance.** BTL1 It is the ratio of induced emf on no load and the transient symmetrical rms current $X_{d'} = \frac{E_g}{I'}$
21.	**Define direct axis reactance.(Nov/Dec 2015)** BTL1 The reactance represented by the machine in the initial period of the short circuit is called as the direct axis short circuit sub transient reactance of the machine. It is the ratio included emf on no load and the sub transient symmetrical rms current.
22.	**Define bolted fault or solid fault. (Nov/Dec 2017)**BTL1 A fault represents a structural network change equivalent with that caused by the addition of an impedance at the place of fault. If the fault impedance is zero, then the fault is called as bolted or solid fault.
23.	**Define fault in a power system. (Nov/Dec 2007)** BTL1 - A fault in a circuit is any failure which interprets with the normal value of current, voltage and frequency. The faults may cause damage to the equipment, if it is allowed to persist for a long time. - Various causes of faults are lightning, sudden loss of lines, switching surges.

24.	**How the shunt and series faults are classified? (Nov/Dec 2016)** BTL1 **Shunt Fault** • Line to ground fault • Line to line fault • Double Line to ground fault • Three phase fault **Series Fault** • Open conductor fault • Two open conductor fault

PART*B

Q.No.	**Questions**
1.	**A generator is connected through a transformer to a synchronous motor the sub transient reactance of generator and motor are 0.15 p.u. and 0.35 p.u. respectively. The leakage reactance of the transformer is 0.1 p.u. All the reactances are calculated on a common base. A three phase fault occurs at the terminals of the motor when the terminal voltage of the generator is 0.9 p.u. The output current of generator is 1 p.u. and 0.8 p.f. leading. Find the sub transient current in p.u. in the fault, generator and motor. Use the terminal voltage of generator as reference vector. (May/June 2007) (13 M)** BTL3 **Answer: Page S.5- M.Jeraldin Ahila** **Explain:** • Single line diagram (1M) • Reactance diagram (2 M) • Thevenin equivalent reactance(3 M) • Thevenin equivalent voltage(2 M) • Fault current(2 M) • Current contribution from generator and motor(3 M)
2.	**Explain the step by step procedure for systematic fault analysis using bus impedance matrix. (May/June 2007) (13 M)** BTL1 **Answer: Page 8.30 - M.Jeraldin Ahila** **Explain:** • Prefault per phase network (2 M) • Obtain Z_{bus} using bus building algorithm(3 M) • Obtain fault current (2 M) • Obtain thevenin network (2 M) • Post fault bus voltage(2 M) • Post fault line current(2M)
3.	**A 60 MVA, Y connected 11 KV synchronous generator is connected to a 60 MVA, 11/132 KV /Y transformer. The sub transient reactance X"$_d$ of the generator is 0.12 p.u. on a 60 MVA base, while the transformer reactance is 0.1 p.u. on the same base. The generator is unloaded when a symmetrical fault is suddenly placed at point p as shown in Fig. Find the**

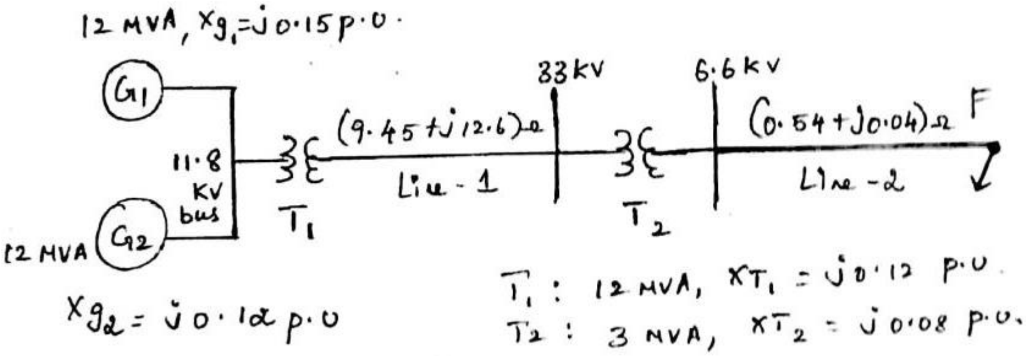
	sub transient symmetrical fault current in p.u. amperes and actual amperes on both side of the transformer. Phase to neutral voltage of the generator at no load is 1.0 p.u. **(13 M)** BTL3  **Answer: Page 8.24- M.Jeraldin Ahila** 1. $Z_{p.u.new}$ for the generator and transformer(2 M)  $I_{F\ p.u.} = \frac{E_{Th}}{Z_{Th}} = \frac{1 \angle 0°}{j0.22} = -j4.54$ p.u. 2. Reactance diagram (4 M) 3. Base values for the primary side and secondary side of transformer (4 M) 4. Actual current values for the primary side and secondary side of transformer (3M)
4.	**A three –phase transmission line operating at 33 kV and having a resistance and reactance of 5 ohms and 15 ohms respectively is connected to the generating station busbar through a 5000 KVA step up transformer which has a reactance of 0.05 p.u. connected to the bus bars are two alternators are 10000KVA having 0.08 p.u. reactance and another 5000KVA having 0.06 p.u. reactance. Calculate the KVA at a short circuit fault between phases occurring at the high voltage terminals of the transformers. (13 M)** BTL3



Answer: Page 8.25 - M.Jeraldin Ahila

- $Z_{p.u.new}$ for the G1,G2 (2M)
- $Z_{p.u.new}$ for the transmission line and transformer(3M)
- Reactance diagram (3 M)
- Total impedance and short circuit KVA upto the fault 1 (2 M)
- Total impedance and short circuit KVA upto the fault 2.(3 M)

5. **For the radial network shown in fig Phase fault occurs at point F, Determine the fault current and the line voltage at 11.8 KV bus under fault condition. (Nov/Dec 2016) (13 M)** BTL3



Answer: Page 8.22 - M.Jeraldin Ahila

Reactance Diagram: **(3M)**

Fault Current **(4M)**

$$I_f = \frac{E_{th}}{Z_{th}} = \frac{1\angle 0}{0.2528+j0.6564} = 0.5109\text{-}j1.3266 \text{ p.u}$$

$$\text{Base Current} = \frac{MVA}{\sqrt{3}*KV_b} \quad \frac{12*1000}{\sqrt{3}*6.6} = 1049.72 \text{ A}$$

$$I_f = 1.4215 * 1049.72 = 1492.2A$$

Line voltage at 11.8 KV : Formula **(2M)**

$$V = E + Z_f I_f$$

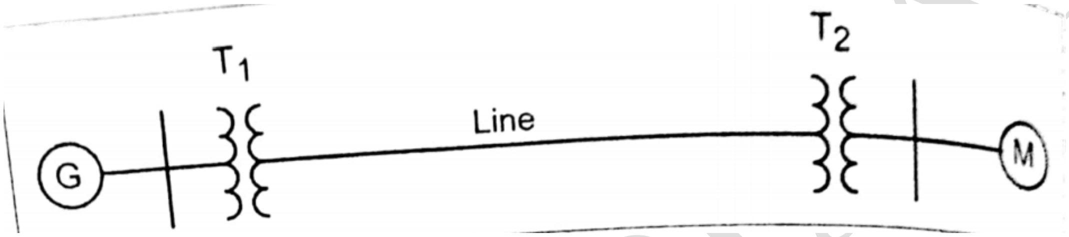
Value of Z_f: **(2M)**

$$Z_f = 0.2528 + j0.5898$$

Actual Voltage: **(2M)**

V = 0.912 P.u
Actual Voltage = 0.912*base voltage
0.912*11.8
10.76 KV

6. **A synchronous generator and a synchronous motor each rated 30 MVA, 11 kV having 20% sub-transient reactance are connected through transformers and a line as shown in fig. The transformers are rated 30 MVA, 11/66 KV and 66/11 kV with leakage reactance of 10% each. The line has a reactance of 10% on a base of 30 MVA, 66 kV. The motor is drawing 20 MW at 0.8 power factor leading and a terminal voltage of 10.6 KV. When a symmetrical 3 phase fault occurs at the motor terminals. Find the sub-transient current in the generator and motor. (Nov/Dec 2015) (13 M)** BTL3



Answer: Page 8.46 - M.Jeraldin Ahila

Thevenin theorem: **(4M)**

$$z_{th} = \frac{j0.2 * j0.5}{j0.2 + j0.5} = j0.1428$$

$V_{p.f} = E_{th} = \frac{10.6}{11} = 0.9636\, p.u$

Fault current : **(5M)**

$I_f = \frac{E_{th}}{z_{th}} = \frac{0.9636}{j0.1428}$ = -j6.745 p.u

Base Current = $\frac{MVA}{\sqrt{3} * KV_b}$ $\frac{30}{\sqrt{3} * 11}$ = 1.5746 KA

$$I_f = j6.745 * 1.5746 = -j10.62\, KA$$

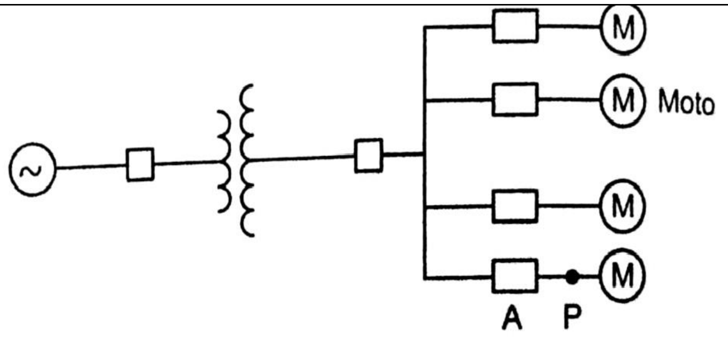
Subtransient Current in Generator and Motor **(4M)**

$I_{Gf}^{''} = \frac{I_f * j0.2}{j0.5 + j0.2}$ = -j1.9272 p.u

$I_g^{''} = I_{Gf}^{''} + I_L = -j1.9272 + (0.865\angle 36.87)$ = 0.692-j1.408

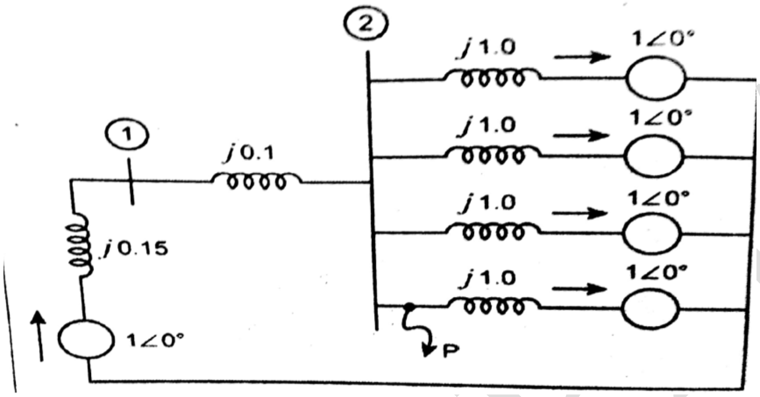
$I_m^{''} = I_{mf}^{''} + I_L = -j4.818 + (0.865\angle 36.87)$ = 0.692-j5.337

7. **A 25,000 KVA, 13.8 kV generator with X”d = 15% is connected through a transformer to a bus which supplies four identical motors as shown in Fig. The sub transient reactance X”d of each motor is 20% on a base of 5000 KVA, 6.9 kV. The three-phase rating of the transformer is 25,000 KVA, 13.8/6.9 kV, with a leakage reactance of 10%. The bus voltage at the motors is 6.9 kV when a three-phase fault occurs at point p. for the fault specified, determine (i) the sub transient current in the fault (ii) the sub transient current in breaker A and (iii) the symmetrical short-circuit interrupting current in the fault and in breaker A. (Nov/Dec 2007) (13 M)** BTL3

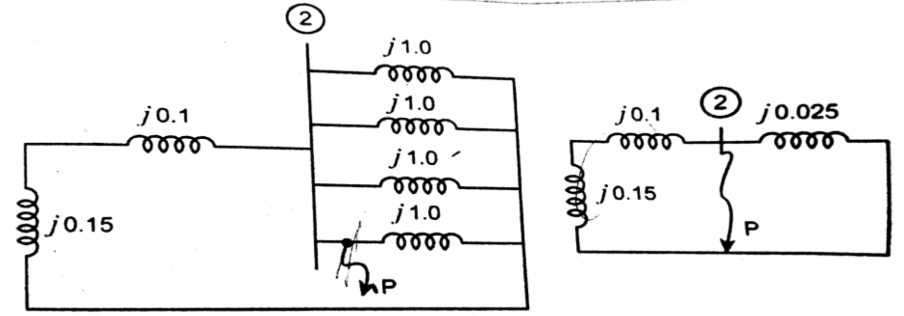


Answer: Page 8.56- M.Jeraldin Ahila

Reactance Diagram: (2M)



Thevenin Circuit: (3M)



Actual Value of Fault current (3M)

$I_f = \frac{E_{th}}{X_{th}} = \frac{1\angle 0}{j0.023}$ = -j43.48 p.u and $I_f = -j43.48 * 2.09 = 90.87\ KA$

Current contributed by generator: (2M)

$I_G = \frac{-j43.48 * j0.025}{j0.275}$ = -j 4 p.u

Each motor contribution (3M)

$$\frac{-j4}{4} = -j1.0\ p.u$$

8.

With a help of a detailed flowchart, explain how a symmetrical fault can be analyzed using Zbus. (Nov/Dec 2011,12) (7 M) BTL4

Answer: Page 8.34 - M.Jeraldin Ahila

Flowchart: (3M)

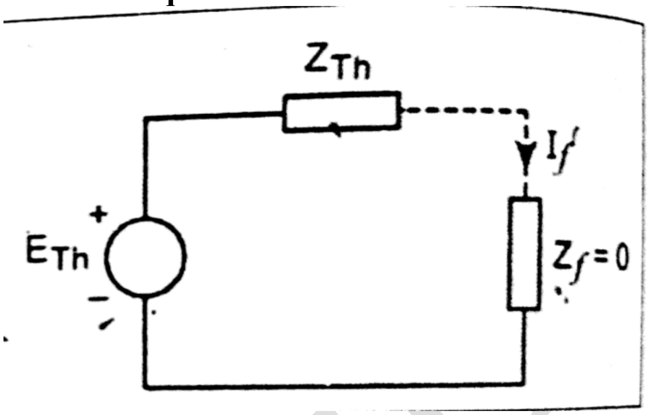
Expalnation: (4M)

1. Prefault per phase network
2. Obtain Z_{bus} matrix
3. Obtain the fault current
4. Obtain thevenin network
5. Post fault bus voltage
6. Post fault line current

Derive an expression for the short circuit capacity SCC or fault level or Fault MVA. (6 M) BTL1

Answer: Page 8.14 - M.Jeraldin Ahila

Thevenin Equivalent Circuit (2M)



Short circuit capacity Definition (1M)

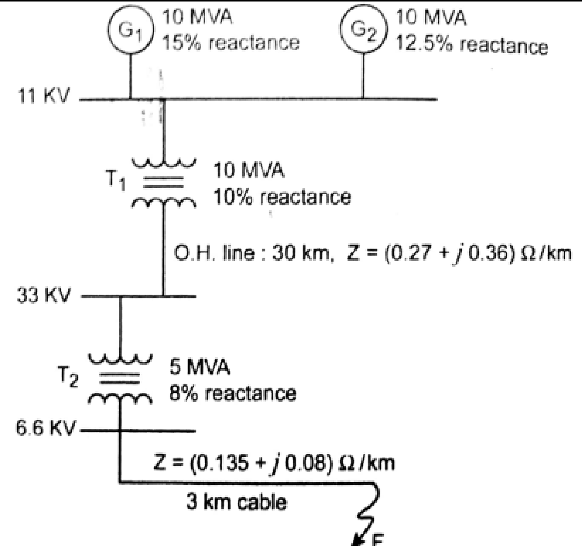
Short circuit capacity at a bus is defined as the magnitude of prefault bus voltage and post fault current.

$$I_f = \frac{E_{th}}{X_{th}} * \frac{MVA_b * 10^3}{\sqrt{3} * KV_b}$$ **(2M)**

Short Capacity = $|E_{th}| * |I_f|$ **(1M)**

9.

For the radial network shown below a three phase fault occurs at F. Determine the fault current and the line voltage at 11 kV bus under fault conditions.(Nov/Dec 2014) (13M) BTL3



Answer: Page 8.22 - M.Jeraldin Ahila

Reactance Diagram (3M)

Fault Current (4M)

$I_f = \frac{E_{th}}{Z_{th}} = \frac{1\angle 0}{0.2528+j0.6564}$ = 0.6425-j1.85p.u

Base Current = $\frac{MVA}{\sqrt{3}* KV_b}$ $\frac{10*1000}{\sqrt{3}*6.6}$ = 874.77A

$$I_f = 1.959 * 874.77 = 1714A$$

Line voltage at 11 KV : Formula (2M)

$V = E + Z_f I_f$

Value of Z_f: (2M)

$$Z_f = 0.2528 + j0.5898$$

Actual Voltage: (2M)

V = 0.447P.u

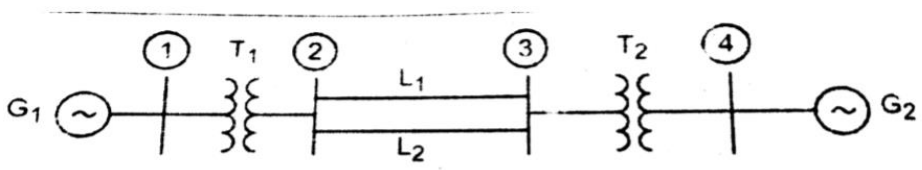
Actual Voltage = 0.875*base voltage

0.875*11

9.615 KV

10.

A symmetrical fault occurs at bus 4 for the system shown in figure. G1,G2: 100 MVA, 20 KV,X" = 15% Transformers T1,T2: $X_{leakage}$ = 9%, L1,L2: X" = 10% . Determine the fault current and post fault voltages using Z bus building algorithm. (Nov/Dec 2017) (13 M) BTL3



Answer: Page 8.35 - M.Jeraldin Ahila

Z bus using Bus building algorithm **(5M)**

$$\begin{bmatrix} j0.1075 & j0.172 & j0.068 & j0.0424 \\ j0.172 & j0.13 & j0.108 & j0.068 \\ j0.068 & j0.108 & j0.13 & j0.082 \\ j0.0424 & j0.13 & j0.082 & j1.075 \end{bmatrix}$$

Fault Current **(2M)**

$I_f = \frac{V^0}{Z_{qq}+Z_f}$ = -j 0.9302

Actual current = p.u value*Base current = 26.85 KA **(2M)**

Post fault voltages for the given system **(4M)**

$V_1^f = v^0 - Z_{14}I_f$ = 0.6056 p.u

$V_2^f = v^0 - Z_{24}I_f$ = 0.3686 p.u

$V_3^f = v^0 - Z_{34}I_f$ = 0.2374 p.u

$V_4^f = v^0 - Z_{44}I_f$ = 0.0006 p.u

11.

(i)The bus admittance matrix is given by Y-Bus = $\begin{bmatrix} -j5 & j3 \\ j3 & -j8 \end{bmatrix}$**. Determine bus impedance matrix.(4M)** BTL2

Answer: Page 4.1 - M.Jeraldin Ahila

Z-Bus = $\begin{bmatrix} j0.258 & j0.097 \\ j0.097 & j0.161 \end{bmatrix}$ (4M)

(ii) Describe the Z_{Bus} building algorithm in detail by using a three bus system. (Nov/Dec 2017)

(9 M) BTL3

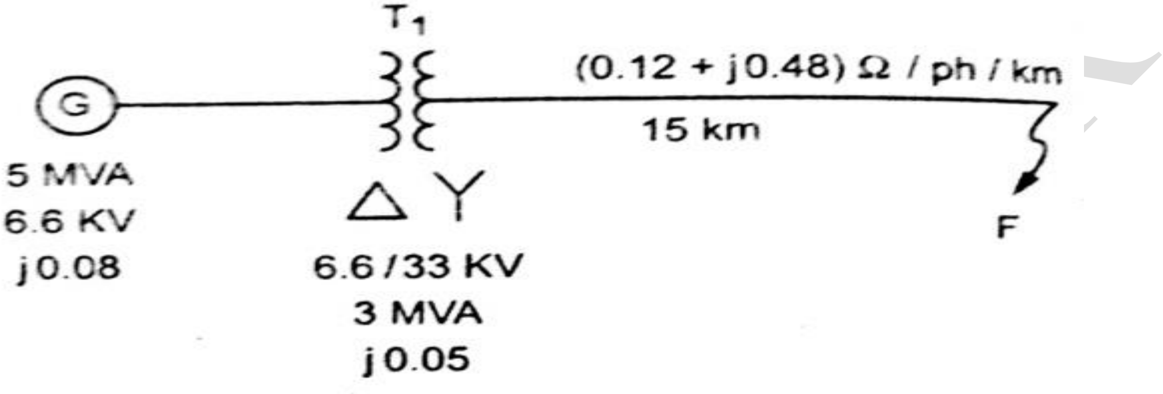
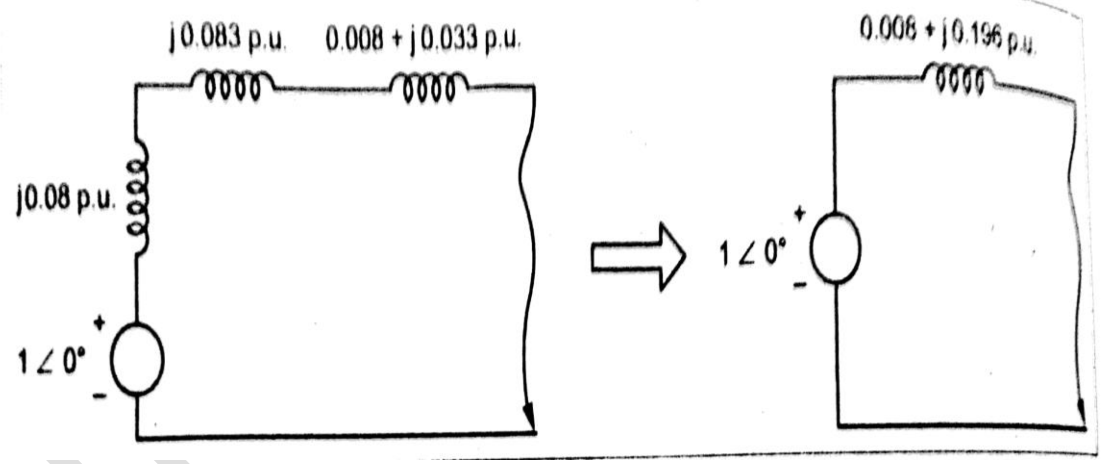
Answer: Page 4.2 - M.Jeraldin Ahila

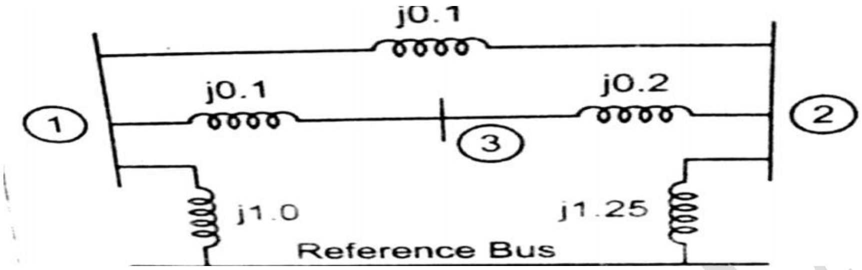
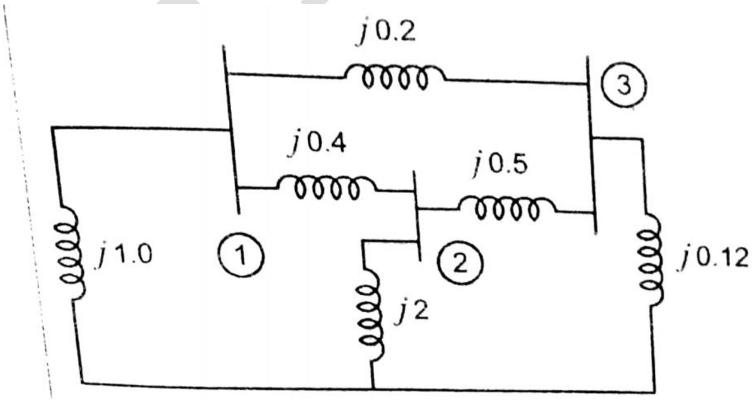
Modification 1: Add an element with impedance Z connected between the reference node and new node (n+1). (3M)

Modification 2: Add an element with impedance Z connected between the existing node and new node (n+1). (2M)

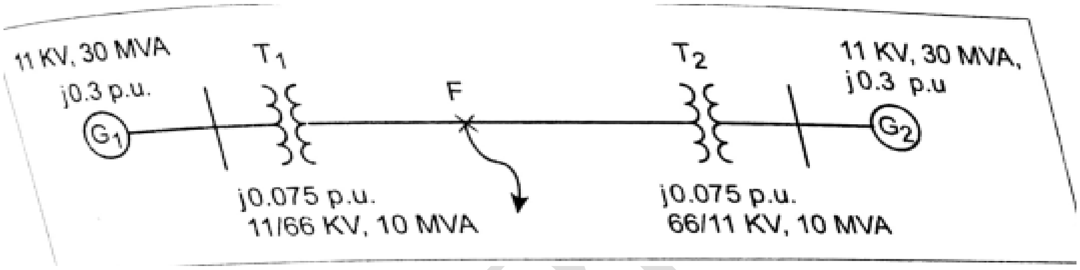
Modification 3: Add an element with impedance Z connected between the existing node and reference node. (2M)

Modification 4: Add an element with impedance Z connected between the existing node i and j. (2 M)

	PART*C
1.	**A 3-phase 5 MVA, 6.6 KV alternator with a reactance of 8 % is connected to a feeder of series impedance (0.12+j0.48) ohm/phase/km through a step up transformer. The transformer is rated at 3 MVA, 6.6 KV/33 KV and has a reactance of 5%. Determine the fault current supplied by the generator operating under no load with a voltage of 6.9 KV, when a 3 phase symmetrical fault occurs at a point 15 km along the feeder. (Nov/Dec 2016) (15M)** BTL3  **Answer: Page S.39-M.Jeraldin Ahila** **Reactance Diagram** **(5M)**  **Fault Current** **(6M)** $I_f = \frac{E_{th}}{Z_{th}} = \frac{1\angle 0}{0.008+j0.196}$ = 0.207-j5.093 p.u **Actual value of Fault current** **(4M)** Base Current = $\frac{MVA}{\sqrt{3}* KV_b}$ $\frac{5}{\sqrt{3}*6.9}$ = 0.418 KA $I_f = 5.097 * 0.418 = 2.13\ KA$
2.	**A 11KV, 100 MVA alternator having a sub-transient reactance of 0.25 p.u is supplying a 50 MVA motor having a sub-transient reactance of 0.2 p.u through a transmission line.**

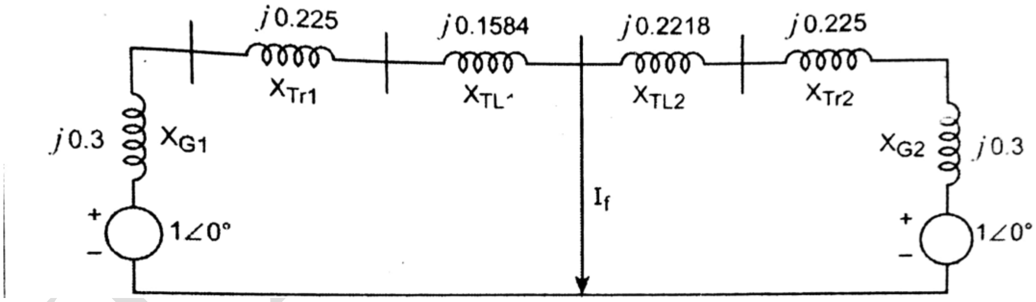
	The line reactance is 0.05 pu on a base of 100 MVA. The motor is drawing 40 MW at 0.8p.f. leading with a terminal voltage of 10.95 KV when a 3 phase fault occurs at the generator terminals. Calculate the total current in the generator and motor under fault conditions. (April/May 2011) (15M) BTL5 **Answer: Page S.66 - M.Jeraldin Ahila** 1. Draw the reactance diagram. (4M) 2. Prefault current for the motor. (4M) 3. Voltage behind subtransient reactance for the alternator. (3M) 4. Voltage behind subtransient reactance for the motor. (4M)
3.	**Determine the Z_{bus} for a 3 bus system as shown in figure, where the impedances are shown and the values are in per unit. (May/June 2009) (15M)** BTL3  **Answer: Page S.50 - M.Jeraldin Ahila** Explain: 1. Add the element between reference node and 1. (2 M) 2. Add a reference node to the new bus (2) (3 M) 3. Add an element between bus (1) and bus(3). (3 M) 4. Add an element existing buses (2) and (3). (2 M) 5. Apply kron reduction. (2 M) 6. Add an element between existing buses (1) and (2). (3M)
4.	**Using building algorithm method, Determine Z_{bus} for the network shown in figure where the impedance labeled are shown in per unit. (Nov/Dec 2007) (15M)** BTL3  **Answer: Page S.16 - M.Jeraldin Ahila** Explain:

<table>
<tr><td></td><td>
1. Add the element between reference node and 1. (2 M)
2. Add a reference node to the new bus (2) (3 M)
3. Add an element between bus (1) and bus (3). (3 M)
4. Add an element existing buses (2) and (3). (2 M)
5. Apply kron reduction. (2 M)
6. Add an element between existing buses (1) and (2). (3 M)
</td></tr>
<tr><td>5.</td><td>
Generator G1 and G2 are identical and rated as 11 KV, 30 MVA and have a transient reactance of 0.3 p.u at own MVA base. The transformer T1 and T2 are also identical and are rated 11/66 KV, 10 MVA and have a reactance of 0.075 per unit to their own MVA base. Then the line is 60 km long, each conductor has a reactance of 0.92 ohm/km. The 3 phase fault is assumed at point F, which is 25 km from generator G1. Find the short circuit current. (Nov/Dec 2015) (15 M) BTL3

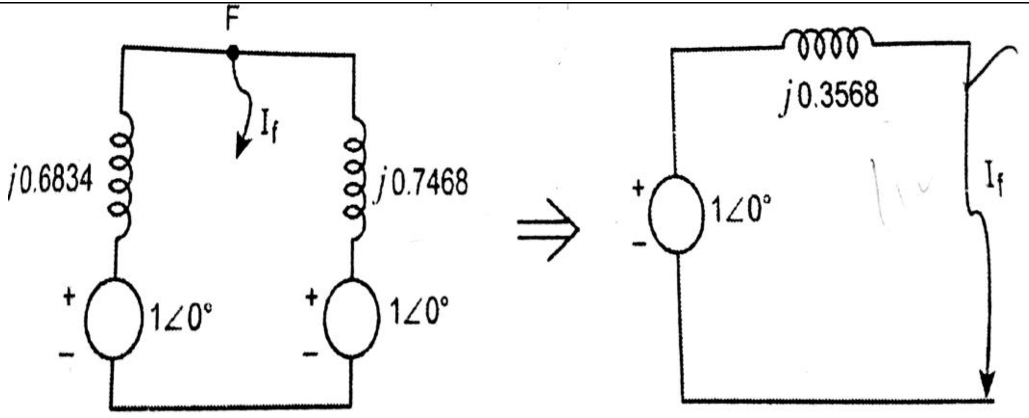


Answer: Page 8.37 - M.Jeraldin Ahila

Reactance Diagram: (4M)



Thevenin Circuit: (4M)
</td></tr>
</table>



Fault current **(4M)**

$I_f = \frac{E_{th}}{X_{th}} = \frac{1\angle 0}{j0.3568}$ = -j2.8023 p.u

Actual Fault current **(3M)**

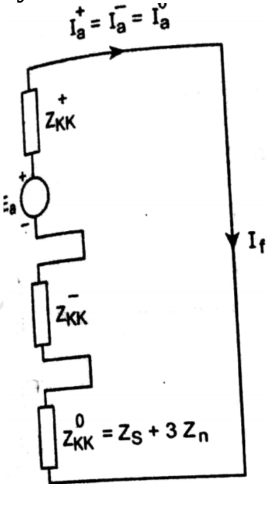
Base Current = $\frac{MVA}{\sqrt{3}* KV_b}$ $\frac{30*10^3}{\sqrt{3}*66}$ = 262.432 KA

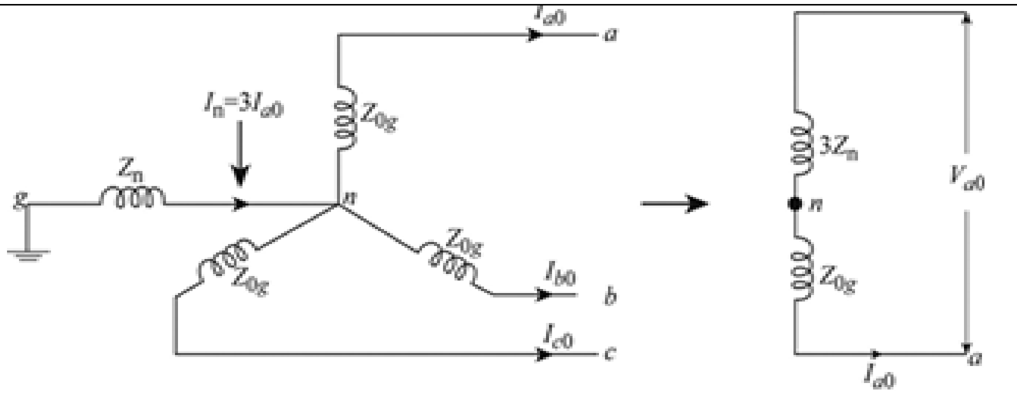
Actual Fault current = 2.8023*262.432 = 735.413A

UNIT IV FAULT ANALYSIS – UNBALANCED FAULTS

Introduction to symmetrical components – sequence impedances – sequence circuits of synchronous machine, transformer and transmission lines - sequence networks analysis of single line to ground,line to line and double line to ground faults using Thevenin's theorem and Z-bus matrix.

PART*A

Q.No.	**Questions**
1.	**Define unsymmetrical faults.** BTL1 - Line to ground fault - Line to line fault - Double Line to ground fault - One or two open conductor fault.
2.	**Write the symmetrical components of three phase system. (Nov/Dec 2015)** BTL1 In a 3-phase system, the 3-phase unbalanced vectors (either current or voltage vectors) can be resolved into three balanced system of vectors. They are - Positive sequence components - Negative sequence components - Zero sequence components
3.	**Define positive sequence impedance and negative sequence impedance. (Nov/Dec 2011)** BTL1 The positive sequence impedance of equipment is the impedance offered by the equipment to the flow of positive sequence current. The negative sequence impedance of equipment is the impedance offered by the equipment to the flow of negative sequence current.
4.	**Draw the equivalent sequence network diagram for a single phase to ground fault in a power system.** BTL1  where Z_{KK}^+ = Positive sequence impedance Z_{KK}^- = Negative sequence impedance Z_{KK}^0 = Zero sequence impedance Z_S = Source impedance Z_n = Neutral impedance I_f = Fault current
5.	**Draw the zero sequence equivalent network diagram for a 3 phase star connected alternator with reactance earthing.** BTL1

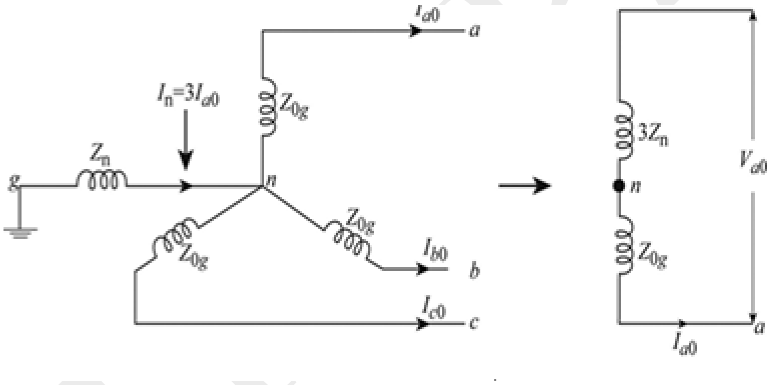


6. **Write down the equation to determine symmetrical components of currents from unbalanced currents. (Nov/Dec 2017)** BTL1

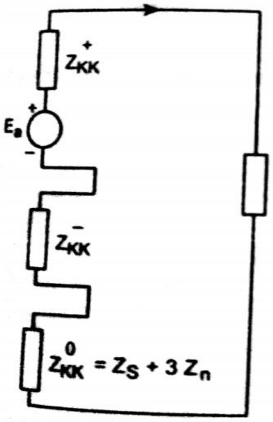
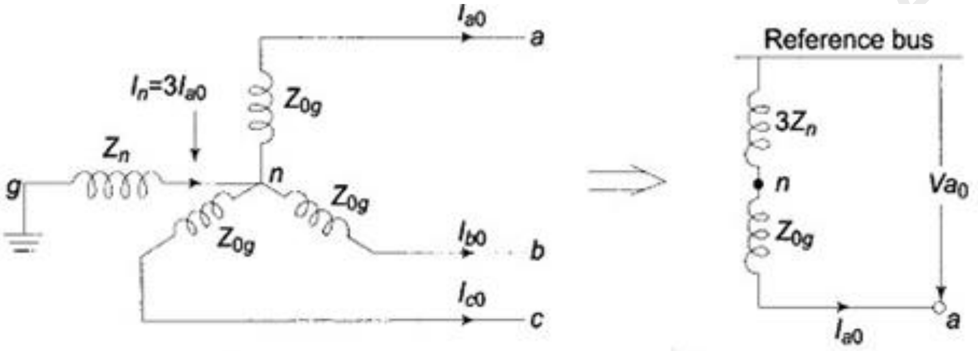
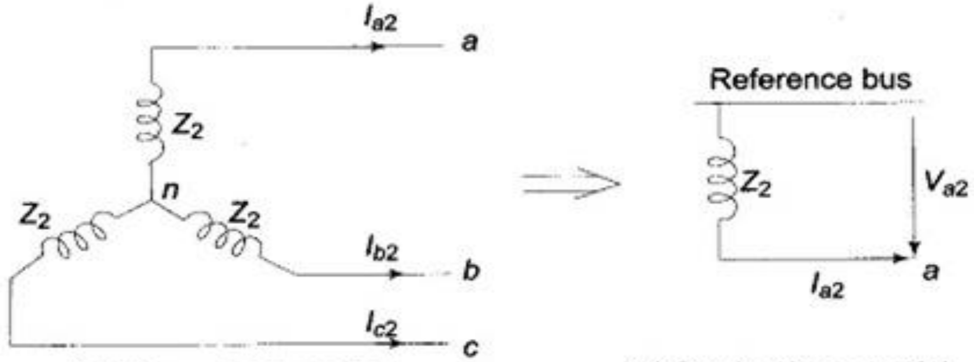
$$\begin{bmatrix} I_a^0 \\ I_a^+ \\ I_a^- \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

Where a=1∠120 degree; a^2 = 1∠240 degree.

7. **Draw the zero sequence network of star connected alternator with zero sequence impedance Z_{go} when the neutral is grounded through impedance Z_n.** BTL1

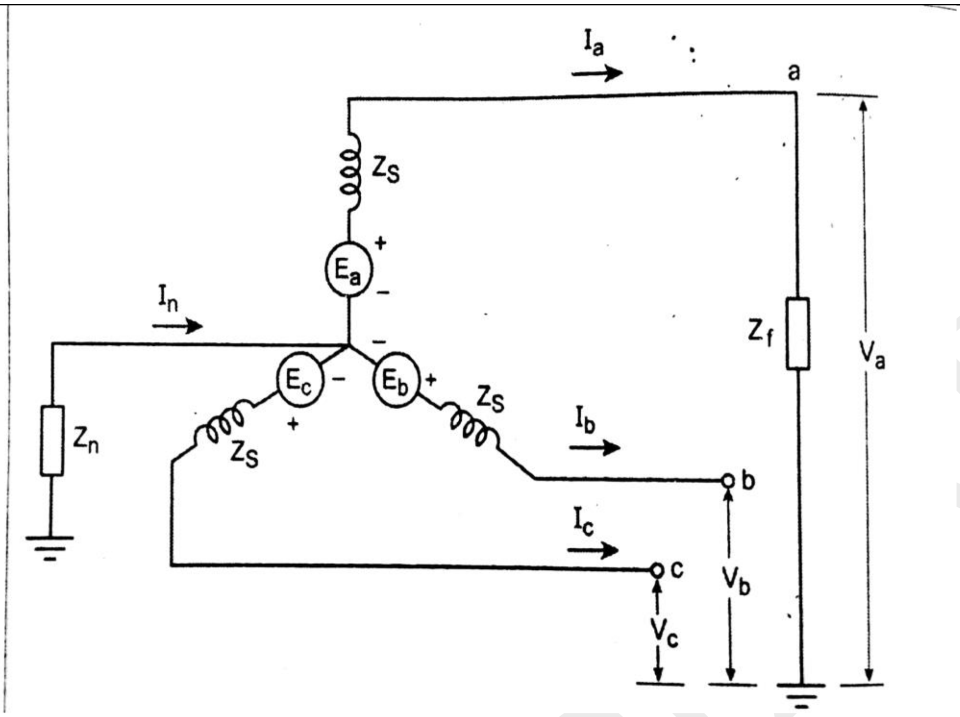


8. **Draw the equivalent sequence network diagram for a single phase to ground fault with fault impedance in a power system.** BTL1

	 where Z^+_{KK} = Positive sequence impedance Z^-_{KK} = Negative sequence impedance Z^0_{KK} = Zero sequence impedance Z_S = Source impedance Z_n = Neutral impedance I_f = Fault current Z_f = Fault impedance
9.	**Draw the zero sequence diagram of a synchronous generator with neutral grounded.** BTL1  (a) Three-phase model (b) Single-phase model
10.	**Draw the negative sequence diagram of a synchronous machine.** BTL1  (a) Three-phase model (b) Single-phase model

11.	**Why is the zero sequence impedance of a transmission line is more than its sequence impedance?** BTL4 The positive and negative sequence currents have no return path and they have phase difference of Degree. But for zero sequence currents have return path. The magnetic field due to zero sequence current is different from the magnetic field caused by either positive or negative sequence current.
12.	**Why the sequence reactance of a transformer is equal?** BTL4 In power transformer, the magnetizing current is neglected. The transformer is modelled with the equivalent series leakage impedance. Since the transformer is a static device, the leakage impedance will not change when the phase sequence is change. If the transformer permits zer sequence current flow at all, the zero sequence is equal to the leakage impedance.
13.	**Write down symmetrical component transformation matrix.** BTL1 Symmetrical transformation matrix [T] = $\begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}$ Where a=1∠120 degree; a^2 = 1∠240 degree
14.	**Name any two methods of reducing short circuit current.** BTL1 •By providing neutral reactances •By introducing a large value of shunt reactance between buses.
15.	**State the reason for transient during short circuits.**BTL4 The faults or short circuits are associated with sudden change in currents. Most of the components of the power system have inductive property which opposes any sudden changes in currents, so the faults (short circuits) are assosciated with transients.
16.	**Why is the synchronous impedance more than transient reactance?** BTL4 The short circuit current as measured immediately following the short circuit is of larger magnitude than the current measured half a second later. This means the magnitude of Z will have a minimum value immediately following the fault and then grow.
17.	**Give the reason for occurrence for L-G fault and write the boundary condition for single line to ground fault. (Nov/Dec 2013)** BTL2 Lightning and Conductors making contact with grounded strucutures like towers or poles. $V_a = Z_f I_a$ $I_b = I_c = 0$ $I_f = I_a$
18.	**Write the equation to determine fault current for L-L-G fault with fault impedance between phases b and c.** BTL1 **Fault current** = $I_f = 3\,I_a^0 = -3\,[\frac{E_a - Z_{KK}^{+} I_a^{+}}{Z_{KK}^{0} + 3\,Z_f}]$ Where I_a^+ = positive sequence current. E_a = prefault voltage Z_{KK}^0andZ_{KK}^+ are zero sequence impedance and positive sequence impedance. Z_f = Fault impedance

19.	**Name the fault in which positive and negative sequence component currents together is equal to zero sequence current in magnitude**. BTL1 Double line to ground fault is the fault in which positive and negative sequence component currents together is equal to zero sequence current in magnitude.
20.	**List out the causes of unsymmetrical faults.** BTL2 Lightning, wind damage, trees falling across lines, vehicles colliding with towers or poles, birds, shorting lines. Breaks due to excessive ice loading or snow loading, salt spray.
21.	**Define Sequence operator. (Nov/Dec 2015)** BTL1 Sequence operator consists of three components of equal magnitude dispalced each other by 120 degree in phase and will have the phase sequence as abc to operate in the power system.
22.	**Write the significance of 'a' operator. (Nov/Dec 2005,2015)** BTL2 The symmetrical component of one vector is rotated by 120 degree to get the symmetrical components of other vectors. a=1$\angle$120 degree; a^2 = 1$\angle$240 degree
23.	**Define Symmetrical components. (Nov/Dec 2005,12)** BTL1 Symmetrical components are applied to unbalanced faults are analyzed using per phase basis. Two functions are developed for the symmetrical component transformation. These are transformation from phase quantities into symmetrical components and symmetrical components to phase quantities.
24.	**Define sequence Network. (April/May2008),(Nov/Dec 2014)** BTL1 The single phase equivalent circuit of a power system consists of impedances to current of any one sequence only is called as sequence network.
25.	**Name the fault which do not have zero sequence current flowing. (Nov/Dec 2011)** BTL1 Line to Line fault is the fault which do not have zero sequence current flowing because there will not be zero sequence network in the system.
PART*B	
Q.No.	**Questions**
1.	**Derive the expression for fault current in Single Line-to-Ground fault on an unloaded generator in terms of symmetrical components. (Nov/Dec 2017) (13 M)** BTL1 **Answer: Page 9.32 - M.Jeraldin Ahila** **Explain:** **Single line to ground fault at phase 'a' (2M)**



Fault Bus K: **(4M)**

$$V_a = Z_f I_a$$

$$I_b = I_c = 0$$

$$I_f = I_a$$

symmetrical components of current **(2M)**

$$\begin{bmatrix} I_a^0 \\ I_a^+ \\ I_a^- \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} I_a \\ 0 \\ 0 \end{bmatrix}$$

$I_a^0 = I_a^+ = I_a^- = \frac{I_a}{3}$

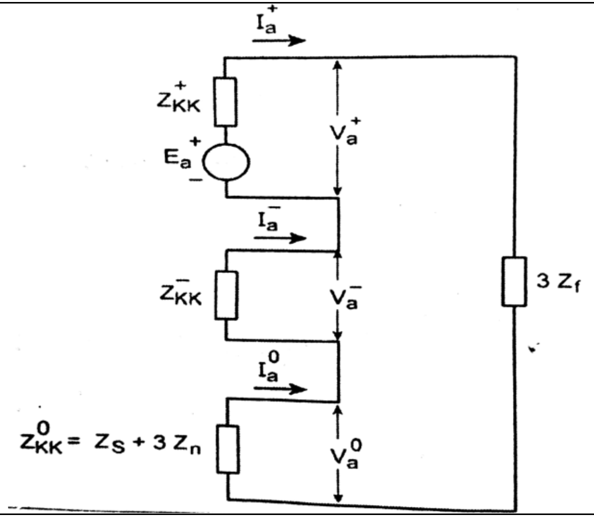
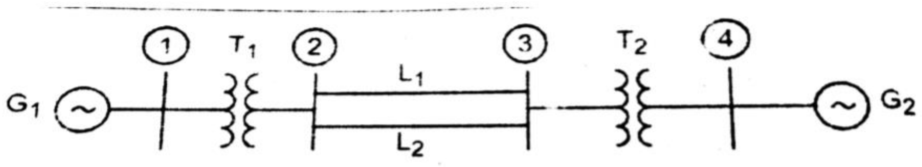
Symmetrical components of Voltages **(1M)**

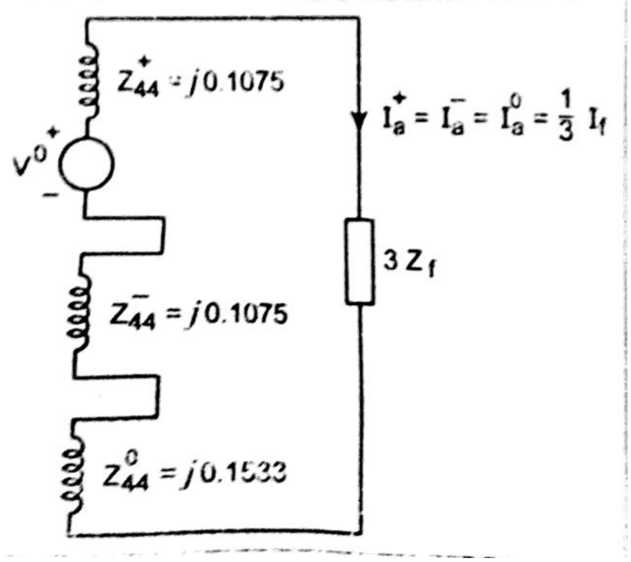
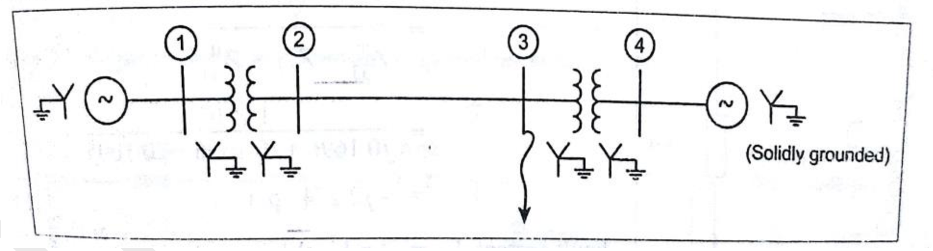
$$\begin{bmatrix} v_a^0 \\ v_a^+ \\ v_a^- \end{bmatrix} = \begin{bmatrix} 0 \\ E_a \\ 0 \end{bmatrix} - \begin{bmatrix} Z_{kk}^0 & 1 & 1 \\ 1 & Z_{kk}^+ & a \\ 1 & a & Z_{kk}^- \end{bmatrix} \begin{bmatrix} I_a^0 \\ I_a^+ \\ I_a^- \end{bmatrix}$$

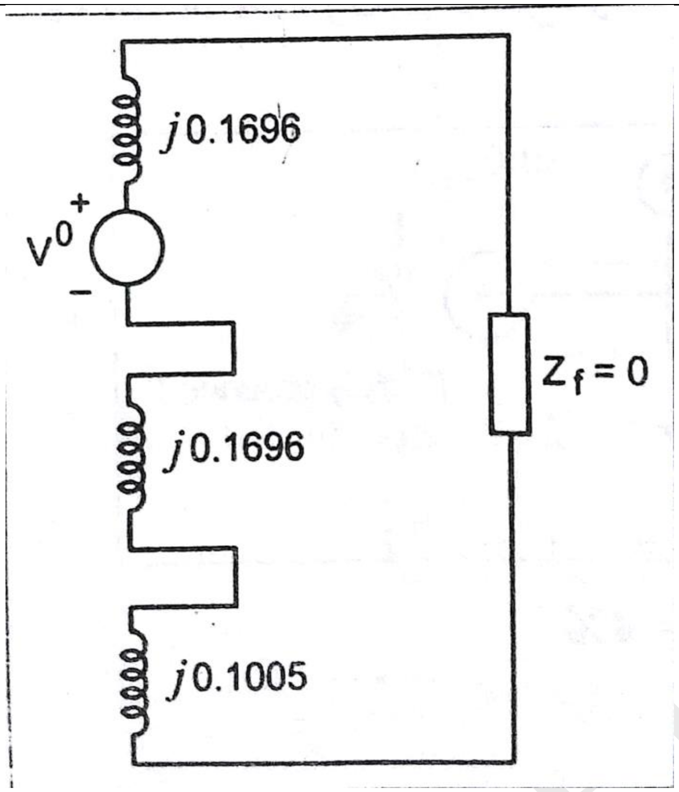
Fault Current **(2M)**

$$I_f = I_a = 3\, I_a^+ = \frac{3E_a}{3Z_f + Z_{kk}^- + Z_{kk}^0 + Z_{kk}^+}$$

Sequence network: **(2M)**

	
2.	**Determine the fault current and MVA at faulted bus for a line to ground (solid) fault at bus 4 as shown in fig below. (13M)** BTL3  **G_1, G_2: 100 MVA, 11kV, X^+ , X^- = 15%, X^0 = 5%, X_n = 6%** **T_1, T_2: 100 MVA, 11kV/220 kV, X leak = 9%** **L_1, L_2: X^+ = X^- = 10%, X^0 = 10% on base of 100 MVA. Consider a fault at phase a.** **Answer: Page 9.16 - M.Jeraldin Ahila** **Positive sequence impedance : (3M)** Positive Thevenin equivalent circuit viewed from bus 4 **Zero sequence impedance diagram: (3M)** Zero Thevenin equivalent circuit viewed from bus 4 **Sequence network: (3M)**

	 **Prefault voltage: (2M)** Ea= 1∠0 Ia=-j2.7152 **Fault current: (2M)** Fault current = $3I_a^+$ Fault current =-j8.1455 p.u
3.	**A single line to ground fault occurs on bus 4 of the system shown in fig below.** 1. **Draw the sequence networks and(10M)** 2. **Compute the fault current.(3M)** **Gen 1 and 2: 100 MVA, 20kV; X’ = X’ ’ 20%; X_0 = 4%; X_n = 5%.** **Transformer 1 and 2 : 100 MVA, 20/345 KV; $X_{leakage}$ = 8% on 100 MVA** **Tr. Line: X’ = X’ = 15% X0 = 50% on a base of 100 MVA, 20 kV. (13M)** BTL3  **Answer: Page 9.15 - M.Jeraldin Ahila** **Positive sequence impedance :(3M)** Positive impedance value = j0.1696 p.u **Zero sequence impedance: (3M)** Zero impedance value = j0.1005 p.u **sequence network :(4M)**



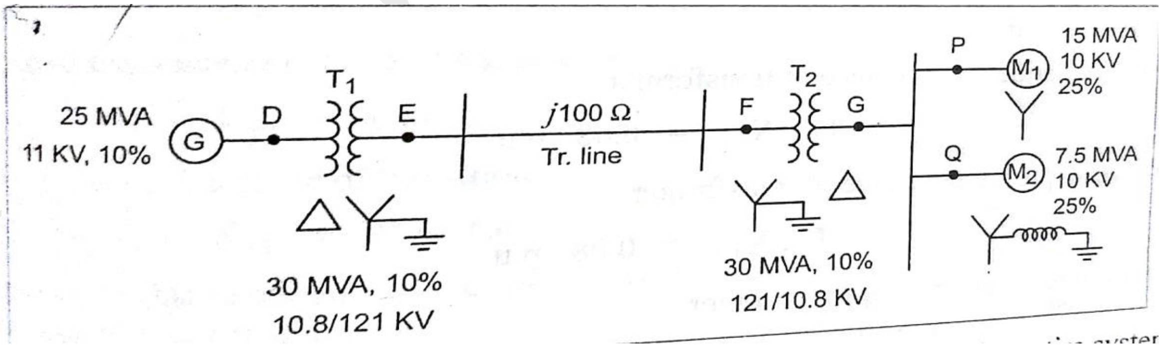
Find the prefault voltage, Fault current: (3M)

Prefault voltage = Ea = 1∠0

Fault current = $3I_a^+$

4.

Determine the positive, negative and zero sequence networks for the system shown in fig below. Assume zero sequence reactance for the generator and synchronous motors as 0.06 p.u. current limiting reactors of 2.5 are connected in the neutral of the generator and motor No.2 The zero sequence reactance of the transmission line is j 300. (13 M) BTL3



Answer: Page.7.27 - M.Jeraldin Ahila

Determine sequence reactance of Generator : (3M)

$$X_{GN} = \frac{Actual\ neutral\ reactance}{Base\ reactance}$$

Determine sequence reactance of T1 and T2 : (2M)

$$X_{GN} = \frac{Actual\ neutral\ reactance}{Base\ reactance}$$

Determine sequence reactance of transmission line: (3M)

$$X_{GN} = \frac{Actual\, neutral\, reactance}{Base\, reactance}$$

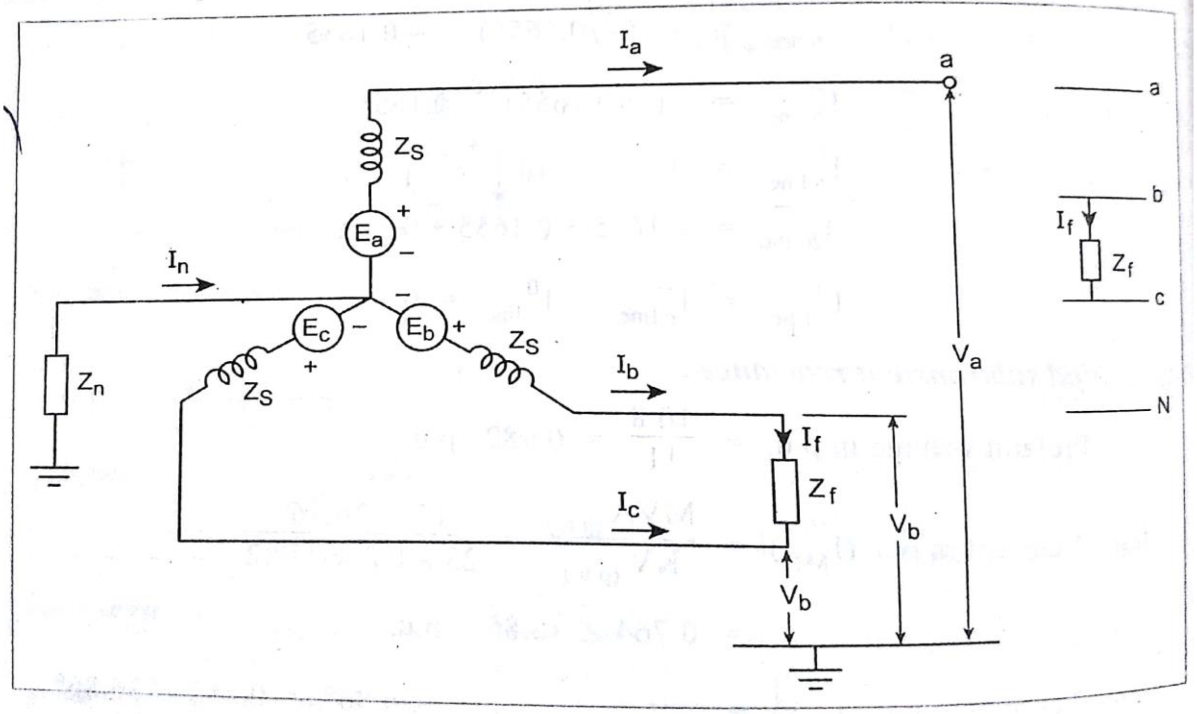
Determine sequence reactance of synchronous motor: (2M)

$$X_{GN} = \frac{Actual\, neutral\, reactance}{Base\, reactance}$$

Determine the positive, negative and zero sequence network: (3M)

5. **Draw the sequence network connection for DLG fault at any point in a power system. From that obtain an expression for the fault current.(Nov/Dec 2012) (13 M)** BTL4

Answer: Page 9.42 -9.47 - M.Jeraldin Ahila



Double line to ground fault between phases: (3M)

$$\begin{bmatrix} v_a^0 \\ v_a^+ \\ v_a^- \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

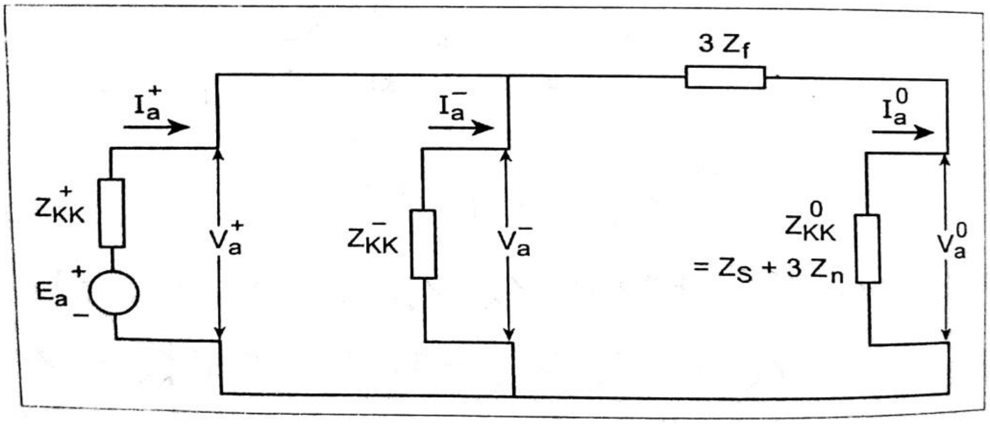
Determine Phase currents and phase voltage : (4M)

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}\begin{bmatrix} v_a^0 \\ v_a^+ \\ v_a^- \end{bmatrix}$$

Find the symmetrical component voltages: (3M)

$$\begin{bmatrix} v_a^0 \\ v_a^+ \\ v_a^- \end{bmatrix} = \begin{bmatrix} 0 \\ E_a \\ 0 \end{bmatrix} - \begin{bmatrix} Z_{KK}^0 & 0 & 0 \\ 0 & Z_{KK}^+ & 0 \\ 0 & 0 & Z_{KK}^- \end{bmatrix}\begin{bmatrix} I_a^0 \\ I_a^+ \\ I_a^- \end{bmatrix}$$

Draw the sequence network: (3M)

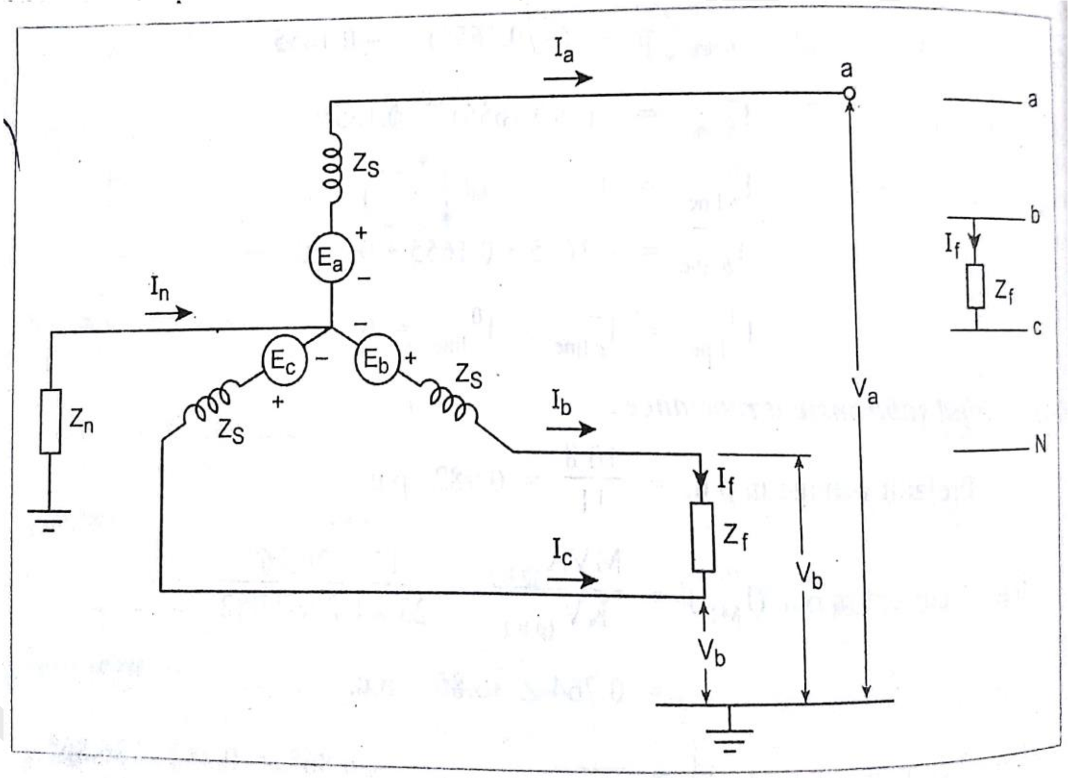


6.

Develop the connection of sequence network when line to line fault occurs in a power network. (Nov/Dec 2013) (13 M) BTL3

Answer: Page 9.32 - M.Jeraldin Ahila

Three phase generator with a fault through an impedance between phase b and c : (3 M)



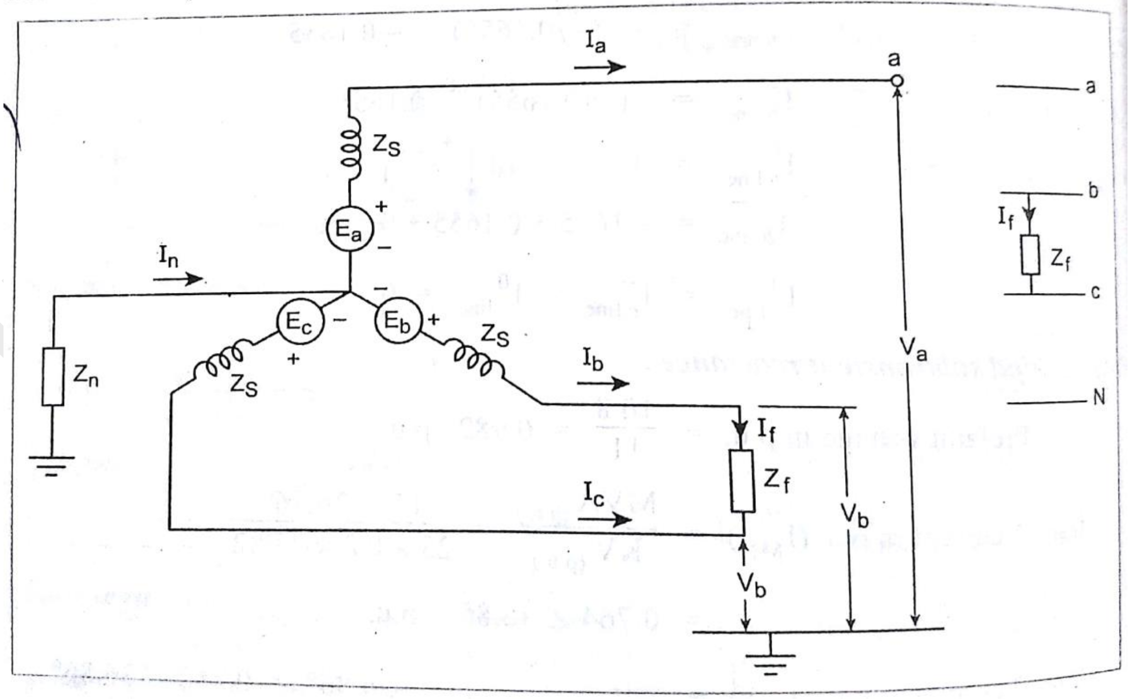
Find the symmetrical components of current : (3M)

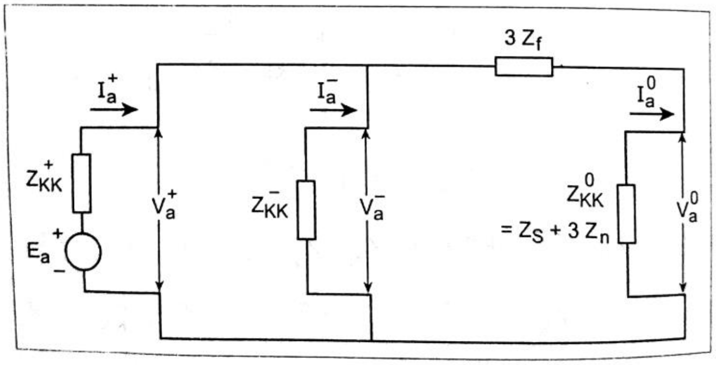
$$\begin{bmatrix} I_a^0 \\ I_a^+ \\ I_a^- \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

Determine the sequence voltage: (3M)

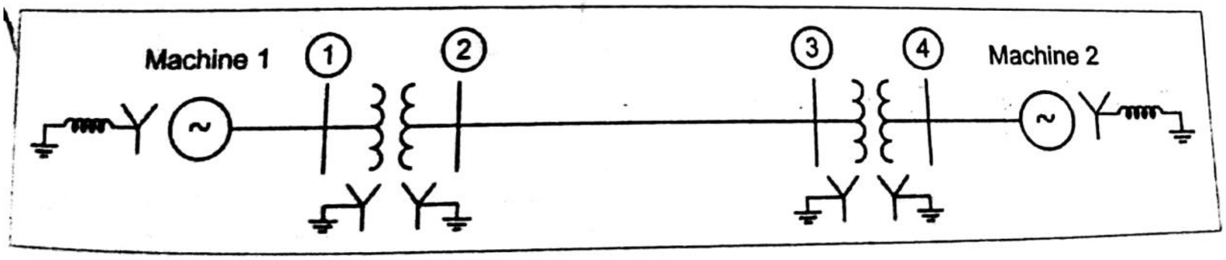
$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}\begin{bmatrix} 0 \\ v_a^+ \\ v_a^- \end{bmatrix}$$

Determine the phase Current: (2M)

	$\begin{bmatrix} I_a^0 \\ I_a^+ \\ I_a^- \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$ **Draw the sequence network: (2M)**
7.	**Explain how an unbalanced set of three phase voltages can be represented by system of balance voltages. (13 M)** BTL2 **Answer: Page 7.6 - M.Jeraldin Ahila** **Write the phase voltage: (3M)** $\boldsymbol{v_a = v_a^0 + v_a^+ + v_a^-}$ $\boldsymbol{v_b = v_b^0 + v_b^+ + v_b^-}$ $\boldsymbol{v_c = v_c^0 + v_c^+ + v_c^-}$ **Substitute the symmetrical components: (3M)** **Symmetrical component voltages can be written interms of phase voltage : (4M)** $\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}\begin{bmatrix} v_a^0 \\ v_a^+ \\ v_a^- \end{bmatrix}$ **The balance voltages are derived: (3M)** $\begin{bmatrix} v_a^0 \\ v_a^+ \\ v_a^- \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$
8.	**Derive the expression for fault current in double line to ground fault on unloaded generator. Draw an equivalent network showing the inter connection of networks to simulate double line to ground fault. (13 M)** BTL1 **Answer: Page 9.42 - M.Jeraldin Ahila** **Double line to ground fault between phase b and c: (3M)**  **Write the symmetrical components of voltages: (3M)**

	$$\begin{bmatrix} v_a^0 \\ v_a^+ \\ v_a^- \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$ **Write the phase current and phase voltage: (3M)** $$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}\begin{bmatrix} v_a^0 \\ v_a^+ \\ v_a^- \end{bmatrix}$$ **Derive for symmetrical components of voltages and fault current: (2M)** $$I_A^+ = \frac{E_a}{Z_{kk}^+}$$ **Draw the sequence network: (2M)** 
9.	**Explain about the concept of symmetrical components.(Nov/Dec 2014) (13M)** BTL2 **Answer: Page 7.4 - M.Jeraldin Ahila** **Symmetrical components of currents from phase currents: (4 M)** $$\begin{bmatrix} I_a^0 \\ I_a^+ \\ I_a^- \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$ **Unbalanced voltages in terms of symmetrical component: (3M)** $$\begin{bmatrix} v_a^0 \\ v_a^+ \\ v_a^- \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$ **Symmetrical component voltages in term of phase voltage:(3M)** $$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}\begin{bmatrix} v_a^0 \\ v_a^+ \\ v_a^- \end{bmatrix}$$ **Derive the balance voltages : (3M)** $$v_S = [T]^{-1}[v_P]$$
10.	**Two synchronous machines are connected through three-phase transformers to the transmission line as given below in Fig below The ratings and reactance of the machines and transformers are Machines 1 and 2 : 100 MVA, 20 KV; X"$_d$ = X $_1$ = X$_2$ = 20%,X$_0$ = 4%; X$_n$ = 5%.Transformers T$_1$ and T$_2$: 100 MVA, 20Y/345Y kV ; X= 8%Both transformers are solidly grounded on two sides. On a chosen base of 100 MVA, 345 kV in the transmission line circuit the line reactance are X$_1$ =X$_2$ = 15% and X0 = 50%. The system is operating at**

nominal voltage without prefault currents when a bolted (Zf = o) single line-to-ground fault occurs on phase A at bus (3) Using the bus impedance matrix for each of the three sequence networks, determine the sub transient current to ground at the fault. (13 M) BTL3



Answer: Page 9.7- M.Jeraldin Ahila

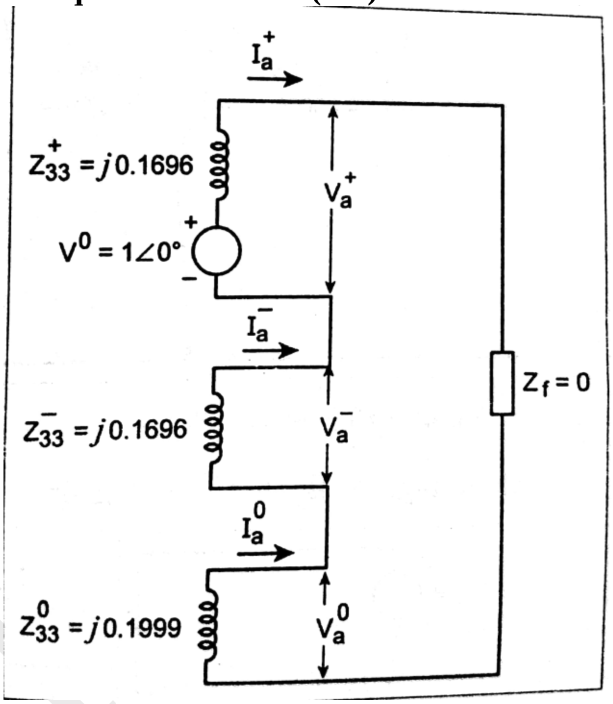
Draw the positive sequence impedance diagram: (3M)

Thevenin Circuit viewed from bus 3.

Draw the negative and zero sequence impedance diagram : (4 M)

Negative and zero sequence viewed from bus 3.

Draw the sequence network : (3M)

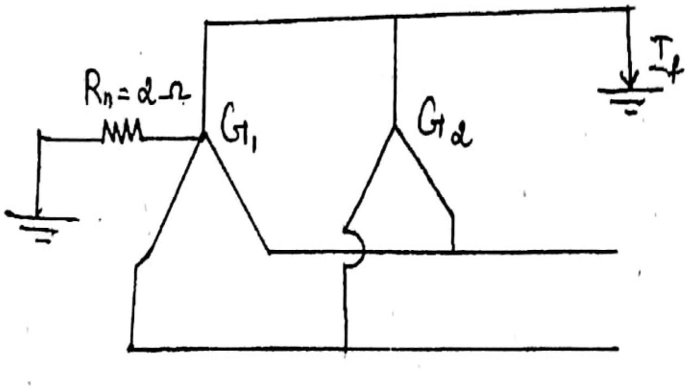
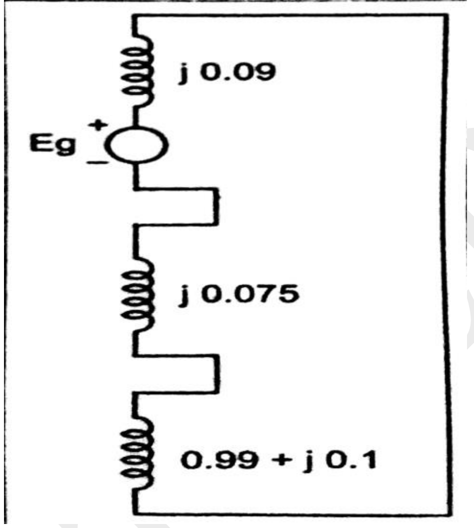


Find the fault current in p.u and ampere: (3M)

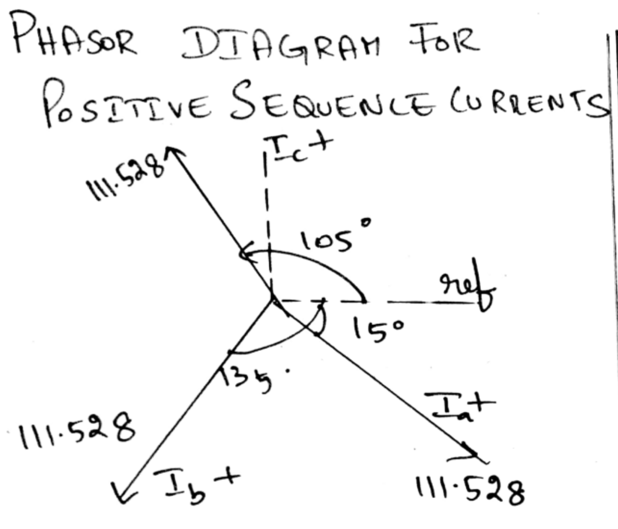
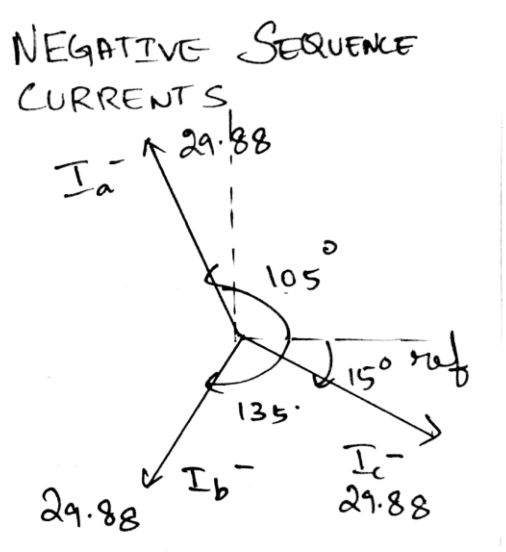
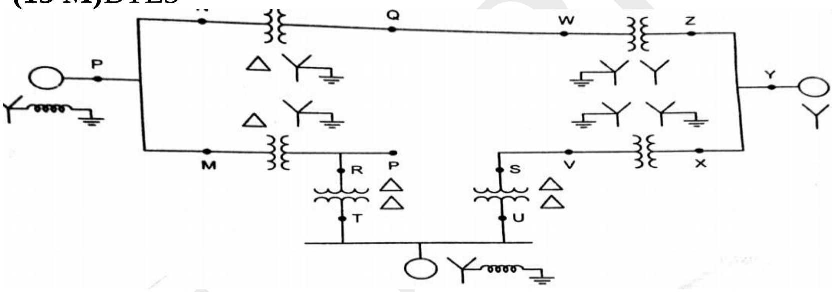
Fault current in p.u = $3I_a^+$

Fault current in Amp = $3I_a^+$ * base current

11. **Two 11 KV, 20 MVA, three phase star connected generators operate in parallel. The positive, negative and zero sequence reactance are j0.18,j0.15,j0.10 p.u.The star point of one of the generator is isolated and that of other is earthed through 2.0 ohm resistor. A single line to ground fault occurs at the terminals of one of the generators. Estimate i) Fault current ii) Current in grounded resistor iii) Voltage across grounding resistor. (April/May 2011) (13 M)** BTL3

	 **Answer: Page S.68 - M.Jeraldin Ahila** **Determine the positive sequence network: (3M)** $Z^{+} = j0.09$ **Determine the negative sequence network: (3M)** $Z^{-} = j0.075$ **Determine the zero sequence network:(3M)**  **Find the fault current: (2M)** $I_f = 3\ I_a^{+}$ =2.827-j0.756 p.u **Find the current and voltage across grounding resistor: (2M)** V= 3.07*2=6.14 KV
12.	**Derive the expression for three phase power in terms of symmetrical components. (Nov/Dec 2015) (13 M)** BTL1 **Answer: Page 7.4,7.6 and 7.7 - M.Jeraldin Ahila** **Symmetrical components of currents from phase currents: (4 M)** $\begin{bmatrix} I_a^0 \\ I_a^{+} \\ I_a^{-} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$ **Unbalanced voltages in terms of symmetrical component: (3M)**

	$\begin{bmatrix}v_a^0\\v_a^+\\v_a^-\end{bmatrix}=\frac{1}{3}\begin{bmatrix}1&1&1\\1&a^2&a\\1&a&a^2\end{bmatrix}\begin{bmatrix}v_a\\v_b\\v_c\end{bmatrix}$ **Symmetrical component voltages in term of phase voltage:(3M)** $\begin{bmatrix}v_a\\v_b\\v_c\end{bmatrix}=\begin{bmatrix}1&1&1\\1&a^2&a\\1&a&a^2\end{bmatrix}\begin{bmatrix}v_a^0\\v_a^+\\v_a^-\end{bmatrix}$ **Derive the power: (3M)** $v_S = [T]^{-1}[v_P]$ $Apparent\ power = [V_p]$^T $[I_p]*$ $Total\ unbalanced\ power - sum\ of\ symmetrical\ components\ powers.$
	PART*C
1.	**The currents flowing in the line towards a balanced load connected in delta are I_a = 100 ∠0^0 ,I_b = 141.4 ∠225^0 and I_c = 100 ∠90^0.Find the symmetrical components of the given line currents. Draw phasor diagrams of the positive and negative sequence line and phase currents. (Nov/Dec 2007) (15M)** BTL4 **Answer: Page S.23 - M.Jeraldin Ahila** **Symmetrical components of currents: (8M)** $\begin{bmatrix}I_a^0\\I_a^+\\I_a^-\end{bmatrix}=\frac{1}{3}\begin{bmatrix}1&1&1\\1&a&a^2\\1&a^2&a\end{bmatrix}\begin{bmatrix}I_a\\I_b\\I_c\end{bmatrix}$ I_a^0 = 0.007 ∠45^0 I_a^+ = 111.528 ∠-15^0 I_a^- = 29.88∠105^0 I_b^0 = 0.007 ∠45^0 $I_b^+ = a^2 I_a^+$ = 111.528 ∠-135^0 $I_b^- = aI_a^-$ = 29.88∠-135^0 I_c^0 = 0.007 ∠45^0 $I_c^- = a^2 I_a^-$ = 29.88 ∠-15^0 $I_c^+ = aI_a^+$ = 11.528∠105^0 **Phasor Diagram for positive and Negative sequence components: (7M)**

	 PHASOR DIAGRAM FOR POSITIVE SEQUENCE CURRENTS  NEGATIVE SEQUENCE CURRENTS
2.	**Draw the zero sequence diagram for the system whose one-line diagram is shown in fig. (15 M)**BTL3  **Answer: Page 7.40 - M.Jeraldin Ahila** Equivalent circuit for zero sequence impedance depends on • The winding connection: (3 M) • Whether the neutral grounded or not : (3M) • Find the sequence impedance : (4M) • Draw the sequence diagram: (5M)
3.	**A salient pole generator without dampers is rated 20 MVA, 13.6 KV and has direct axis subtransient reactance of 0.2 per unit. The negative and zero sequence reactances are 0.35 and 0.1 p.u. respectively. The neutral of the generator is solidly grounded. With the generator operating unloaded at rated voltage with $E_{an} = 1.0\angle 0^0$ per unit, a single line to ground fault occurs at the machine terminals, which then have per unit voltages to ground, $V_a = 0$; $V_b = 1.013\angle -102.25^0$; $V_c= 1.013\angle 102.25^0$. Determine the subtransient current in the**

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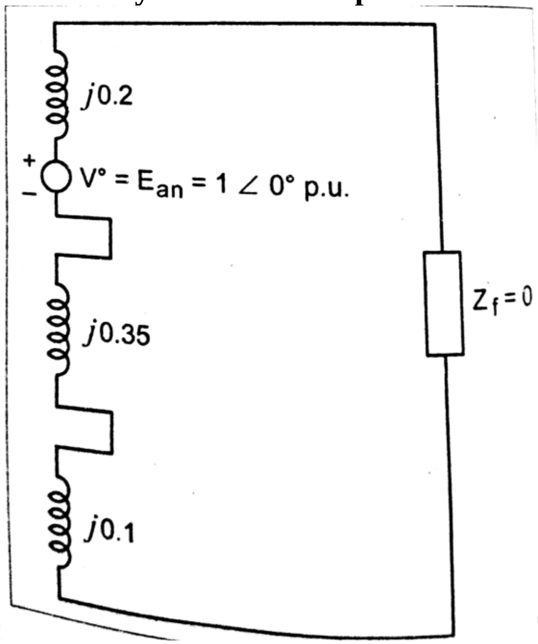
generator and the line-line voltages for subtransient conditions due to fault.(Nov/Dec 2007) (15 M) BTL3

Answer: Page S.26 - M.Jeraldin Ahila

Find the symmetrical components of fault current : (4 M)



$\begin{bmatrix} I_a^0 \\ I_a^+ \\ I_a^- \end{bmatrix}$ = -j1.538

Find the fault current in p.u. and Amp:(3M)

Fault current = 3 I_a^+ = -j4.615 p.u

Find the subtransient current : (4M)

$$\begin{bmatrix} I_a^0 \\ I_a^+ \\ I_a^- \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

Find the line-line voltage for fault condition: (4M)

$$v_{ab} = 0.215 + j0.9899\, p.u$$

v_{bc} =-j1.979 p.u

v_{ac} = 0.215-j0.989p.u

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A single line to ground fault occurs in bus 1 of the system as shown in figure. Find current in the fault, Short circuit current on the transmission line in all the three phases, voltage of the healthy phase of the bus1. Given value: Rating of each machine 1200 KVA, 600 V with X1=X2=10% and X0=5%. Each three phase transformer is rated 1200 KVA, 600V/3300V (Delta/star) with leakage reactance of 5%. The reactances of transmission line are X1=X2=20% and X0=40% on the base of 1200 KVA, 3300V. The reactances of neutral grounding reactors are 5% on the KVA and voltage base of the machine.(May/June 2009)(Nov/Dec 2014) (15 M) BTL3

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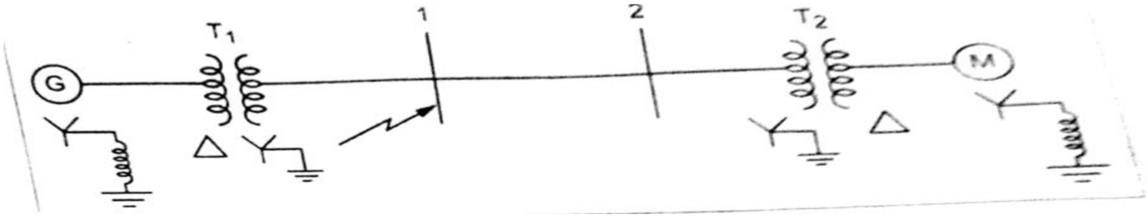
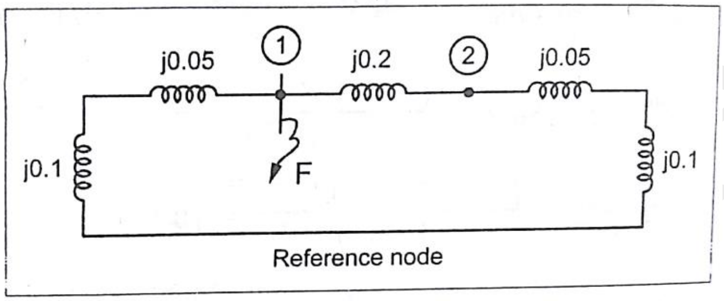


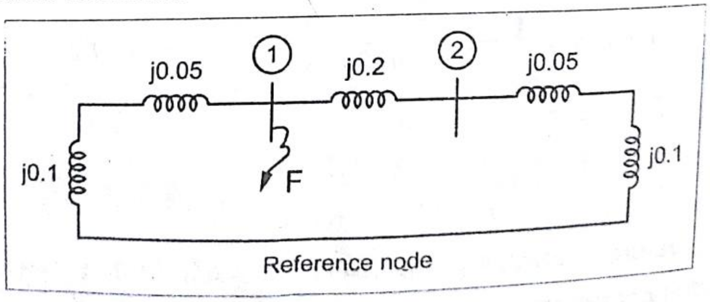
Answer: Page S.53 - M.Jeraldin Ahila

Determine positive and negative sequence network : (5M)

Positive sequence network:



Negative sequence network:



Formulate Z_{bus}: (4M)

$$Z_{bus} = \begin{bmatrix} j0.0045 & j0.005 \\ j0.005 & j0.045 \end{bmatrix}$$

Find the short circuit current on transmission line : (4M)

$$I_{12}^{+} = \frac{V_{f1}^{+} - V_{f2}^{-}}{Z_{12}^{+}}$$

Find the voltage of healthy phase of the bus-1: (2M)

$v_a = 0$

$$v_b = 0.9056\angle -107$$

$$v_c = 0.9056\angle 107$$

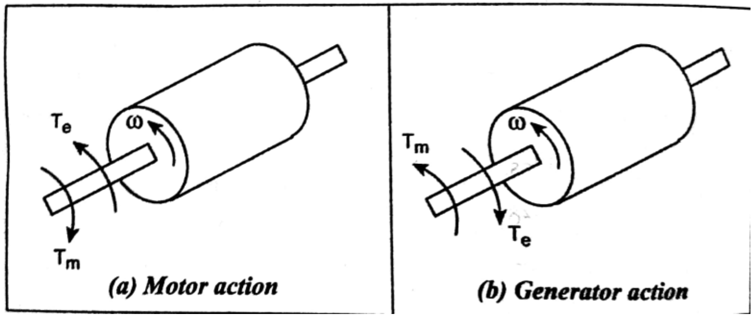
UNIT V -STABILITY ANALYSIS

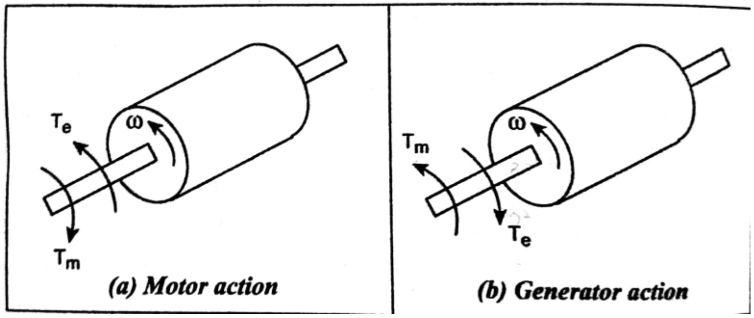
Importance of stability analysis in power system planning and operation - classification of power system stability - angle and voltage stability – Single Machine Infinite Bus (SMIB) system: Development of swing equation - equal area criterion - determination of critical clearing angle and time– solution of swing equation by modified Euler method and Runge-Kutta fourth order method.

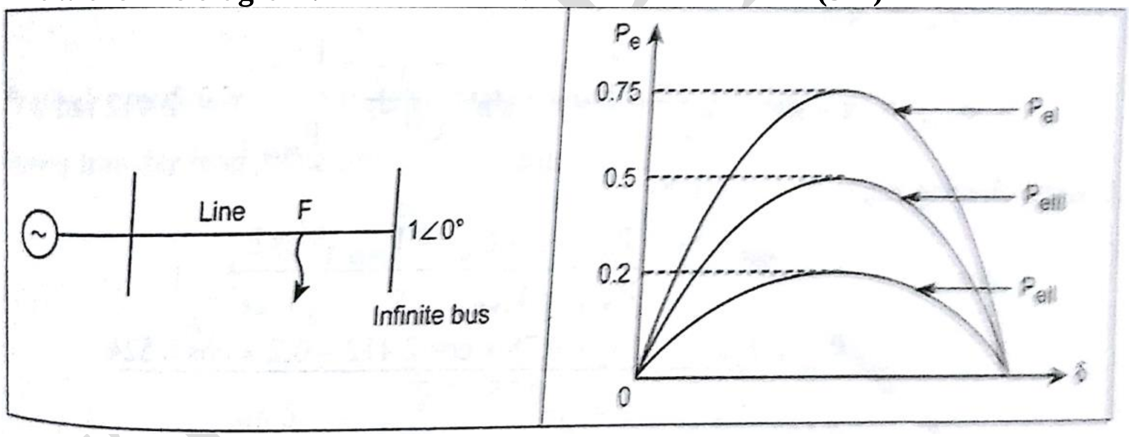
PART*A

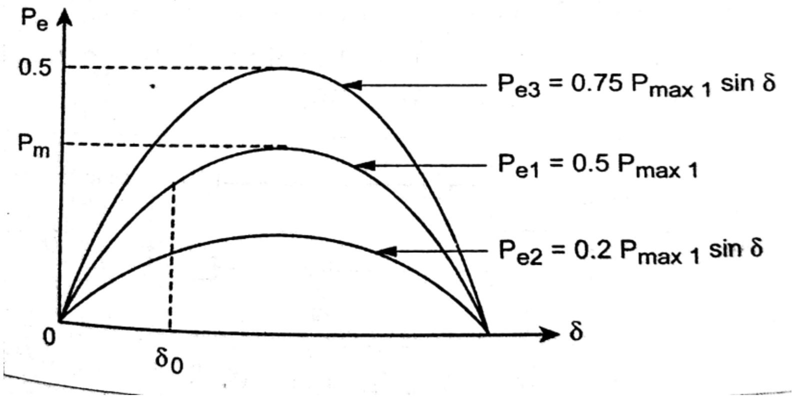
Q.No.	Questions
1.	**Define infinite bus in a power system. (Nov/Dec 2012)** BTL1 A bus's voltage remains constant and does not altered by any changes in generator excitation is called infinite bus.
2.	**Define stability.** BTL1 The stability of a system is defined as the ability of the power system to return to stable (synchronous) operation when it is subjected to a disturbance.
3.	**Define steady state and transient state stability.** BTL1 The steady state stability of a system is defined as the ability of power system to remain stable (without losing synchronism) for small disturbances. The steady state stability of a system is defined as the ability of power system to remain stable (without losing synchronism) for large disturbances.
4.	**Define power angle.** BTL1 The power angle (or torque angle) is defined as the angular displacement of the rotor from synchronously rotating reference frame.
5.	**Define power system stability.** BTL1 Power system stability is the property of the system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance.
6.	**Write the expression for power transfer.** BTL1 $P_{max} = \frac{\lvert E' \rvert \lvert V \rvert}{X_{12}}$ E' =transient internal source voltage $X_{12} = Transient\ reactance$ $X_{12} = Infinite\ bus\ voltage$
7.	**Write the concept of critical clearing angle. (Nov/Dec 2012)** BTL1 The critical clearing angle, δ_{cc} is the maximum allowable change in the power angle δ before clearing the fault, without loss of synchronism. The time corresponding to this angle is called critical clearing time, t_{cc}
8.	**Define steady state stability limit. (Nov/Dec 2014)** BTL1 The steady state stability limit is the maximum power that can be transmitted by a machine (or transmitting system) to a receiving system without loss of synchronism. In steady state the power transferred by synchronous machine (or power system) is always less than the steady state stability limit.
9.	**State equal area criterion. (Nov/Dec 2011,17)**BTL1 The equal area criterion for stability states that the system is stable if the area under P_a- δ Curve reduces to zero at some value of δ .

	This is possible only if the positive (accelerating) area under P_a- δ curve is equal to the negative (deceleration) area under P_a- δ curve for a finite change in δ .Hence this stability criterion is called equal area criterion.
10.	**List any two methods of improving the transient stability limit of power system.** BTL1 The following are the methods used to improve the transient stability of a system. - Increase of system voltage and use of AVR (Automatic Voltage Regulation). - Use of high speed excitation systems. - Reduction in system transfer reactance. - Use of high speed reclosing breakers.
11.	**Define swing curve. Mention the necessity of swing curve.** BTL1 The swing curve is the plot or graph between the power angle δ and time t.It is usually plotted for a transient state to study the nature of variation in δ for a sudden large disturbance. From the nature of variation of δ the stability of the system for any disturbance can be determined.
12.	**Define critical clearing time and critical clearing angle. (Nov/Dec 2014)** BTL1 The critical clearing angle, δ_{cc} is the maximum allowable change in the power angle δ before clearing the fault, without loss of synchronism. The time corresponding to this angle is called critical clearing time, t_{cc}. The critical clearing time, t_{cc} can be defined as the maximum time delay that can be allowed to clear a fault without loss of synchronism.
13.	**Write the swing equation and explain the terms involved in it. (Nov/Dec 2011,15)** BTL1 $\frac{H}{\pi f}\frac{d2\delta}{dt2} = P_{m(p.u)}-P_{e(p.u)}$ Where H=p.u inertia constant F=frequency δ = Power angle
14.	**Bring out the use of swing equation and state the methods used to solve it.** BTL1 During any disturbance rotor will accelerate or decelerate with respect to the synchronously rotating air gap and a relative motion begins. Equation used to describe the behavior of the synchronous machine. Methods used to solve swing equation are Modified Euler method and Runge –Kutta method
15.	**If two machines are swinging coherently with inertia M_1 M2 and M3. What will be the inertia constant of equivalent machine?** BTL1 $M_{eq} = \frac{M1S1}{SB}+\frac{M2S2}{SB}+\frac{M3S3}{SB}$ S_B = Base MVA and S_1,S_2,S_3 are MVA ratings of machine 1,2, and 3.
16.	**How is power system stability classified? (Nov/Dec 2015)** BTL1 - Angle stability - voltage stability - Frequency stability
17.	**Define Voltage stability. (Nov/Dec 2016)** BTL1 It is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance.
18.	**State the factors on which critical clearing time depends.** BTL1 $$t_{cr} = \sqrt{\frac{2\,H}{\pi f P_m}\,(\xi_{cr}-\xi_0)}$$

	It depends on inertia constant, frequency, mechanical power, critical clearing angle, rotor angle.
19.	**State the causes of voltage instability.** BTL4 A system causes a state of voltage instability when a disturbance, increase in load demand or change in system condition causes a progressive and uncontrollable drop in voltage. The main factor causing instability is the inability of the power system to meet the demand for reactive power.
20.	**Define inertia constant (M).** BTL1 M-Constant or inertia constant is defined as the angular momentum at synchronous speed. If energy is measured in Joules and speed in mechanical radians per second.
21.	**Write the power angle Equation. (Nov/Dec 2015)** BTL1 $P_1 = P_e = E' G_{11} + \frac{E'}{X_{12}} V\, Sin\, \delta$ $P_e = P_C + P_{max}\, Sin\, \delta$ This equation is called as the power angle equation.
22.	**State few techniques to improve the steady state stability.** BTL2 - Reduce the reactance - Increase the voltage regulation - Higher excitation voltages
23.	**Define transient stability of a power system. (Nov/Dec 2017)** BTL1 The ability of the system to bring to a stable condition after a large disturbance like sudden outage of line, sudden loss of excitation, sudden application or removal of loads.
PART*B	
Q.No.	**Questions**
1.	**Derive swing equation and discuss the importance of stability studies in power system planning and operation. (Nov/Dec 2016) (13M)** BTL1 **Answer: Page 10.8 to 10.11 - M.Jeraldin Ahila** **Assumption in stability studies: (4M)** 1. Machine represented by classical model 2. Controllers are not considered 3. Loads are constants 4. Voltage and currents are sinusoidal **Diagram of motor action and generator action: (3M)**  **Inertia constant: (3 M)**

	M-Constant or inertia constant is defined as the angular momentum at synchronous speed. Energy is measured in Joules Speed in mechanical radians per second. **Draw the swing curve and derive the Equation: (3M)** $\frac{H}{\pi f}\frac{d2\delta}{dt2} = P_{m(p.u)}-P_{e(p.u)}$ Where H=p.u inertia constant F=frequency
2.	**With a neat flowchart, explain how the transient stability study can be made by the modified Euler method. (Nov/Dec 2012) (13M)** BTL4 **Answer: Page 11.7 to 11.10 -M.Jeraldin Ahila** **Initial bus voltages, magnitudes and phase angle using load flow: (2M)** $\begin{bmatrix}Y_{nn} & Y_{nm}\\ Y_{mn} & Y_{mm}\end{bmatrix}\begin{bmatrix}V_n\\ E'_m\end{bmatrix}=\begin{bmatrix}0\\ I_m\end{bmatrix}$ **Node equation and electrical power transfer: (3M)** $P_{ei}=\{E_i^* I_i\}$ **swing equation: (3M)** $\frac{H}{\pi f}\frac{d2\delta}{dt2} = P_{m(p.u)}-P_{e(p.u)}$ **state variable model of swing equation: (2M)** $\frac{d\delta_i}{dt}=\Delta\omega_i$ **Flow chart: (3M)**
3.	**Derive swing equation for a synchronous machine. (Nov/Dec 2015) (13M)** BTL1 **Answer: Page 10.9 to 10.12 -M.Jeraldin Ahila** **Assumption in stability studies: (4M)** 1. Machine represented by classical model 2. Controllers are not considered 3. Loads are constants Voltage and currents are sinusoidal **Diagram of motor action and generator action: (3M)**  *(a) Motor action* *(b) Generator action* **Inertia constant: (3M)**

	1. M-Constant or inertia constant is defined as the angular momentum at synchronous speed. 2. Energy is measured in Joules. 3. Speed in mechanical radians per second. **swing curve and derive the Equation: (3M)** $\frac{H}{\pi f}\frac{d2\delta}{dt2} = P_{m(p.u)} - P_{e(p.u)}$ Where H=p.u inertia constant f=frequency
4.	**A 50 Hz generator is delivering 50% of the power that it is capable of delivering through a transmission line to an infinite bus. A fault occurs that increases the reactance between the generator and the infinite bus to 500% of the value before the fault. When the fault is isolated, the maximum power that can be delivered is 75% of the original maximum value. Determine the critical clearing angle for the condition described. (Nov/Dec 2011) (13M)** BTL3 **Answer: Page 10.54 -M.Jeraldin Ahila** **Draw the line diagram: (3M)**  **Determine the prefault condition: (3M)** $P_{e1} = \frac{\|E'\|\|v\|}{X_{12}} Sin\ \delta_0$ **Determine the power during fault condition: (3M)** $P_{e2} = \frac{\|E'\|\|v\|}{5} Sin\ \delta$ **Determine the power during post fault condition: (2M)** $P_{e3} = 0.75\ Pmax1\ Sin\ \delta$

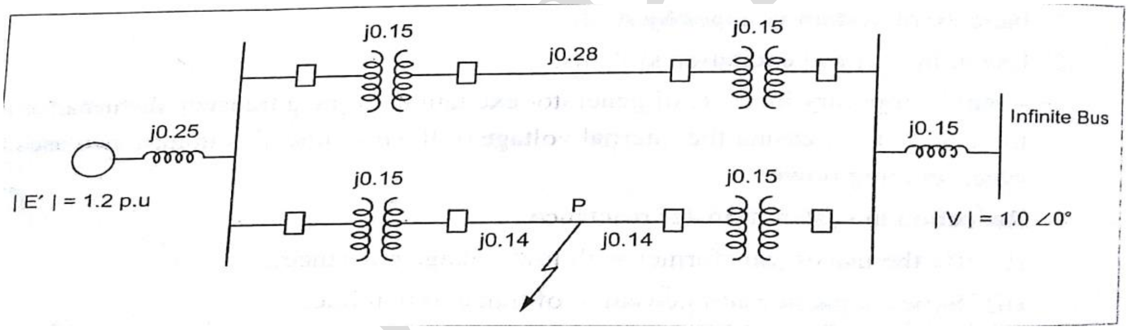


Equation for critical clearing angle: **(2M)**

$$t_{cr} = \sqrt{\frac{2\,H}{\pi f P_m}\ (\xi_{cr} - \xi_0)}$$

5.

Find the critical clearing angle for clearing the fault with simultaneous opening of the breakers 1 and 2. The reactance values of various components are indicated on the diagram. The generator is delivering 1.0 p.u. power at the instant preceding the fault. The fault occurs at point p as shown in the figure. (May/June 2009) (13M) BTL3



Answer: Page S.58 -M.Jeraldin Ahila

Prefault operating power angle equation: **(3M)**

$$P_{e1} = \frac{|E'||v|}{X_{12}}\ Sin\ \delta_0$$

Power during fault and post fault operation condition : **(4M)**

$$P_{e2} = 0$$
$$P_{e3} = 1.5\ Sin\ \delta$$

Apply equal area criterion: **(3M)**

A1=A2

$A_1 = P_m\ (\delta_{cr} - \delta_0)$

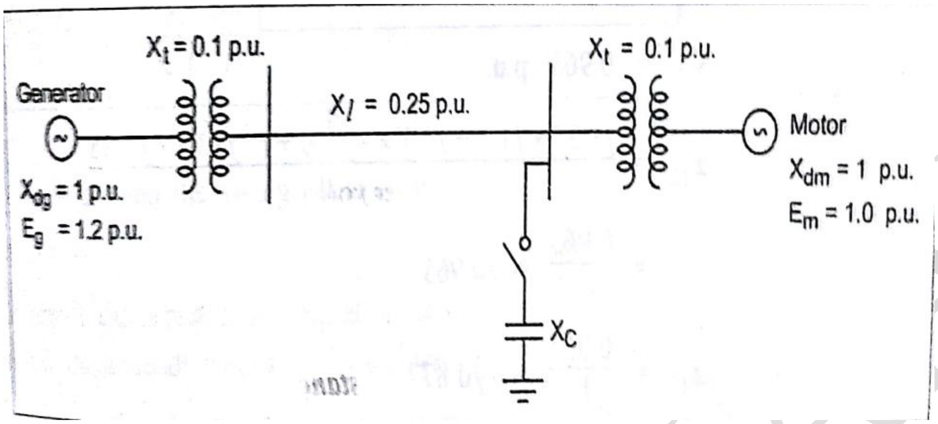
$A_2 = \int_{\delta_{cr}}^{\delta_{max}} (\ P_{e3}\ \text{-}\ P_m\ )$

Critical clearing angle: **(3M)**

$$\delta_{cr} = 55.8\ degree$$

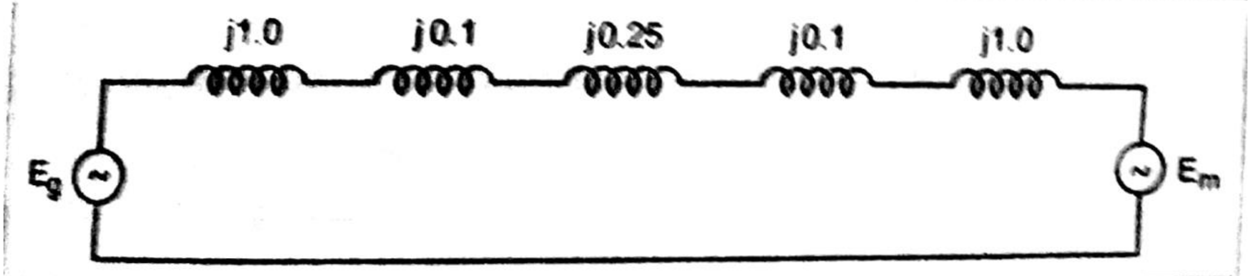
6.

In the system shown in Fig, a three phase static capacitive reactor of reactance 1 p.u. per phase in connected through a switch at motor bus bar. Calculate the limit of steady state power with and without reactor switch closed. Recalculate the power limit with capacitance reactor replaced by an inductive reactor of the same value. Assume the internal voltage of the generator to be 1.2 pu. and motor to be 1.0 p.u. (13M) BTL3

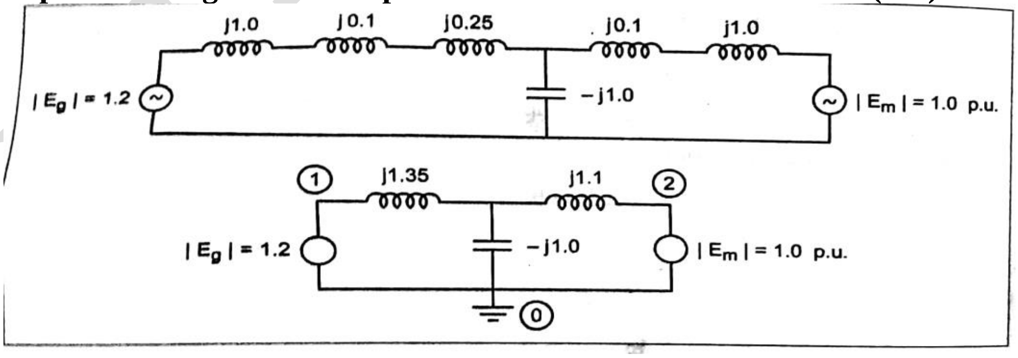


Answer: Page 10.27 - M.Jeraldin Ahila

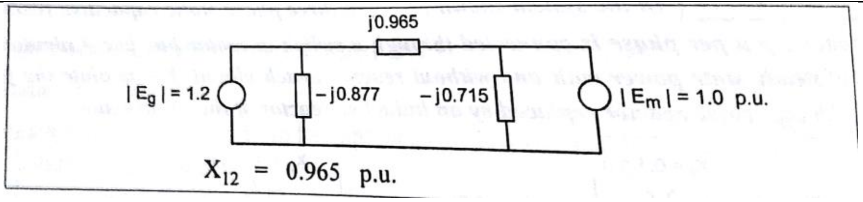
Impedance diagram without reactor: (3M)



Impedance diagram with capacitive reactor : (4M)



steady state power limit, using the steady state power conversion: (3M)



Steady state power limit: **(3M)**

$$\frac{|E_g||E_m|}{X_{12}} = 1.244 \text{ p.u}$$

7.

Derive the swing equation of a single machine connected to an infinite bus and explain the steps of solution by Runge Kutta method. (Nov/Dec 2011) (13M) BTL4

Answer: Page 10.15 and11.10 -M.Jeraldin Ahila

Swing Equation: **(4M)**

Iteration of I,II,III IV and final estimates : **(3M)**

Update the first iteration: **(3M)**

$$\Delta K_k = \frac{1}{6}\left[K_1 + 2K_2 + 2K_3 + K_4\right]$$

$$\Delta l_k = \frac{1}{6}\left[l_1 + 2l_2 + 2l_3 + l_4\right]$$

$$\delta_{k+1} = \delta_k + \Delta K_k$$

$$\Delta\omega_{k+1} = \Delta\omega_k + \Delta l_k$$

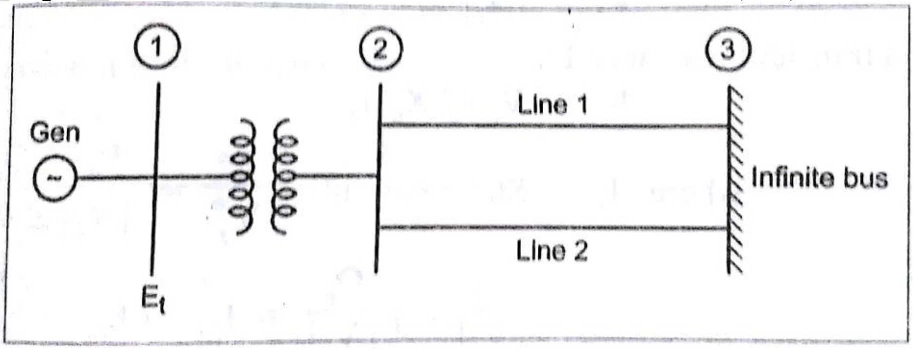
Check for convergence: **(3M)**

1. **Check if $\delta_{i+1} - \delta_i = 0$**
2. **Check $\Delta\omega_{i+1} - \Delta\omega_i = 0$**

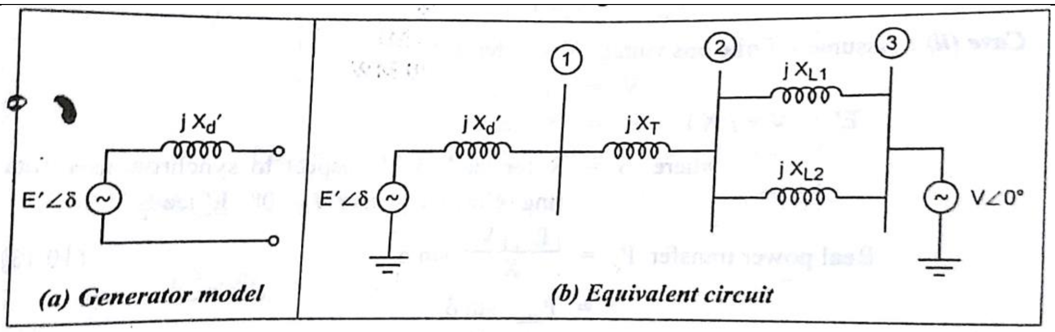
Derive the swing equation of a synchronous machine swinging against an infinite bus. Clearly state the assumption in deducing the swing equation. (13M) BTL1

Answer: Page 10.15 to 10.18 -M.Jeraldin Ahila

Consider a generator connected to infinite bus: **(3M)**

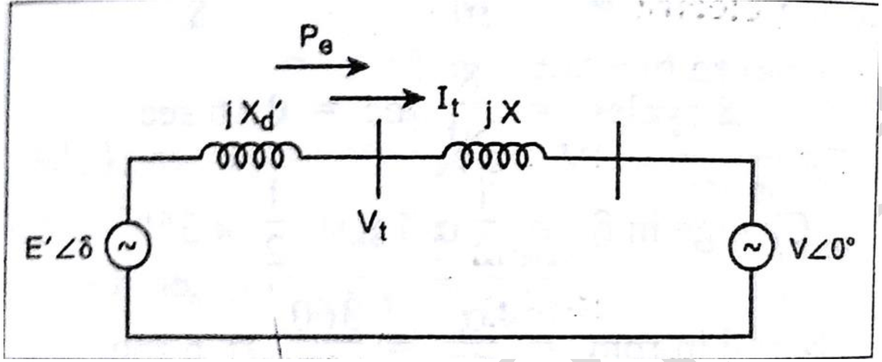


Generator model and equivalent circuit: **(3M)**



(a) Generator model (b) Equivalent circuit

Real power transfer equation: **(3M)**



$$P_e = \frac{|E'||v|}{X} Sin\,\delta$$

$$P_e = P_{max} \quad Sin\,\delta$$

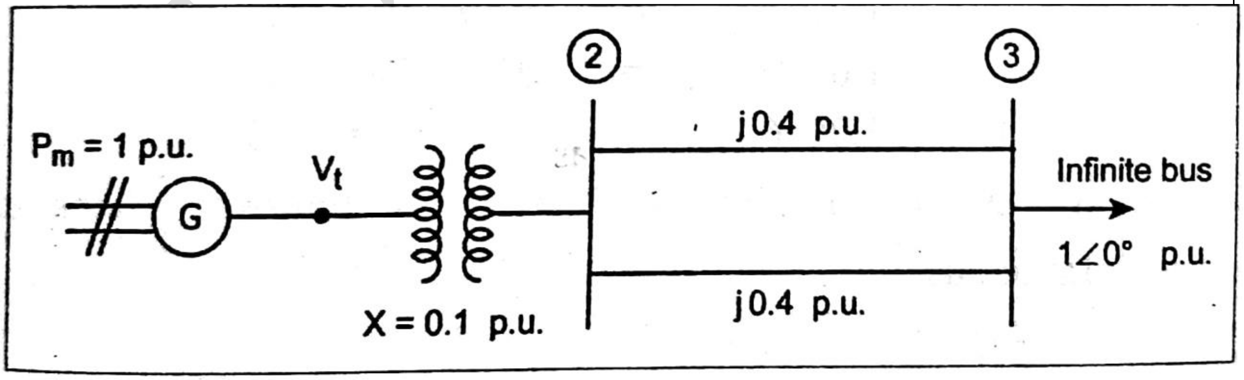
Derive the power angle equation using nodal equation: **(2M)**

$$P_e = P_C + P_{max} \quad Sin\,\delta$$

Power angle curve : **(2 M)**

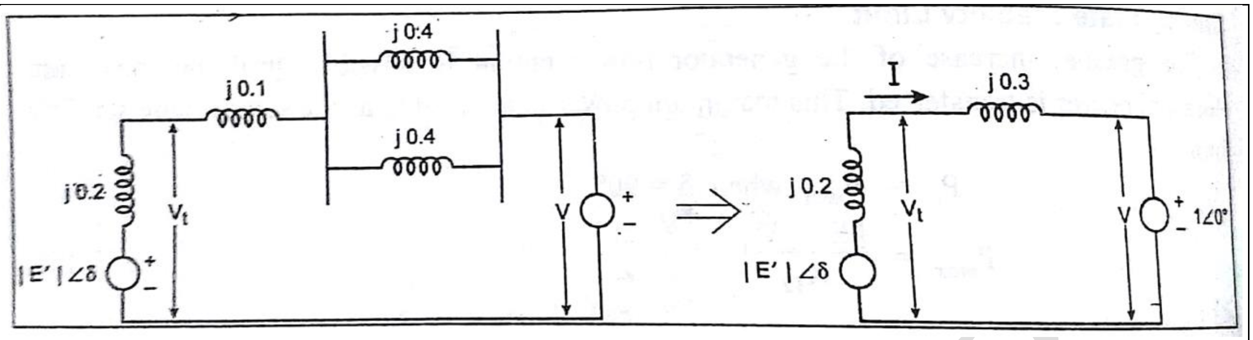
9.

The generator shown in Fig is delivering power to infinite bus. Take Vt =1.1 p.u. Find the maximum power that can be transferred when the system is healthy. **(13M)** BTL3



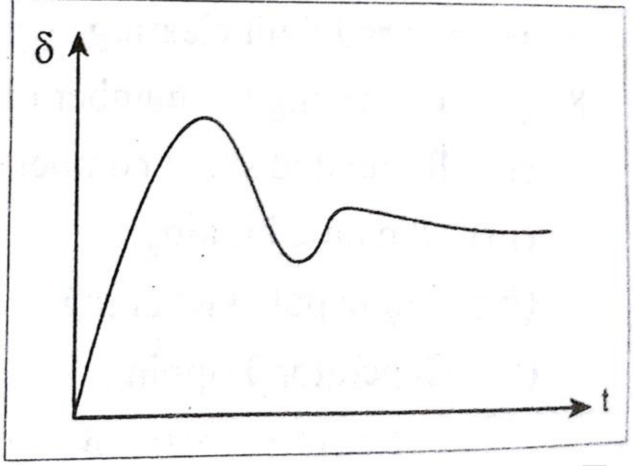
Answer: Page 10.19- M.Jeraldin Ahila

Reactance diagram: **(3M)**

	 **Electrical power transferred: (4 M)** $P_e = \frac{\|V_t\|\|v\|}{X} Sin\ \delta$ **Transient internal voltage: (3M)** $E' = v_t + j\ 0.2\ I$ **Power for the healthy section: (3M)** $P_e = \frac{\|E'\|\|v\|}{X_{12}} Sin\ \delta$
10.	**A 2-pole 50 Hz, 11kV turbo alternator has a ratio of 100 MW, power factor 0.85lagging. The rotor has a moment of inertia of 10,000 kgm2. Calculate H and M. (Nov/Dec 2015) (13M)** BTL3 **Answer: Page 10.13 -M.Jeraldin Ahila** **synchronous speed in rpm and rps: (3M)** $N = \frac{120f}{P}$ $N_S = \frac{120f}{P*60}$ **p.u. inertia constant: (3M)** $H = \frac{\left(\frac{1}{2}\right) J\omega_{sm}^2}{S_B}$ **MVA rating of machine: (3M)** $S = \frac{P}{p.f}$ **With the base values, find the inertia constant: (4M)** H= 4.194 MJ/MVA
11.	**Describe the equal area criterion for transient stability analysis of a system. What are the advantages and limitation of this method? (April/May 2008) (13M)** BTL4 **Answer: Page 10.29 -M.Jeraldin Ahila** **Swing Equation for the machine : (4M)**

$$\frac{H}{\pi f_0}\frac{d^2\delta}{dt^2} = p_a = (p_m) - p_e$$

swing curve: (3M)



Equal area criterion condition: (3M)

System is stable if area under $P_a - \delta$ curve reduces to zero at some value of δ

Positive are under $P_a - \delta$ curve is equal to negative area under $P_a - \delta$ curve for a finite change in δ

plot for stable and unstable system: (3M)

Stable system : $\frac{d\delta}{dt} = 0$

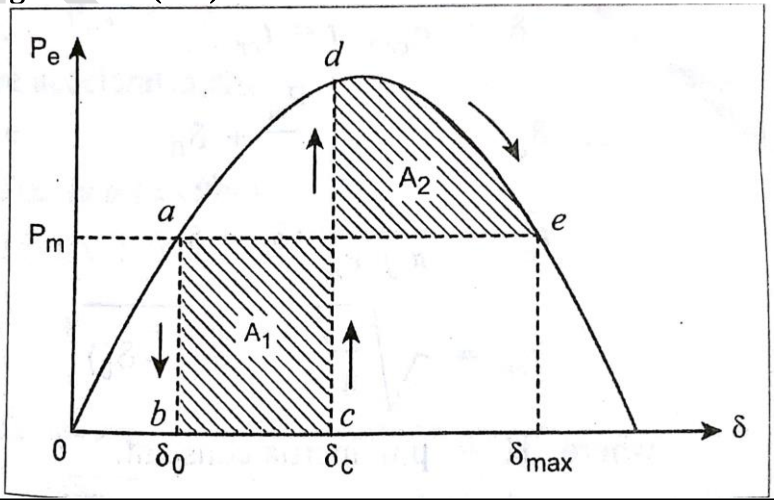
Unstable system : $\frac{d\delta}{dt} > 0$

PART*C

1. **Derive an expression for the critical clearing angle and clearing time. (April/May 2011) (15M)** BTL4

Answer: Page 10.37 -M.Jeraldin Ahila

Power angle curve: (3M)



	Apply Equal area criterion: **(4M)** Area $A_1 = A_2$ $\int_{\delta_0}^{\delta_c} P_m d\delta = \int_{\delta_c}^{\delta_{max}} (P_{max} \sin \delta - P_m)\, d\delta$ **Consider the stable system equation:** **(4M)** **Integrate and derive the final equation:** **(4 M)** $t_{cr} = \sqrt{\frac{2\,H}{\pi f P_m}\,(\xi_{cr} - \xi_0)}$
2.	**How can the transient stability of the system be improved? Discuss the traditional as well as new approaches to the problem. (May/June 2008) (15 marks)** BTL5 **Answer: Page S.57 -M.Jeraldin Ahila** **Explain:** 1. Reduction in the disturbing influence (3M) 2. Increasing the restoring synchronizing force (2 M) 3. Reduction of accelerating torque (2 M) 4. Dynamic braking (2 M) 5. Single pole switching (2 M) 6. Generator tripping (2 M) **7.** Recent trends-HVDC links and breaking resistor (2 M)
3.	**A 50 HZ, 500 MVA, 400 KV generator (with transformer) is connected to a 400 KV infinite busbar through an interconnector. The generator has H=2.5 MJ/MVA, voltage behind transient reactance of 450 KV and is loaded 460 MW. The transfer reactance between generator and bus bar under various conditions are** **Prefault 0.5 p.u.** **During fault 1.0 p.u.** **Post fault 0.75 p.u.** **Calculate the swing curve using intervals of 0.05 sec and assuming that the fault is cleared at 0.15 sec. (Nov/Dec 2007) (15M)** BTL3 **Answer: Page S.31 -M.Jeraldin Ahila** **Using modified Euler method, Find the different iteration:** (3M) $P_e = \frac{\|E'\|\|v\|}{X} Sin\ \delta$ $\frac{d\delta}{dt}$ **(*change*) :** (4 M) $X_1^P = X_0 + \left(\frac{\left(\frac{dx}{dt}\right)_{X_0} + \left(\frac{dx}{dt}\right)_{X_1^P}}{2} \right) \Delta t$ $X_{i+1}^c = X_i + \left(\frac{\left(\frac{dx}{dt}\right)_{X_i} + \left(\frac{dx}{dt}\right)_{X_{i-1}^P}}{2} \right) \Delta t$

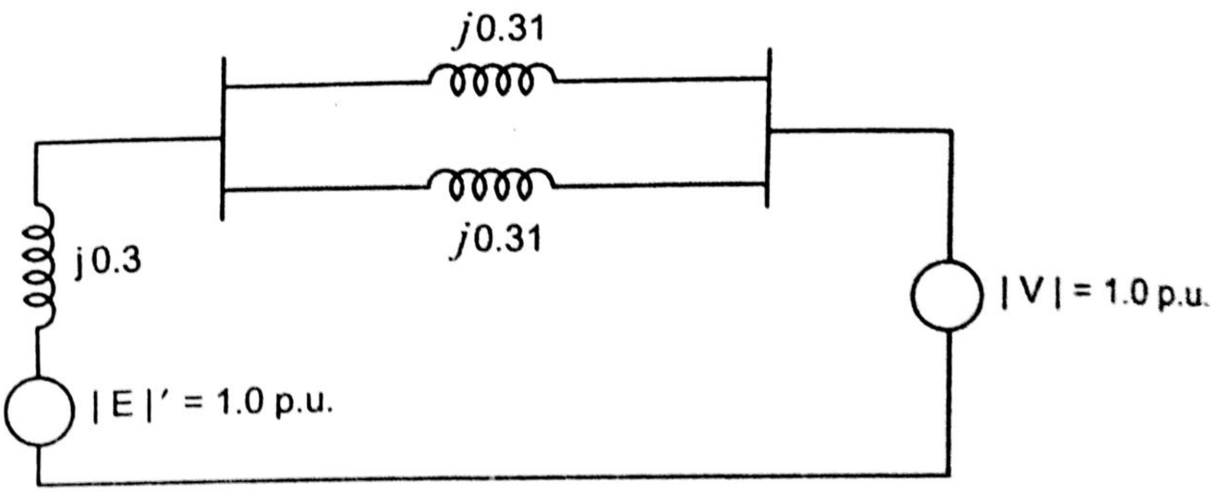
Calculate the swing curve: (4M)
corrected value: (4M)

4.

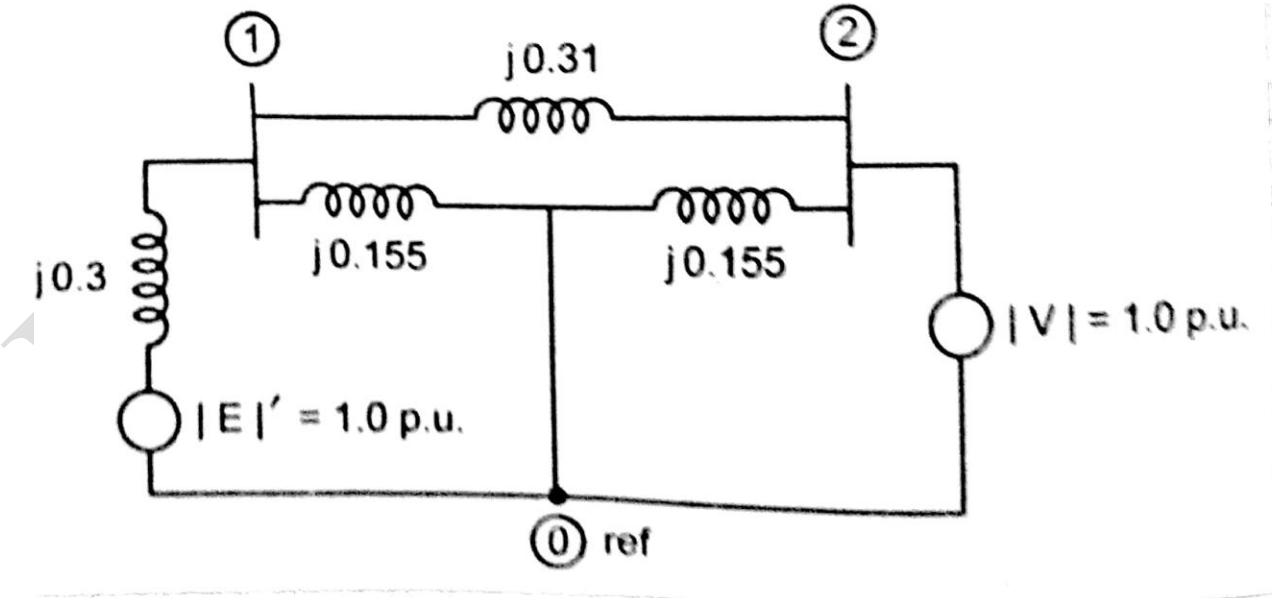
A 150 MVA generator-transformer unit having an overall reactance of 0.3 p.u. is delivering 150 MW to infinite bus bar over a double circuit 220 KV line having reactance per phase per circuit of 100 ohms. A 3 phase fault occurs midway along one of the transmission lines. Calculate the maximum angle of swing that the generator may achieve before the fault is cleared without loss of stability. (Nov/Dec 2007) (15 M) BTL5

Answer: Page S.27 -M.Jeraldin Ahila

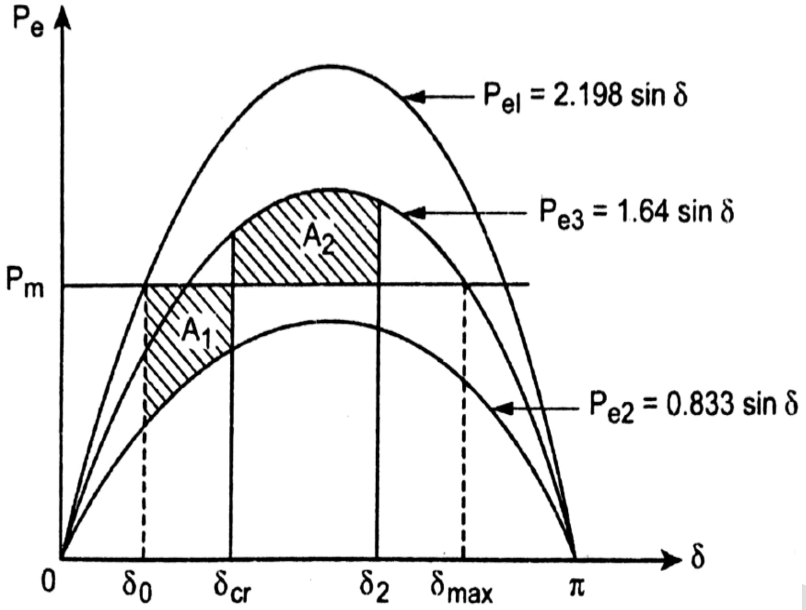
Prefault, during fault condition: (3M)



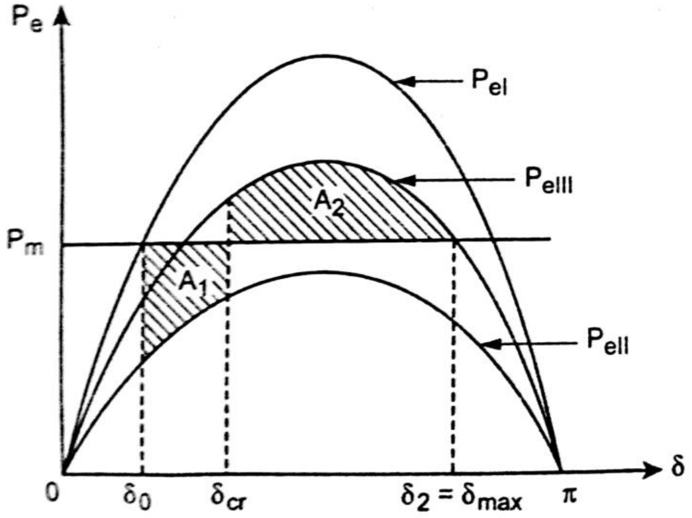
Prefault, during post fault condition: (4M)



Power angle curve : (4M)



critical clearing angle by applying equal area criterion: (4 M)



OBJECTIVE TYPE QUESTIONS

UNIT I- INTRODUCTION

1. Single line diagram of which of the following power system is possible?

a) Power system with LLG fault

b) Power system with LG fault

c) Power system with LL fault

d) Balanced power system

Answer:d

2. A single phase distributor of 1 km long has resistance and reactance per conductor of 0.1Ω and 0.15 Ω respectively. If the far end voltage Vb=200V and current is at 100A at 0.8 lag. At the midpoint a current of 100A is tapped at a pf of 0.6 pf with ref to voltage Vm at mid point. The voltage magnitude at M is

a)218V

b)200V

c)232V

d)220V

Answer:a

3. A single phase motor is connected to 400V, 50Hz supply. The motor draws a current of 31.7A at a power factor 0.7 lag. The capacitance required in parallel with motor to raise the power factor of 0.9 lag is

a)94.62

b)282.81

c)108.24

d)46.87

Answer:a

4. A single phase motor is connected to 400V, 50Hz supply. The motor draws a current of 31.7A at a power factor 0.7 lag. The additional reactive power (in VAR) to be supplied by the capacitor bank will be

a)4756

b)4873

c)4299

d)9055.3

Answer:a

5. A 275 kV TL has following line constants A=0.85L5 degree, B=200L75 degree. The active power received if the voltage to be maintained is 275kV will be

a)117.63

b)220

c)120

d)115.25

Answer:a

6. A 275 kV TL has following line constants A=0.85L5o, B=200L75o. The active power angle such that the voltage to be maintained at the other end will be 275 kV

a)16

b)22

c)18

d)24

Answer:b

7. A power system has a maximum load of 15 MW. Annual load factor is 50%. The reserve capacity of plant is _____ if the plant capacity factor is 40%.

a)5.75MW

b)4.75MW

c)18.75MW

d)3.75MW

Answer:d

8. A 100 MVA synchronous generator operates on full load at a frequency of 50 Hz. The load is suddenly reduced to 50 MW. Due to time lag in governor system, the steam valve begins to close after 0.4s. The change in the frequency is ________(H=5 kW-s/KVA).

a)0.8

b)0.5

c)-1.5

d)1

Answer:d

9. A 50 Hz four pole turbo-generator rated 100 MVA, 11 kV has an inertia constant of 8 MJ/MVA. If the mechanical input is suddenly raised to 80 MW for an electrical load of 50MW, then the rotor acceleration is

a)337.5

b)3.375

c)457.5

d)4.57

Answer:a

10. A single phase TL has copper conductor of 0.775 cm2 cross section through which 200 kW at UPF at 330 V is to be maintained. If the efficiency of transmission line is 90%, then the minimum length of TL is ___________(in km and take specific resistance to be 1.785 μΩ/cm).

a)13.6km

b)14km

c)136km

d)16.4km

Answer:a

11. A three phase transformer has a nameplate rating of 30 MVA, 230Y/69Y kV with a leakage -reactance of 10% and the transformer connection is wye-wye. Choosing a base of 30MVA and 230 kV on high voltage side, the reactance of transformer in per units is

a)0.3

b)0.1

c)0.03

d)1.5

Answer:b

12. A three phase transformer has a nameplate rating of 30 MVA, 230Y/69Y kV with a leakage -reactance of 10% and the transformer connection is wye-wye. Choosing a base

of 30MVA and 230 kV on high voltage side, the high voltage side impedance ____________

a)1763.3Ω

b)158.7Ω

c)15.87Ω

d)176.3Ω

Answer:a

13. A three phase transformer has a nameplate rating of 30 MVA, 230Y/69Y kV with a leakage -reactance of 10% and the transformer connection is wye-wye. Choosing a base of 30MVA and 230 kV on high voltage side, the low voltage side impedance is ___________

a)158.7Ω

b)176.3Ω

c)1763.3Ω

d)15.87Ω

Answer:a

14. A three phase transformer has a nameplate rating of 30 MVA, 230Y/69Y kV with a leakage -reactance of 10% and the transformer connection is wye-wye. Choosing a base of 30MVA and 230 kV on high voltage side, the transformer reactance referred to the high voltage side will be

a)176.33Ω

b)17.67Ω

c)158.7Ω

d)15.87Ω

Answer:a

15. What is the main purpose of reactance diagram?

a) Load flow analysis

b) Fault analysis

c) Calculation of ratings of Alternators

d) Calculation of ratings of Transformers

Answer:b

16.Which of the following is not neglected during formation of reactance diagram from impedance diagram?

a) Resistance of various power system components

b) Static loads

c) Shunt component of Transformers

d) Reactance of alternators

Answer:d

17. Impedance diagram is used for analysis of __________

a) Load flow

b) Alternator

c) Fault

d) Transmission Line

Answer:a

18. Reactance diagram contains which of the following ?

a) Resistance of Alternator

b) Resistance of transformer winding

c) Induction motor's equivalent corcuit

d) Inductive reactance of transmission lines

Answer:d

19. Single line diagram does not represents:

a) Star connection of transformer winding

b) Delta connection of transformer winding

c) Neutral wire of transmission lines

d) Ratings of machines

Answer:c

20. In impedance diagram different power system elements are represented by symbols.

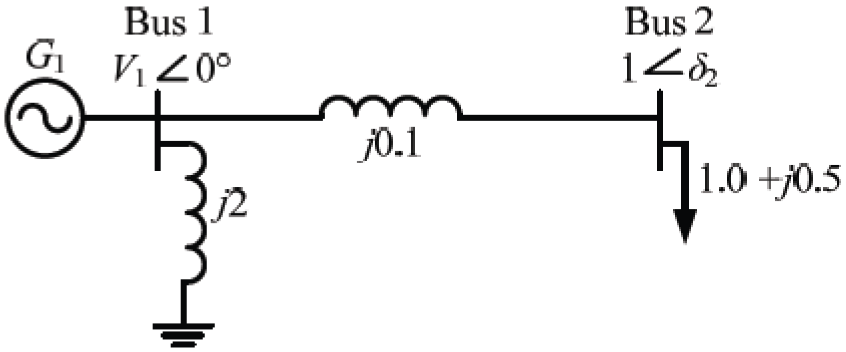
a) True

b) False

Answer:b

UNIT II-POWER FLOW ANALYSIS

1.A two bus power system shown in the figure supplies load of 1.0+*j*0.5 p.u.



The values of V_1 in p.u. and δ_2 respectively are

a)0.95 and 6.00 ^{o}

b)1.05 and -5.44^{o}

c)1.1 and -6.00 ^{o}

d)1.1 and -27.12^{o}

Answer:b

2. A 183-bus power system has 150 PQ buses and 32 PV buses. In the general case, to obtain the load flow solution using Newton-Raphson method in polar coordinates, the minimum number of simultaneous equations to be solved is ___________.

a) 332 to 332
b) 330 to 334
c) 336 to 336
d) 324 to 324

Answer:a

3. Consider two buses connected by an impedance of (0+j5) Ω. The bus 1 voltage is 100∠30°100∠30°V, and bus 2 voltage is 100∠ 0^{o}100∠0°100∠0°V.The real and reactive power supplied by bus 1, respectively, are

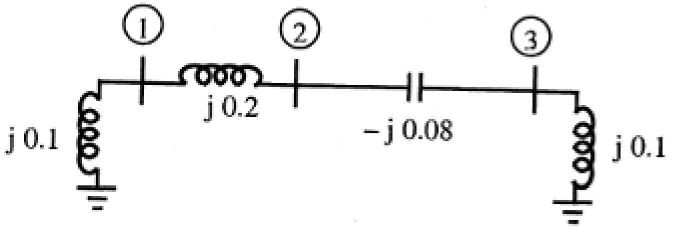
a) 1000W, 268VAr

b)–1000W, –134Var

c) 276.9W, –56.7Var

d) –276.9W, 56.7Var

4. A three – bus network is shown in the figure below indicating the p.u. impedance of each element



The bus admittance matrix, Y -bus, of the network is

a) $j\begin{bmatrix} 0.3 & -0.2 & 0 \\ -0.2 & 0.12 & 0.08 \\ 0 & 0.08 & 0.02 \end{bmatrix}$

b) $j\begin{bmatrix} -15 & 5 & 0 \\ 5 & 7.5 & -12.5 \\ 0 & -12.5 & 2.5 \end{bmatrix}$

c) $j\begin{bmatrix} 0.1 & 0.2 & 0 \\ 0.2 & 0.12 & -0.08 \\ 0 & -0.08 & 0.10 \end{bmatrix}$

d) $j\begin{bmatrix} -10 & 5 & 0 \\ 5 & 7.5 & 12.5 \\ 0 & 12.5 & -10 \end{bmatrix}$

Answer:b

5. For the Y-bus matrix of a 4-bus system given in per unit, the buses having shunt elements are

$$Y_{bus} = j \begin{matrix} -5 & 2 & 2.5 \\ 2 & -10 & 2.5 \\ 2.5 & 2.5 & -9 \end{matrix}$$

a) 1 and 2
b) 2 and 3
c) 3 and 4
d) 1 and 4

Answer:a

6. Which among the following quantities are to be determined in voltage controlled bus?

a. P and Q
b. Q and |V|
c. |V| and δ
d. Q and δ

Answer:d

7. Which among theses quantities are to be determined in slack bus?

a. P and Q
b. Q and |V|
c. |V| and δ
d. Q and δ

Answer:a

8. Which among the following buses constitute the maximum number in a power system?

a. Slack bus
b. P Q bus
c. P V bus
d. All of these
e. None of these

Answer:b

9. What percentage of buses in the power system are generator buses?

a. 5 %
b. 25 %
c. 70 %
d. 10 %

Answer:d

10. Which among the following quantities are specified at the generator bus?

a. P and Q
b. P and |V|
c. Q and |V|
d. P and δ

Answer:b

11. Which among the following quantities are specified at the load bus?

a. P and Q
b. P and |V|
c. Q and |V|
d. P and δ

Answer:a

12. Why are load flow studies carried out?

a. To study of stability of the system
b. For fault calculations
c. For planning the power system
d. All of these

Answer:c

13. Which of the following matrix is used for load flow studies?

a) Y bus matrix

b) Z bus matrix

c) Unit matrix

d) null matrix

Answer:b

14. Gauss seidel iterative method can be used for solving a set of

a. linear differential equation only

b.linear algebraic equation only

c.both linear and non linear algebraic equation

d. both linear and non linear differential equation

Answer:b

15. Transient in synchronous generator is similar to which of the following circuit?

a) Parallel RLC circuit

b) Series RLC circuit

c) Series RL circuit

d) Parallel RL circuit

Answer:c

16. When all three phases of a synchronous generator on no load are suddenly short circuited then symmetry of the short circuit current depends on which of the following?

a) Position of fault

b) Symmetry of fault

c) Instantaneous Voltage at which fault occurs

d) Resistance of armature winding

Answer:c

17. In a synchronous generator for how much time subtransient period of symmetrical short circuit current lasts?

a) For 200 Cycles

b) For 500 Cycles

c) For 30 Cycles
d) For 2 Cycles

Answer:d

18. Steady state direct axis reactance is greater than subtransient direct axis reactance and transient direct axis reactance.

a) True
b) False

Answer:a

19. Which of the following reactance is eliminated first in synchronous generator just after the symmetrical fault?

a) Leakage reactance
b) Damper winding reactance
c) Armature winding reactance
d) Field winding reactance

Answer:b

20. After how many cycles in a synchronous generator symmetrical short circuit current reaches to its steady state value?

a) After 200 Cycles
b) After 500 Cycles
c) After 30 Cycles
d) After 2 Cycles

Answer:c

UNIT III FAULT ANALYSIS-BALANCED FAULTS

1. On which among the following factors does the magnitude of the fault current depend?

a. Total impedance upto the fault.

b. Voltage at the fault point

c. Both (a) and (b)

d. None of these

Answer:c

2. Which among the following methods are generally used for the calculation of symmetrical faults?

a. Norton theorem

b. Thevnin’s theorem

c. Kirchhoff’s laws

d. Only (b) and (c)

e. All of these

Answer:d

3. Which among the following reactance have a greater value?

a. Sub transient reactance

b. Transient reactance

c. Synchronous reactance

d. All of these

e. None of these

Answer:c

4. What is the expression for the symmetrical short circuit current? If the total short circuit current consists of two parts namely symmetrical short circuit current and DC offset current.

a. $(V_m / Z) * \sin(\omega + \alpha t - \theta)$

b. $(V_m / Z) * \sin(\omega t + \alpha - \theta)$

c. $(V_m * Z) * \sin(\omega t + \alpha t - \theta)$

d. $(V / Z_m) * \sin(\omega t + \alpha - \theta)$

Answer:b

5. In which portion of the transmission system is the occurrence of the fault more common?

a. Alternators

b. Transformers

c. Transmission lines

d. Underground cables

Answer:c

6. Which among these is the most commonly occurring fault?

a. Single line to ground fault.

b. Double line to ground fault

c. Line to line fault

d. Fault due to all the three phases to earth.

Answer:a

7. Which of the following fault results into a three phase faults?

a. Single line to ground fault.

b. Double line to ground fault

c. Line to line fault

d. Fault due to all the three phases to earth.

Answer:d

8. The rating of circuit breakers are generally decided on the basis of

a. unsymmetrical fault currents

b. symmetrical fault currents

c. Normal circuit currents

d. none of the above

Answer:b

9. When all the three phases are short circuited the current through the system is

a. low

b.zero

c.very large

d.none of the above

Answer:c

10. Reactors are connected with the system in

a.series

b.parallel

c.series-parallel

d.none of the above

Answer:a

11. When a short circuit occurs in a power system

a. The voltage at fault point is zero

b. a very large current flows in the system

c. it results in overheating of equipement

d. all of the above

Answer:d

12. The fault on a power system that gives symmetrical fault current is

a. line to line fault

b. three phase short circuit fault

c.single line – ground fault

d.none of the above

Answer:b

13. The use of reactors permit the installation of circuit breakers of

a. lower rating

b. same rating

c.higher rating

d.none of the above

Answer:a

14. The short circuit KVA is maximum when fault occurs

a. Near the generator

b. at the end of transmission line

c.in the middle of the transmission line

d.none of the above

Answer:a

15.Current limiting reactors in power system have

a. large resistance and low reactance

b. large reactance and low resistance

c.large reactance and resistance

d. none of the above

Answer:b

16. The impedance of the transformers and alternators are mostly

a. resistive

b.inductive

c.capacitive

d.none of above

Answer:b

17. What percentage of fault occurring in the power system is line to line fault?

a. 5 %

b. 30 %

c. 25 %

d. 15 %

Answer:d

18. What is the value of zero sequence impedance in line to line faults?

a. $Z_0 = 1$

b. $Z_0 = \infty$

c. $Z_0 = 3\ Z_n$

d. $Z_0 = 0$

Answer:d

19. What happens if the neutral is not grounded in case of the single line to ground fault?

a. Only the zero sequence impedance will be zero

b. The zero sequence impedance will be infinite

c. Fault current will be zero

d. Both (b) and (c)

e. All of these

Answer:d

20. What happens to the value of the fault current in case of SLG fault, if fault impedance is introduced?

a. The fault current increase

b. The fault current remains same as in case of SLG fault.

c. The fault current becomes zero

d. The fault current is reduced

Answer:d

UNIT IV FAULT ANALYSIS- UNBALANCED FAULTS

1.A three phase transformer has a name plate details of 30 MVA and voltage rating of 230Y kV/69Δ kV with a leakage reactance of 10% and the transformer connection via wye-delta. Taking a base of 230 kV on the high voltage side, turns ratio of the windings is ______

a)1

b)1.5

c)6

d)2

Answer:d

2.A three phase transformer has a name plate details of 30 MVA and voltage rating of 230Y kV/69∆ kV with a leakage reactance of 10% and the transformer connection via wye-delta. Taking a base of 230 kV on the high voltage side, the transformer reactance on the LV side is __________

a)17633Ω
b)176.33Ω
c)47.6Ω
d)15.87Ω
Answer:b

3.A three phase transformer has a name plate details of 30 MVA and voltage rating of 230Y kV/69∆ kV with a leakage reactance of 10% and the transformer connection via wye-delta. Taking a base of 230 kV on the high voltage side, the transformer reactance referred to the low voltage side in ohms is

a)47.61Ω
b)15.87Ω
c)176.33Ω
d)157.8Ω
Answer:a

4. A three phase transformer has a name plate details of 30 MVA and voltage rating of 230Y kV/69∆ kV with a leakage reactance of 10% and the transformer connection via wye-delta. Taking a base of 230 kV on the high voltage side, the transformer reactance referred to the low voltage side in ohms is

a)0.4
b)0.2
c)0.198
d)0.1

Answer:d

5. A 200 bus power system has 160 PQ bus. For achieving a load flow solution by N-R in polar coordinates, the minimum number of simultaneous equation to be solved is ____________

a)325

b)329

c)359

d)320

Answer:c

6. Two alternators A and B having 5% speed regulation are working in parallel at a station. Alternator A is rated at 15 MW while B is at 20 MW. When the total load to be shared is 12 MW, then how much of the load will be shared by the alternator B?

a)6MW

b)5.14MW

c)6.85MW

d)7MW

Answer:b

7. A 400 V, 50 Hz three phase balanced source ripples to a star connected load whose rating is S(=300+j400) kVA. The rating of the delta connected capacitor bank needed to bring p.f. to 0.9 lagging in KVAR is

a)254.7

b)25.4

c)84.9

d)284.5

Answer:a

8. A 400 V, 50 Hz three phase balanced source ripples to a star connected load whose rating is S(=300+j400) kVA. A delta connected capacitor bank needed to bring p.f. to 0.9 lagging. The operating power factor of the system is

a)0.6

b)4/3

c)3/4

d)0.8

Answer:a

9. A given system to be analysed was found with the below phasor representation of the system voltages. Which of the symmetrical components will be present in the mentioned system?

a)Positive sequence components

b)Negative sequence components

c)Zero sequence components

d)All of them mentioned

Answer:d

10. The phasor operator which is used to depict the unbalanced phase voltages into three phase quantities,provides a rotation of

a)120degreecounterclockwise

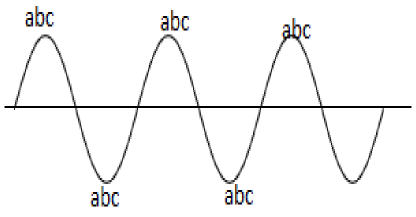
b)120degreeclockwise

c)90degreecounterclockwise

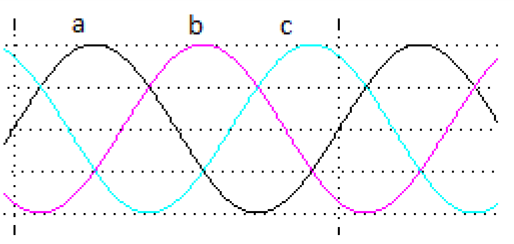
d)90degreeclockwise

12. The zero sequence depiction of the unbalancing occurring at the terminals of the induction motor will be most likely ______________

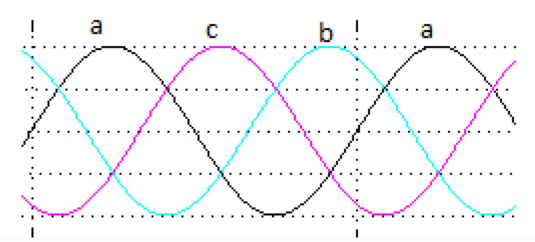
a)



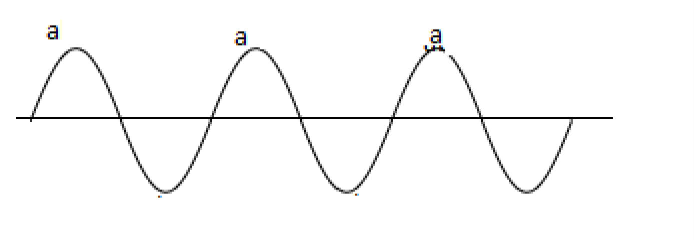
b)



c)

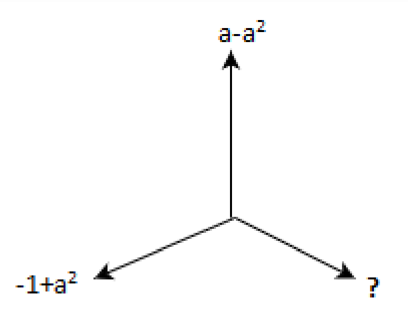


d)



Answer:a

13. Complete the given phasor diagram by assuming that operator 'a' is unity magnitude and counter clockwise rotation of 120 degrees.



a)1-a

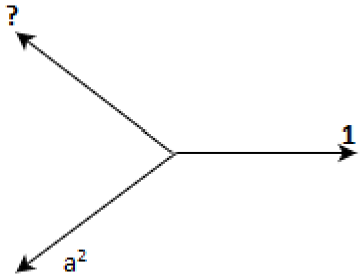
b)a-1

c)1

d)$-a^3$

Answer:a

14. The unknown vector in the given figure is ______ if we assume the system is balanced with a as unity magnitude and counter clockwise rotation of 120 degrees.



a)0

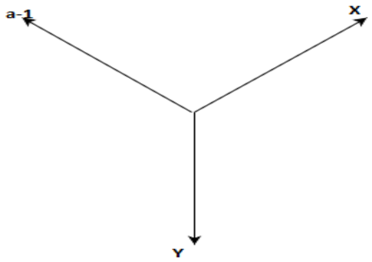
b)b

c)a^3

d)a^4

Answer:a

15. For a balanced three phase system having a vector representation as mentioned in the figure, Complete the vector x and y



a)$X=1-a^2$;$Y=a^2-a$

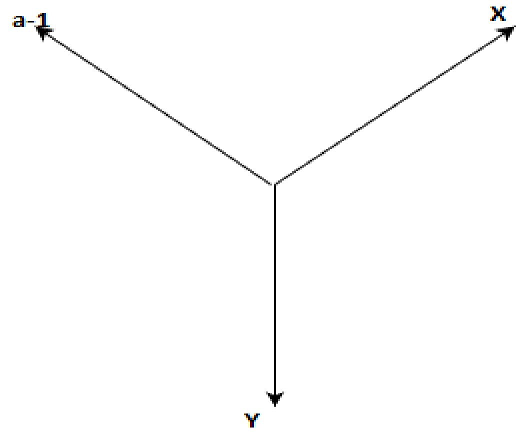
b)$X=a^2$ -a;$Y=1-a^2$

c)$X=a^2$ -1;Y=1-a

d)$X=a^2$ -1;Y=a-1

Answer:a

16. For a balanced three phase system having a vector representation as mentioned in the figure, complete the vector x and y.



a)X=√3∠30°;Y=√3∠-90°

b)X=√3∠-30°;Y=√3∠90°

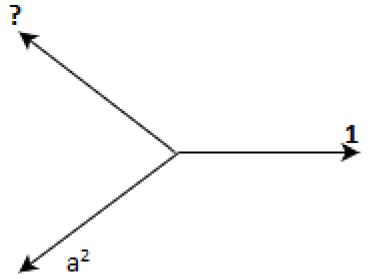
c)X=√3∠-30°;Y=√3∠-150°

d)X=√3∠30°;Y=√3∠150°

Answer:a

17. The unknown vector in the given figure is ______ if we assume the system is balanced with a as unity magnitude and counter clockwise rotation of 120 degrees

.



a)1∠0°

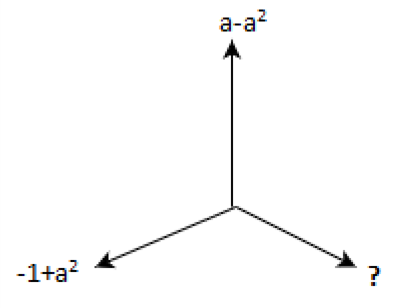
b)1∠30°

c)1∠120°

d)1∠-120°

Answer:c

18.Complete the given phasor diagram by assuming that operator ‘a’ is unity magnitude and counter clockwise rotation of 120 degrees.



a)√3∠90°

b)√3∠30°

c)√3∠-60°

d)√3∠-30°

Answer:d

19.In the cylindrical rotor alternator, the sub transient and negative sequence reactances are same.

a)True

b)False

Answer:a

20.The zero sequence impedance of a synchronous machine is independent of the pitch of the armature coil

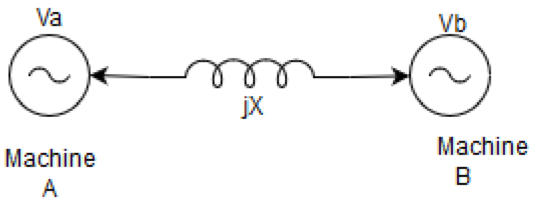
a)True

b)False

Answer:b

UNIT V- STABILITY ANALYSIS

1. **For the figure depicting the two generators connected via the transmission line having and impedance 'jX' ohms. Machine A at voltage Va at angle δ will supply active power to machine B at voltage Vb and angle zero, when δ is _____________**



a)positive

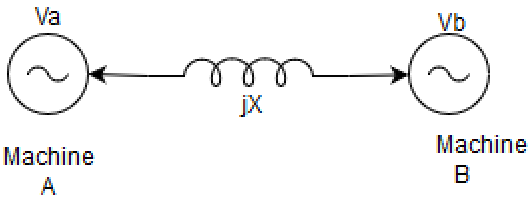
b) negative

c) zero

d) any of the mentioned

Answer:a

2. **For the figure depicting the two generators connected via the transmission line having and impedance 'jX' ohms. Machine A at voltage Va at angle δ will supply active power to machine B at voltage Vb and angle zero, when δ is _____________**



a) Va>Vb

b) Va<Vb

c) Va = Vb

d) Any of the mentioned.

Answer:a

3. **A three phase alternator can supply a maximum of 5000 KVA at 66 kV. The machine has internal resistance of 6%. The reactance per phase of the limiting reactor if the steady apparent power on the short circuit do not exceed 5 times full load is ____________**

a) 1.22 Ω

b) 2.44 Ω

c) 5 Ω

d) 1.84 Ω

Answer:a

4. **A transmission line has Z= (2+j8) Ω has 10% of the voltage regulation with the lagging load of 0.8. If the load is 0.707 leading, the V.R. is ________(Assume the current is same in both cases)**

a) -6.63%

b) -5.77%

c) -10%

d) -8.63%

Answer:b

5. **The symmetrical components are used in fault analysis because of _______________**

   a) sequence of network do not have mutual coupling

   b) number of equations is smaller

   c) results are required in symmetrical components

   d) none of the mentioned

Answer:a

6. **A generator delivers power of 1 pu to an infinite bus through a purely reactive network. The maximum power that could be delivered by generator is 2 pu. A three phase fault occurs at the generator which reduces the generator output to zero. The fault is restored after 'tc' seconds. The maximum swing of rotor angle is found to be δmax = 110o electrical. The rotor angle at 'tc' is ________ electrical deg.**

   a) 69.14^o

   b) 159.14^o

   c) 63.08^o

   d) 65.7^o

Answer:a

7. **A system consists of an alternator having reactance of 0.5pu connected to an infinite bus through a series of reactance of 1 pu. The generator terminal voltage of IBB is 1 pu and that of 1.2 pu. The steady state power system limit (in pu) is ___________**

   a) 1.167

   b) 1.152

   c) 1.765

   d) 1.729

Answer:b

8. **A system consists of an alternator having reactance of 0.5pu connected to an infinite bus through a series of reactance of 1 pu. The generator terminal voltage of IBB is 1 pu and that of 1.2 pu. The Steady state occurs at power angle of ________degree.**

   a) 0

   b) 90

   c) 180

   d) 45

Answer:b

9. A system consists of an alternator having reactance of 0.5pu connected to an infinite bus through a series of reactance of 1 pu. The generator terminal voltage of IBB is 1 pu and that of 1.2 pu. The emf induced in the alternator will have the phase difference with respect to reference for the maximum power transfer is _______________

a) 90

b) 0

c) 73.87

d) 86.25

Answer:a

10. What is the value of transient stability limit?

a. Higher than steady state stability limit

b. Lower than steady state stability limit.

c. Depending upon the severity of load

d. All of these

e. None of these

Answer:b

11. By using which component can the transient stability limit of a power system be improved?

a. Series resistance

b. Series capacitor

c. Series inductor

d. Shunt resistance

Answer:b

12. What is transient stability limit?

a.The maximum flow of power through a particular point in the power system without loss of stability when small disturbances occur.

b. The maximum power flow possible through a particular component connected in the power system.

c. The maximum flow of power through a particular point in the power system without loss of stability when large and sudden disturbances occur

d. All of these

Answer:c

13. Which among the following methods is used for improving the system stability?

a. Increasing the system voltage

b. Reducing the transfer reactance

c. Using high speed circuit breaker

d. All of these

Answer:d

14. What is steady state stability limit?

a. The maximum flow of power through a particular point in the power system without loss of stability when small disturbances occur.

b. The maximum power flow possible through a particular component connected in the power system.

c. The maximum flow of power through a particular point in the power system without loss of stability when sudden disturbances occur

d. All of these

Answer:d

15. Which among these is a classification of power system stability?

a. Frequency stability

b. Voltage stability

c. Rotor angle stability

d. All of these

Answer:d

16. The inertia constant H of a machine of 200MVA is 2 p.u. its value corresponding to 400MVA will be

a.4

b.2

c.1

d.0.5

Answer:c

17. The stability of the power system is not affected by which among these?

a. Generator reactance

b. Line losses

c. Excitation of generators

d. All of these

Answer:b

18. What is power system stability?

a. The maximum power flow possible through a particular component connected in the power system.

b. The ability of the power system to regain the state of operating equilibrium point when the system is subjected to any disturbances.

c. It is a phenomenon in which a power system losses its operating equilibrium when subjected to large disturbances.

d. All of these

Answer:b

19. The Critical Clearance time of a fault in the power system is related to

a) Reactive power limit

b) Short Circuit limit

c) Steady state stability limit

d) Transient stability limit

Answer:d

20. The equal area criteria of stability is used for

a) no load on the busbar

b) One machine and infinite busbar

c) More than one machine and infinite busbar

d) None of the above

Answer:b

EE6502 MICROPROCESSORS AND MICROCONTROLLERS L T P C LTPC 3 0 0 3

OBJECTIVES:

- To study the Architecture of uP 8085 & uC 8051
- To study the addressing modes & instruction set of 8085 & 8051.
- To introduce the need & use of Interrupt structure 8085 & 8051.
- To develop skill in simple applications development with programming 8085 & 8051
- To introduce commonly used peripheral / interfacing

UNIT I 8085 PROCESSOR 9

Hardware Architecture, pinouts – Functional Building Blocks of Processor – Memory organization – I/O ports and data transfer concepts– Timing Diagram – Interrupts.

UNIT II PROGRAMMING OF 8085 PROCESSOR 9

Instruction -format and addressing modes – Assembly language format – Data transfer, data manipulation& control instructions – Programming: Loop structure with counting & Indexing – Look up table - Subroutine instructions - stack.

UNIT III 8051 MICRO CONTROLLER 9

Hardware Architecture, pintouts – Functional Building Blocks of Processor – Memory organization – I/O ports and data transfer concepts– Timing Diagram – Interrupts-Comparison to Programming concepts with 8085.

UNIT IV PERIPHERAL INTERFACING 9

Study on need, Architecture, configuration and interfacing, with ICs: 8255 , 8259 , 8254,8237,8251, 8279 ,- A/D and D/A converters &Interfacing with 8085& 8051.

UNIT V MICRO CONTROLLER PROGRAMMING & APPLICATIONS 9

Data Transfer, Manipulation, Control Algorithms& I/O instructions – Simple programming exercises key board and display interface – Closed loop control of servo motor- stepper motor control – Washing Machine Control.

TOTAL : 45 PERIODS

OUTCOMES:

- Ability to understand and analyze, linear and digital electronic circuits.
- To understand and apply computing platform and software for engineering problems.

TEXT BOOKS:

1. Krishna Kant, “Microprocessor and Microcontrollers”, Eastern Company Edition, Prentice Hall of India, New Delhi , 2007.
2. R.S. Gaonkar, ‘Microprocessor Architecture Programming and Application’, with 8085, Wiley Eastern Ltd., New Delhi, 2013.
3. Soumitra Kumar Mandal, Microprocessor & Microcontroller Architecture, Programming & Interfacing using 8085,8086,8051,McGraw Hill Edu,2013.

REFERENCES:

1. Muhammad Ali Mazidi & Janice Gilli Mazidi, R.D.Kinely ‘The 8051 Micro Controller and Embedded Systems’, PHI Pearson Education, 5th Indian reprint, 2003.
2. N.Senthil Kumar, M.Saravanan, S.Jeevananthan, ‘Microprocessors and Microcontrollers’, Oxford,2013.
3. Valder – Perez, “Microcontroller – Fundamentals and Applications with Pic,” Yeesdee Publishers, Tayler & Francis, 2013.

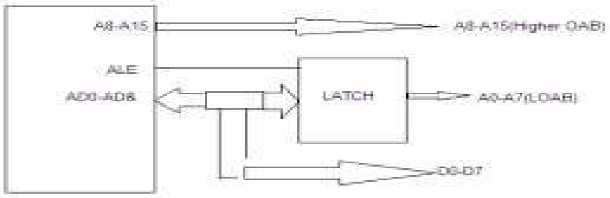
Subject Code:EE6502 **Year/Semester: III /05**
Subject Name: MICROPROCESSOR AND MOCROCONTROLLER
Subject Handler: Ms. P. Vinnarasi Ponnury

UNIT-I 8085 PROCESSOR

Hardware Architecture, pinouts – Functional Building Blocks of Processor – Memory organization – I/O ports and data transfer concepts– Timing Diagram – Interrupts.

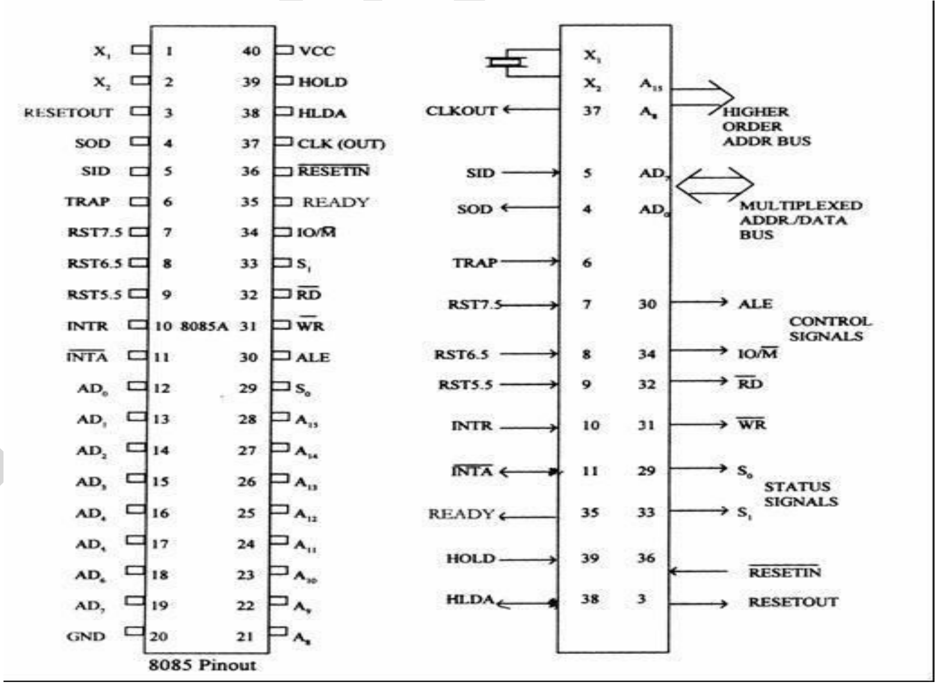
PART*A

Q.No.	Questions
1.	**What is meant by Level triggered interrupt? Which are the interrupts in 8085 level triggered? May/June 2014** BTL1 Triggering is used to enable the signal to make circuit active or to do its function. It is normally by using the clock signal . It can be a negative level triggering in which the circuit is active when the clock signal is low or a positive level triggering in which the circuit is active when the clock signal is high.
2.	**To obtain a 320ns clock what should be the input clock frequency? What is the frequency of clock signal at CLK OUT? May/June 2014** BTL2 The input clock frequency must be 6.25 MHZ to obtain 320ns.The input clock signal frequency at CLK OUT is 3 MHZ.
3.	**What is TRAP interrupt and its significance? May/June 2012** BTL1 TRAP is a Non Maskable Interrupt. It means that it is unaffected by any mask or interrupt enable. It has the highest priority. It is edge and level triggered which means it must go high and remain high until it is acknowledged**.**
4.	**Define the function of parity flag and zero flag in 8085. May/June 2012** BTL1 Parity flag is defined by the number of 1s present in the accumulator. After an arithmetic or logical operation if the result has an even number of ones. i.e. even parity the flag is set,if the parity is odd flag is reset. Zero flag sets if the result of operation in ALU is zero and flag resets if result is non zero.
5.	**Explain the function of program counter in 8085. April /May 2013** BTL1 It is a special purpose register which at a given time stores the address of the next instruction to be fetched. It acts as a pointer to the next instruction**.**
6.	**Write down the control and status signals of 8085.Nov/Dec 2012** BTL1 Two Control signals and three status signals **Control signals**: RD and WR **Status signals**: IO/M, S1, S2
7.	**Specify the size of data, address, memory word and memory capacity of 8085 microprocessor. April/may 2011** BTL2 8085 operate 8bit data. The 8085 has 16 address lines, hence it can access (216) 64 Kbytes of memory.

8.	**Draw the schematic of latching low order address bus in 8085 microprocessor. Nov/Dec 2011** BTL6 
9.	**What are the flags used in 8085? NOV/Dec 2013** BTL1 Sign, Zero, Parity, Carry and Auxiliary Carry
10.	**What is ALE? NOV/Dec 2013** BTL1 ALE is Address Latch Enable. The ALE signal goes high at the beginning of each machine cycle indicating the availability of the address on the address bus, and the signal is used to latch the low order address bus.
11.	**Specify the function of Address bus and the direction of the information flow on the address bus. Nov./Dec 2012** BTL5 The address is an identification number used by the microprocessor to identify or access a memory location or I / O device. It is an output signal from the processor. Hence the address bus is unidirectional.
12.	**What do you mean by masking the interrupt? How it is activated in 8085?** BTL4 Masking is preventing the interrupt from disturbing the current program execution. When the processor is performing an important job (process) and if the process should not be interrupted then all the interrupts should be masked or disabled. In processor with multiple 'interrupts, the lower priority interrupt can be masked so as to prevent it from interrupting, the execution of interrupt service routine of higher priority interrupt.
13.	**What are the two limitations of the 8085 that may not allow it to qualify entirely as a µP ?** BTL1 i. The lower order address buses (AD7-AD0) need to be de multiplexed. ii. Appropriate control signals need to be generated to interface peripherals
14.	**Define T-state and in which T-cycle the ALE signal is activated.** BTL1 T-State is defined as one subdivision of the operation performed in one clock period. These subdivisions are internal states synchronized with the system clock, and each T-State is precisely equal to one clock period.
15.	**What is a flag?** BTL1 The data conditions, after arithmetic or logical operations, are indicated by setting or resetting the flip-flops called flags.
16.	**Differentiate Software and Hardware interrupts .** BTL4 The Software interrupt is initiated by the main program, but the hardware interrupt is initiated by the external device. In 8085, Software interrupts cannot be masked or disabled, but in hardware interrupts except TRAP all other interrupts can be masked.
17.	**Define i) Instruction cycle ii) Machine cycle.** BTLI i) The sequence of operations that a processor has to carry out while executing the instruction is called Instruction cycle. Each instruction cycle of a processor indium consists of a number of machine cycles.

	ii) The processor cycle or machine cycle is the basic operation performed by the processor. To execute an instruction, the processor will run one or more machine cycles in a particular order.
18.	**What do you mean by stack pointer?** BTL1 The stack pointer is a reserved area of the memory in the RAM where temporary information may be stored. A 16- bit stack pointer is used to hold the address of the most of the stack entry.
19.	**What is the need for a timing diagram?** BTL1 The timing diagram provides information regarding the status of various signals, when a machine cycle is executed. The knowledge of timing diagram is essential for system designer to select matched peripheral devices like memories, latches, ports, etc., to form a microprocessor system.
20.	**Why are the program counter and the stack pointer 16-bit registers?** BTL2 Memory locations for the program counter and stack pointer have 16-bit addresses. So the PC and SP have 16-bit registers.

PART*B

Q.No.	**Questions**
1.	**Explain the pin diagram of 8085 microprocessor with neat diagrams.(13M)**BTL2 **(May/June 12)** **Answer: Page No.1.12 -P.S.Manoharan** • Explain about the pin outs in details and explain the function of pins(7 M) • Diagram (6 marks)  • Signals of Power supply and frequency • Address signals • Address bus • Data signals • Address / Data bus • Control and status signals

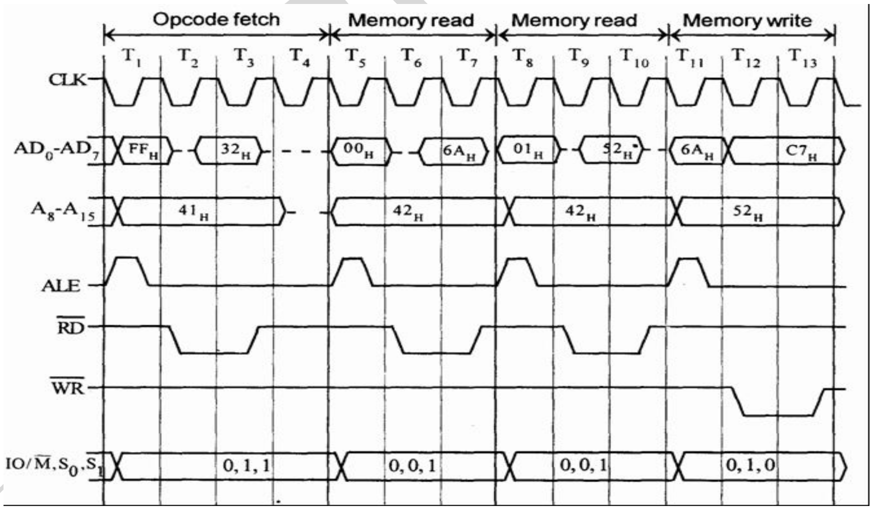
- ✓ IO/$\overline{M}$, $\overline{RD}$, $\overline{WR}$, READY , HOLD , HLDA
- Address Latch Enable (ALE)
- Interrupts
- ✓ TRAP
- ✓ RST 7.5
- ✓ RST 6.5
- ✓ RST 5.5
- ✓ INTR
- Externally initiated signals
- Serial I/O signals
- ✓ SID , SOD
- $\overline{RESET}$ $\overline{IN}$
- $\overline{RESET}$ $\overline{OUT}$
- X1 , X2
- Acknowledgement signals

2.

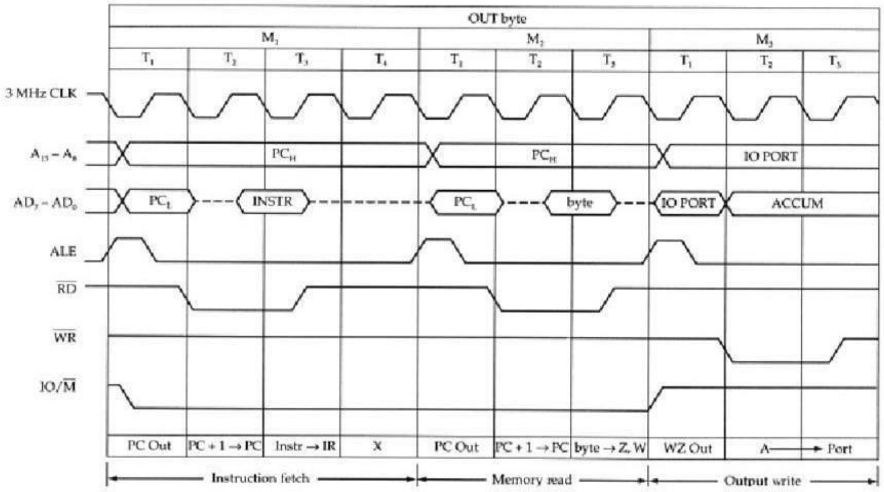
Draw the timing diagram for IN and OUT instruction of 8085 and explain. Timing diagram for IN instruction. May/June 2012BTL6 **(13M)**

Answer: Page No . Appendix A14 , A21 - P.S.Manoharan

Timing diagram for IN instruction (7 M)

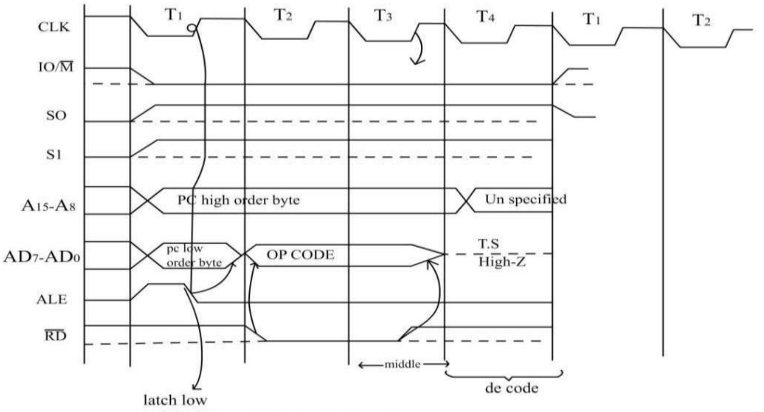


Timing diagram for OUT instruction: (6 M)

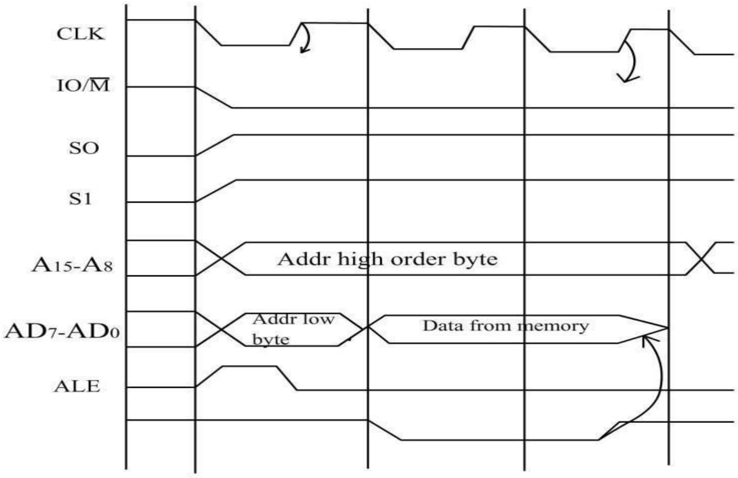
	
3.	**Explain the interrupt structure of 8085 microprocessor.(Nov/Dec'11) (May/June 12)** BTL2(**13M)** **Answer:Page No.1.80 - P.S.Manoharan** There are 5 pins available in 8085 for interrupt: (6 M) 1. TRAP 2. RST 7.5 3. RST6.5 4. RST5.5 5. INTR Two types of interrupts - 8085 Microprocessor: (3 M) 1. Hardware Interrupts • Five types – TRAP ,RST 7.5 , RST 6.5 , RST 5.5 and INTR 2. Software Interrupts • Syntax is RSTn • Maskable/Non-Maskable Interrupt : (2 M) • disabled interruptsfor writing instruction - Maskable Interrupt • others - Non-Maskable Interrupt. • Vectored and Non vectored : (2 M) • mapped address in vector table - vector interrupt • For INTR , CPU produce acknowledgement is called non vectored interrupt
4.	**Explain the functions of 8085 signals.(May/June 2014)** BTL2 **(13M)** **Answer: Page No.1.12 - P.S.**Manoharan • 8085 - 40 pin IC, • Power supply and clock signals (2 M) • Address bus (2 M) • Data bus (2 M) • Control and status signals (2 M) • Interrupts and externally initiated signals(3 M) • Serial I/O ports(2 M) ✓ Address signals ✓ Address bus

	✓ Data signals ✓ Address / Data bus ✓ Control and status signals ✓ Address Latch Enable (ALE) ✓ IO/$\overline{M}$, $\overline{RD}$, $\overline{WR}$, READY , HOLD , HLDA • Interrupts and externally initiated signals ✓ TRAP ✓ RST 7.5 ✓ RST 6.5 ✓ RST 5.5 ✓ INTR • Serial I/O signals • $\overline{RESET}$ $\overline{IN}$ • $\overline{RESET}$ $\overline{OUT}$ • X1 , X2 • SID , SOD • Acknowledgement signals

PART *C

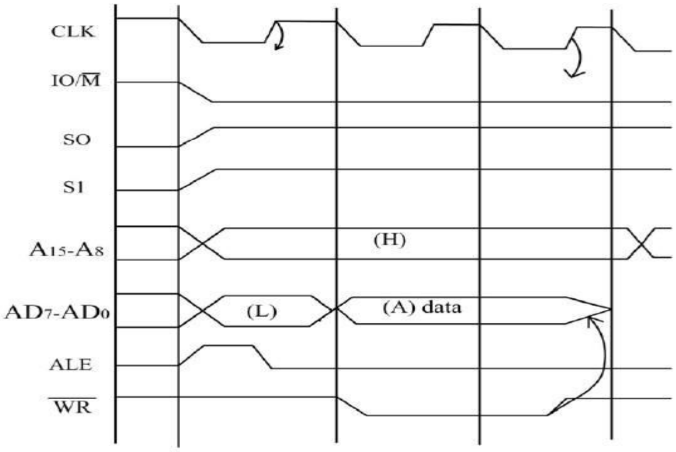
Q.No.	Questions
1.	**Explain various machine cycles supported by 8085. (April/May'11) (May/June 12)** BTL6 **(15M)** **Answer:Page No. APPENDIX A4 - P.S.Manoharan** OPCODE FETCH machine cycle (5 M) ✓ First machine cycle ✓ Fetches instruction from memory to register ✓ During T1 state program counter -16 bit ✓ ALE goes high ✓ During T2 – sends control signal to RD(active low) ✓ During T3 – opcode of A/D – transferred o instruction register ✓ During t4 – Fetched opcode is decoded  OFMC timing diagram

Memory READ m/c cycle (5 M)



- machine cycle required reading of data or address address from memory or I/O device
  - ✓ During T1-content - program counter - placed in Address and A/D bus
  - ✓ ALE signal – high
  - ✓ During T2 – content – select memory location
  - ✓ During T3 – data – moved to microprocessor

MEMORY WRITE MC: (5 M)



- ✓ Send data – register to memory
- ✓ During T1 – places a memory location
- ✓ ALE – high
- ✓ Microprocessor recognizes memory
- ✓ During T2 – WR (active low) – states the content - register
- ✓ During T3 – data bus to specific memory

I/O READ and I/O WRITE M/C cycle:

- ✓ Identical to MRMC & MWRMC - except that appropriate status signals - issued at the beginning of state.

2. **Explain the Internal architecture, dataflow and instruction execution of 8085 microprocessor, (May/June 12) ,(April/May'11)**BTL2 **(15M)**

Answer: Page No.1.7,1.8 - P.S.Manoharan

- Explain about block diagram (7 M)
- Diagram (8 M)

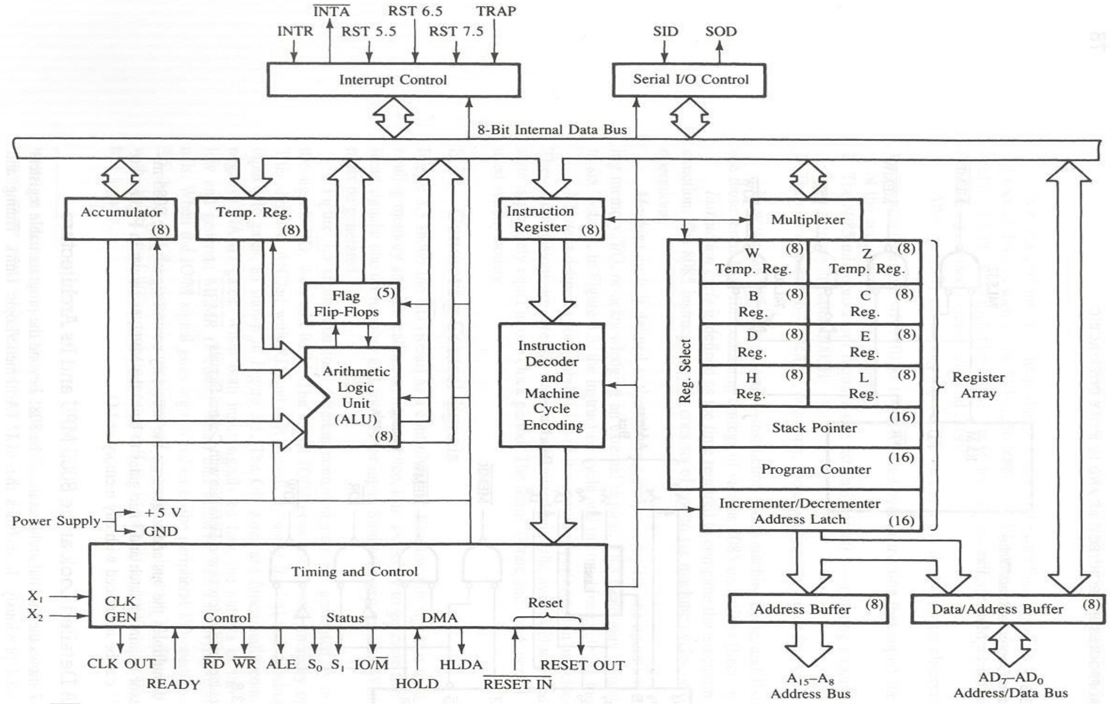
Processor System Architecture

The typical processor system consists of:

- CPU (central processing unit)
- ALU (arithmetic-logic unit)
- Control Logic
- Registers
- Memory
- Input / Output interfaces

Interconnections between these units:

- Address Bus
- Data Bus
- Control Bus



Bus: A shared group of wires used for communicating signals among devices

- ✓ address bus: the device and the location within the device - being accessed
- ✓ data bus: the data value being communicated
- ✓ control bus: describes the action - address and data buses

Flag Bits

- ✓ Indicate the result of condition tests.
- ✓ Carry, Zero, Sign, Parity
- ✓ Conditional operations (IF / THEN) - executed based on flag bits condition .

Program Counter (PC)

- ✓ Contains the memory address (16 bits) instruction - executed in the next step.

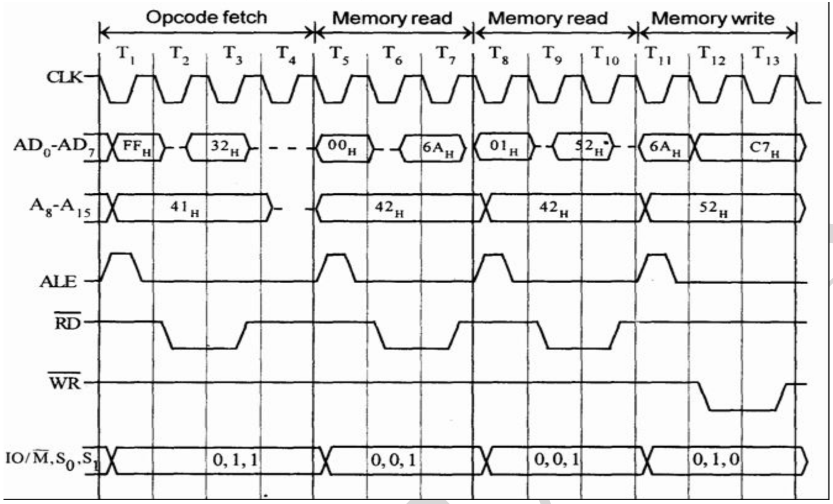
Stack Pointer (SP)

- ✓ 16 bit – address

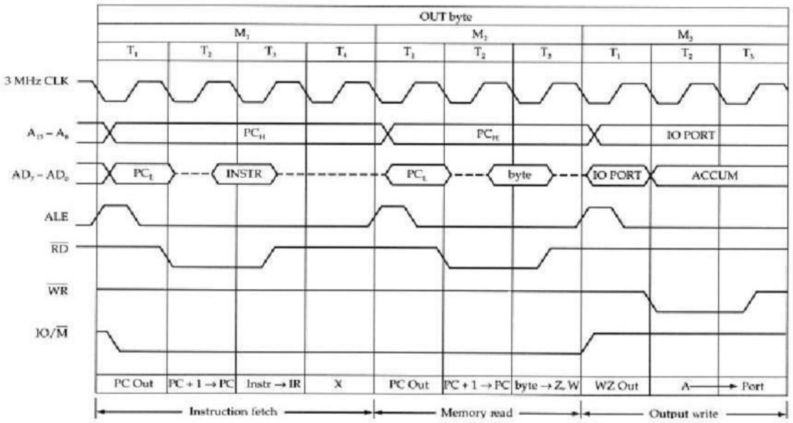
3. **Draw the timing diagram for IN and OUT instruction of 8085 and explain. (Nov/Dec'11)** BTL6 **(15M)**

Answer: Page No.1.19 - P.S.Manoharan

Timing diagram for IN instruction: (8 M)



Timing diagram for OUT instruction: (7 M)



UNIT 2 PROGRAMMING OF 8085 PROCESSOR

Instruction -format and addressing modes – Assembly language format – Data transfer, data Manipulation & control instructions – Programming: Loop structure with counting & Indexing – Look up table - Subroutine instructions - stack.

PART*A

Q.No.	Questions
1.	**Write the different control machine control instructions used in 8085 microprocessor. May/June 2013** BTL1 • EI-Enable Interrupt • Di-Disable interrupt • NOP- No operation • HLT- Halt, SIM, RIM.
2.	**Write the function of stack. May/June 2013** BTL1 Stack is s portion of Read /Write memory location set aside by the user for the purpose of storing the

	information temporarily. When the information is written on the stack the operation is PUSH and when the information is read from the stack it is POP. The type of operation performed in stack is LIFO(last in first out).
3.	**Mention the similarity and difference between compare and Subtract instructions. (May/June 2014)** BTL4 **COMPARE:** This instruction compares the given numbers by subtracting it and gives the result if the number is greater than, lesser than or equal to the status of sign and carry flag will be affected. **SUBTRACT:** This instruction subtracts the two given numbers and the flag registers will not be affected.
4.	**State the purpose and importance of NOP instruction. (May/June 2014)** BTL1 **NOP – No operation** This instruction does not perform any operation. It can also be used to make the clock signals to go in wait state that is delay time can be increased.
5.	**List out the types of addressing modes in 8085. (May/June2012, Nov/Dec 2013)** BTL1 • Immediate • Direct • Register • Indirect • Implied
6.	**What is the use of branching instructions? (May/June2012)** BTL1 These instructions allow the processor to change the sequence of the program either conditionally or unconditionally or under certain test conditions. These include branch instructions, subroutine call and return instructions.
7.	**State the function of given 8085 instruction: JP, JPE, JPO, JNZ.(April/May'11)** BTL1 • JP – 16 bit Address – Jump on Plus • JPE – 16 bit Address – Jump on Even Parity • JPO – 16 bit address – Jump on Odd Parity • JNZ – 16 bit address – Jump on No Zero
8.	**How is PUSH B instruction executed?Find the status after the execution.(April/May'11)** BTL2 This instruction decrements SP by one and copies the higher byte of the register pair into the memory location pointed by SP. Then decrements the SP again by one and copies the lower byte of the register pair into the memory location pointed by SP.
9.	**Why do we need look up table?(Nov/Dec'11)** BTL2 To store the complex parameters in the program memory. It reduces computational complexity. Eg: SIN table.
10.	**How are the 8085 instructions classified according to the functional categories ? (Nov/Dec'11)**BTL2 **Data Transfer, Arithmetic, Logical, Branching, Machine Control.**
11.	**Write a note on stack in an 8085 microcomputer system. (Nov/Dec'12)** BTL1 Stack is s portion of Read /Write memory location set aside by the user for the purpose of storing the information temporarily. When the information is written on the stack the operation I s PUSH and when the information is read from the stack it is POP. The type of operation performed in stack is LIFO last in first out.
12.	**Define indexing. (Nov/Dec'12)** BTL1 Indexing allows the programmer to point or refer the data stored in sequential memory locations one by one.

13.	**What happens when the RET instruction at the end of the subroutine is executed?May/June 2012** BTL1 This instruction pops the return address (address of the instruction next to the CALL instruction in the main program) from the stack and loads program counter with this return address. Thus transfers program control to the instruction next to Call in the main program.
14.	**List out the instructions associated with the subroutine.** (**Nov/Dec 2013)** BTL1 **CALL 16 bit address:** The program sequence is transferred to the address specified by the operand. Before the transfer, the address of the next instruction to CALL(the contents of the program counter) is pushed to the stack. **RET - RETURN:** The program sequence is transferred from the subroutine to the calling program. The two bytes from the top of the stack are copied into the program counter and the program execution begins at the new address. The instruction is equivalent to POP program counter.
15.	**What is the significance of 'XCHG' and 'SPHL' instructions?** BTL1 **'XCHG'**-Exchange the contents of HL register pair with DE register pair ie the contents of register H are exchanged with the contents of register D and the contents of register L are exchanged with the contents of register E **SPHL**-store the contents of HL register pair to the stack pointer. The contents of H register provide the higher order address and the contents of L register provide the low order address. The contents of H and L registers are not altered.
16.	**What do you mean by Looping, Counting and Indexing?** BTL1 **Looping:** In this tech the program is instructed to execute certain set of instructions repeatedly to execute a particular task number of times. **Counting:** This tech allows programmer to count how many times the ins of instruction are executed. Indexing: This tech allows programmer to point or refer the data stored in sequential memory location one by one.
17.	**Write the different instruction formats used in 8085.** BTL6 • One byte instruction –CLR A • Two byte instruction -MVIA, 00 • Three byte instruction-STA 5000
18.	**Define Opcode and operand. -** BTL2 The operation to be performed is called Opcode. The data to be operated is called operand.
19.	**Give the difference between JZ and JNZ.** BTL5 JZ change the program sequence to the location specified by the 16-bit address if the zero flag is set and JNZ change the program sequence to the location specified by the 16-bit address if the zero flag is reset.
20.	**Write a note of register addressing mode.** BTL1 The register addressing mode specifies the source operand, destination operand, or both to be contained in an 8085 registers. This results in faster execution, since it is not necessary to access memory locations for operand. Eg : MOV A, B
PART * B	
Q.No.	**Questions**
1.	**Discuss in detail about the 8085 Instruction set, explain about the various types of operations. Instruction Set of 8085. (April/May'11)(May/June 12)** BTL2 **(13M)** **Answer: Page:1.18 - P.S.Manoharan**

- Explain the instruction with example

Classification of Instruction Set

- Data Transfer Instruction (3 M)
  - ✓ Loading data into register
  - ✓ MOV A,B
  - ✓ MOV M,C
  - ✓ XCHG
- Arithmetic Instructions(3 M)
  - ✓ ADD M
  - ✓ SUB C
  - ✓ INR M
  - ✓ DCX B
  - ✓ DAA
- Logical Instructions(2 M)
  - ✓ ANA B
  - ✓ ORA M
  - ✓ RAL
  - ✓ RRC
- Branching Instructions(2 M)
  - ✓ JMP 9000h
  - ✓ JNZ Loop1
  - ✓ JC Loop2
  - ✓ RET
  - ✓ RST 0
- Control Instructions(3 M)
  - ✓ PUSH D
  - ✓ IN 80h
  - ✓ OUT 07H
  - ✓ RIM

2. **Explain the addressing modes of 8085 microprocessor .(Nov/Dec 2012,May/June 2012)** BTL2 **(13M)**

Answer : Page : 1.19 - P.S.Manoharan

Addressing Modes in 8085 Explanation: (3 M)

- Immediate Addressing Mode (2 M)
  - ✓ The data (operand) is specified within instruction
  - ✓ MVI A,18h
- Register Addressing Mode (2 M)
  - ✓ Instruction specifies name of register
  - ✓ MOV A,B
- Direct Addressing Mode (2 M)
  - ✓ The address of data (operand) is specified within instruction - data available
  - ✓ STA 2005
- Indirect Addressing Mode (2 M)
  - ✓ The address of data (operand) is specified within instruction - address available
  - ✓ MOV A,M

- Implied/implicit Addressing Mode (2 M)
  - ✓ Content of Accumulator
  - ✓ CMA

3. **Write an ALP to multiply two 8 bit numbers. (Nov/Dec 2012)** BTL6 **(13M)**

Answer:Page :1.51 - P.S.Manoharan

- Program (13 M)

```
LXI H,0000H
MVI B,00
LDA 4600H
MOV C,A
LDA 4601H
MOV D,A
LOC 2:DAD B
DCR D
JZ LOC1
JMP LOC2
LOC1:SHLD 9000H
HLT
```

4. **Explain the instruction format and addressing modes of 8085 microprocessor. (April/May'11) (May/June 12)** BTL6 **(13M)**

Answer: Page :1.18 ,1.19 - P.S.Manoharan

- Instruction Format : (4 M)
  - ✓ Instruction - command to the microprocessor - perform a given task - specified data .
  - ✓ two parts: one - performed operation (opcode).
  - ✓ second - data to be operated - operand.
- One-word or 1-byte instructions
  - ✓ Opcode
  - ✓ CMA
- Two-word or 2-byte instructions
  - ✓ Opcode and operand
  - ✓ IN 80h =(DB , 80)
- Three-word or 3-byte instructions
  - ✓ Opcode , operand 1 , operand 2
  - ✓ LDA 5060h = (3A , 60 , 50)

Addressing Modes in 8085: (4 M)

- The method - address of source of data or the address of destination instruction - Addressing Modes (5 M)

- Immediate Addressing Mode
  - ✓ The data (operand) - specified within instruction
  - ✓ MVI A,18h
- Register Addressing Mode
  - ✓ Instruction specifies name of register
  - ✓ MOV A,B
- Direct Addressing Mode
  - ✓ The address of data (operand) - specified within instruction - data available
  - ✓ STA 2005

- Indirect Addressing Mode
- ✓ The address of data (operand) - specified within instruction - address available
- ✓ MOV A,M
- Implied/implicit Addressing Mode
- ✓ Content of Accumulator

5. **Write Assembly Language Program (ALP) to add two 8–bit data.**BTL6 **(13M)**

Answer: Page : 1.47 -P.S.Manoharan

- Program (8 M)
- Label and commands (5 M)

MEMORY ADDRESS	LABEL	MNEMONICS	COMMENTS
2000		LDA 2016H	Load the first data from memory
2003		MOV B,A	Sore data in B register from Accumulator
2004		LDA 2601	Load second data
2007		ADD B	Add two data
200B		JC LOC1	Check carry
200E		MVI A,00h	CY = 0
2010		STA 2603h	Store content – Accumulator
2013		HLT	Stop
2014	LOC 1:	MVI A,01	CY = 1
2016		STA 2603	Store content – Accumulator
2019		HLT	Stop

PART *C

Q.No.	Questions

1. **Describe the operation of stack with a suitable example. (MAY/JUNE 12)** BTL2 **(15M)**

Answer: Page :1.41- P.S.Manoharan

- Explain the instruction with example

STACK (1 M)

- IN (3 M)
- ✓ Input data – accumulator
- ✓ IN 8 – bit port address
- ✓ [A] ← [Port]
- ✓ Example : IN 80h
- OUT (3 M)
- ✓ Output data - Accumulator
- ✓ OUT 8- bit Port address
- ✓ [port] ← [A]
- ✓ Example : OUT 50h
- PUSH (4 M)
- ✓ Push register pair – stack
- ✓ PUSH rp
- ✓ [[SP]-1] ←[rh]
- ✓ [[SP]-2] ←[rl]

- ✓ Example : PUSH B
- POP (4 M)
- ✓ POP – stack to register pair
- ✓ POP rp
- ✓ [rL] ←[SP]
- ✓ [rL] ←[[SP]+1]
- ✓ Example : POP H

2. **Write an ALP for arranging an array of 8-bit unsigned number in ascending order. (MAY/JUNE 12)** BTL5 **(15M)**

Answer: Page : 1.56 - P.S.Manoharan

- Program (10 M)
- commands (5 M)

```
LDA 4300H    Loading data
MOV B,A      Move data from A to B
LOC5:MOV C,B
LXIH 4400H
LOC3:MOV A,M
INX H
CMP M
JC LOC1
MOV D,M
MOV M,A
DCX H
MOV M,D
INX H
LOC1:DCR C
JZ LOC2
JMP LOC3
LOC2:DCR B
JZ LOC4
JMP LOC5
HLT
```

3. **Compare the similarities and differences of CALL and RET instructions with PUSH and POP instructions. (NOV/DEC'11)** BTL5 **(15M)**

Answer: Page : 1.39 - P.S.Manoharan

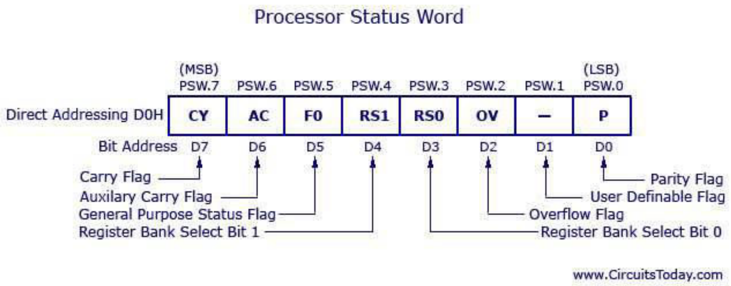
- Explain the instruction with examples (1 M)
- CALL (4 M)
- Unconditional Subroutine call
- ✓ CALL 16-it address
- ✓ Example : CALL 5000
- Conditional Subroutine call
- ✓ CC – Call on Carry
- ✓ CZ – Call on Zero
- ✓ CNZ – Call on Non Zero
- RET (4 M)
- Return from subroutine unconditionally
- ✓ End subroutine

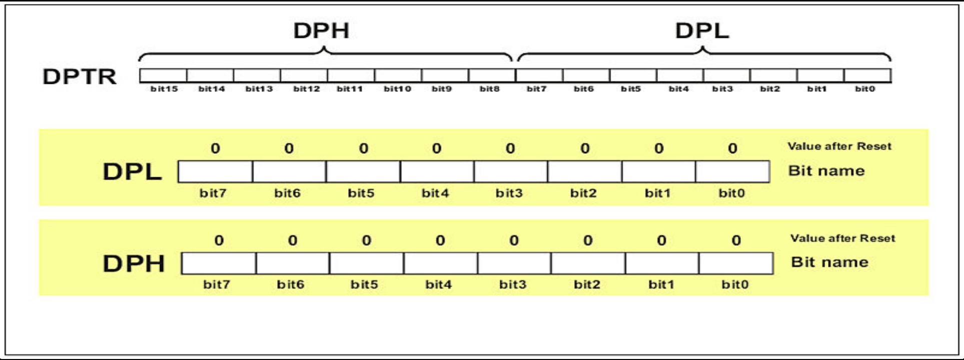
	✓ [PCL] ←[[SP]] ✓ [PCL] ←[[SP]+1] • Conditional Return ✓ RC – Return on Carry ✓ RP – Return on positive ✓ RZ – Return on Zero • PUSH (3M) ✓ Push register pair – stack ✓ PUSH rp ✓ [[SP]-1] ←[rh] ✓ [[SP]-2] ←[rl] ✓ Example : PUSH B • POP (3 M) ✓ POP – stack to register pair ✓ POP rp ✓ [rL] ←[SP] ✓ [rL] ←[[SP]+1] Example : POP H

UNIT 3 8051 MICRO CONTROLLER

Hardware Architecture, pintouts – Functional Building Blocks of Processor – Memory organization – I/O ports and data transfer concepts– Timing Diagram – Interrupts-Comparison to Programming concepts with 8085

PART *A

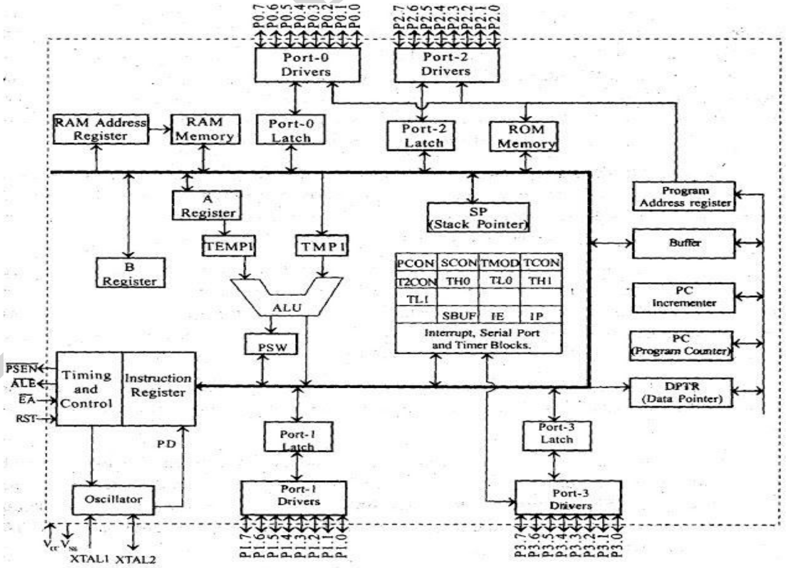
Q.No.	Questions
1.	**Give the memory size of 8051microcontroller.(April/may -2010)**BTL1 The 8051 microcontroller consists of • 4096 bytes On-chip program memory(ROM) • 128 bytes On-chip data memory(RAM)
2.	**Give the details of PSW register in 8051. (April/may -2010, May/June -2012, May/June -2014)** BTL1 
3.	**Mention the size of DPTR and Stack Pointer in 8051 microcontroller. (April/may -2011)** BTL1 The Data Pointer (DPTR) is a 16 bit data Register and Stack pointer (SP) is 8 bit Register.

	
4.	**What are the main features of 8051 microcontroller? (May/June -2012)** BTL1 **The features are:** • Single supply +5 volt operation using HMOS technology. • 4096 bytes program memory on chip (not on 8031) • 128 data memory on chip. • Four register banks. • Two multiple mode,16-bittimer/counter. • Extensive Boolean processing capabilities. • 64 KB external RAM size
5.	**What are the addressing modes of 8051 ?(May/June -2013, Nov/Dec-2011)** BTL1 The addressing modes of 8051 are: • Immediate. • Register. • Register indirect. • Direct. • Indexed.
6.	**What is the function of R register in 8051 ? (May/June -2013)** BTL1 The 8051 uses 8 "R" registers which are used in many of its instructions. These "R" registers are numbered from 0 through 7 (R0, R1, R2, R3, R4, R5, R6, and R7). These registers are generally used to assist in manipulating values and moving data from one memory location to another.
7.	**Mention the purpose of PSEN and EA in 8051 microcontroller.(May/June -2014)** BTL2 If external ROM is used for storing program then a logic zero (0) appears on it every time the microcontroller reads a byte from memory. By applying logic zero to this pin, P2 and P3 are used for data and address transmission with no regard to whether there is internal memory or not. It means that even there is a program written to the microcontroller, it will not be executed. Instead, the program written to external ROM will be executed. By applying logic one to the EA pin, the microcontroller will use both memories, first internal then external (if exists).
8.	**List the on-chip peripherals of 8051 microcontroller. (May/June -2014)**BTL1 • Program memory • Data memory • Parallel ports • Serial port • Timers and • Interrupt controller
9.	**How many ports are bit addressable in 8051 microcontroller? (Nov/Dec-2012)**BTL1 P0, P1, P2 & P3 (all the four ports are bit addressable)

10.	**Give an example of DA instruction of 8051 microcontroller.(Nov/Dec-2012)**BTL1 - DA A -Decimal Adjust of the accumulator - It occupies 1 byte and - has 12 Oscillator period

11.	**Write A program to perform multiplication of 2 no's using 8051. (Nov-2009)** BTL6
	MOV A, data 1
	MOV B, #data 2
	MUL AB
	MOV DPTR, #5000
	MOV @DPTR, A (lower value)
	INC DPTR
	MOV A, B
	MOVX @DPTR,A

12.	**What is memory mapping? (May/June 2011)** BTL1 Memory mapping may refer to: Memory-mapped file, also known as mmap()Memorymapped I/O, an alternative to port I/O; a communication between CPU and peripheral device using the same instructions, and same bus, as between CPU and memory Virtual memory, technique which gives an application program the impression that it has contiguous working memory, while in fact it is physically fragmented and may even overflow on to disk storage.
13.	**Write short notes on interrupt priority.**BTL2 ISR-Interrupt service routine stores all the levels that are currently being serviced.
14.	**List the operating modes of 8255A PPI.**BTL1 - Two 8-bit ports (A and B) - Two 4-bit ports (Cu and CL) - Data bus buffer - (iv) Control logic
15.	**What is USART?** BTL1 USART is an integrated circuit. It is a programmable device; its function and specifications for serial I/O can be determined by writing instructions in its internal registers.
16.	**Name any four additional hardware features available in microcontrollers when compared to microprocessors.**BTL1 - Two multiple mode - 16 bit timers/counters - Four register banks - Integrated Boolean processor
17.	**Write the steps necessary to initialize a counter in write operations.**BTL2 - Write a control word into the control register. - Load the low-order address byte. - Load the high order byte.
19.	**Write the steps necessary to initialize a counter in write operations.**BTL2 Write a control word into the control register - Load the low-order address byte - Load the high order byte
20.	**What is USART?** BTL1 USART is an integrated circuit. It is a programmable device; its function and specifications for serial I/O can be determined by writing instructions in its internal registers.

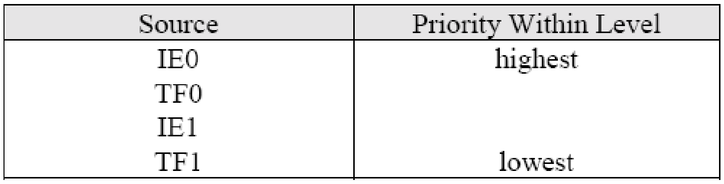
21.	**List the operating modes of 8255A PPI.**BTL1 • Two 8-bit ports (A and B) • Two 4-bit ports (Cu and CL) • Data bus buffer • Control logic
22.	**List the on-chip peripherals of 8051 microcontroller. (Nov/Dec-2011)** BTL1 • Program memory • data memory • 4 parallel ports • serial port • timers and • interrupt controller
PART*B	
Q.No.	**Questions**
1.	**Explain with block diagram the architecture of 8051 microcontroller hardware.(MAY/JUNE 12)** BTL2(**13M**) **Answer: Page 5.2 - P.S.Manoharan** • Explain about block diagram (5 M) • Diagram (8 M)  • **Memory Organization** ✓ Program Memory ✓ Data Memory • **Program Status Word** ✓ The Program Status Word (PSW) contains several status bits that reflect the current state of the CPU. • **Interrupt Structure** ✓ The 8051 provides 4 interrupt sources ✓ Two external interrupts ✓ Two timer interrupts • **Port Structures**

  - ✓ The 8051 contains four I/O ports
  - ✓ All four ports are bidirectional
- **Timer/Counters**
  - ✓ The 8051 has two 16-bit Timer/Counter registers
  - ✓ Timer 0
  - ✓ Timer 1
  - ✓ Mode 0 (13-bit Timer)
  - ✓ Mode 1 (16-bit Timer)
  - ✓ Mode 2 (8-bit Timer with Auto-Reload)
  - ✓ Mode 3 (Two 8-bit Timers)

2\. **Explain the interrupt structure of 8051 microcontroller .(APRIL/MAY'11)** BTL2 **(13M)**

Answer: Page 5.29 - P.S.Manoharan

- 8051 provides 4 interrupt sources
  - ✓ external interrupts (5 M)
- **External Interrupts**



Source	Priority Within Level
IE0	highest
TF0	
IE1	
TF1	lowest

Table 11 Interrupt Priority Within Level

  - ✓ timer interrupts (5 M)
- **Timer 0 and Timer 1 Interrupts**
  - ✓ Timer interrupts - generated by TF0 and TF1 flags - respective Timer/Counter registers
  - ✓ A low-priority interrupt can be interrupted by high-priority interrupt, but not by another low-priority one
  - ✓ A high-priority interrupt can't be interrupted by any other interrupt source
  - ✓ an internal polling sequence determines which request - serviced
  - ✓ Each interrupt source can be individually enabled or disabled by setting or clearing a bit in IE (Interrupt Enable).
  - ✓ IE also exists a global disable bit, which can be cleared to disable all interrupts at once. (2 M)
  - ✓ Each interrupt source can also be individually set to one of two priority levels by setting or clearing a bit in IP (Interrupt Priority) (1 M)

3\. **Explain the vectored interrupts in 8051 microcontroller.**BTL2**(13M)**

Answer: Page 5.29 - P.S.Manoharan

- Explain about the interrupts
- Diagram (3 M)

8051 provides 5 vectored interrupts. They are

- ✓ INTO (2 M)
- ✓ TF0 (2 M)
- ✓ INT1 (2 M)
- ✓ TF1 (2 M)

- ✓ RI/TI (2 M)
- ✓ INT1 and INT0 are external interrupts
- ✓ external interrupts could be negative edge triggered or low level triggered
- ✓ external interrupt flags - cleared on branching to Interrupt Service Routine (ISR)
- ✓ can be - individually enabled or disabled by setting' or clearing
- ✓ IE contains a global enable bit EA which enables/disables all interrupts at once

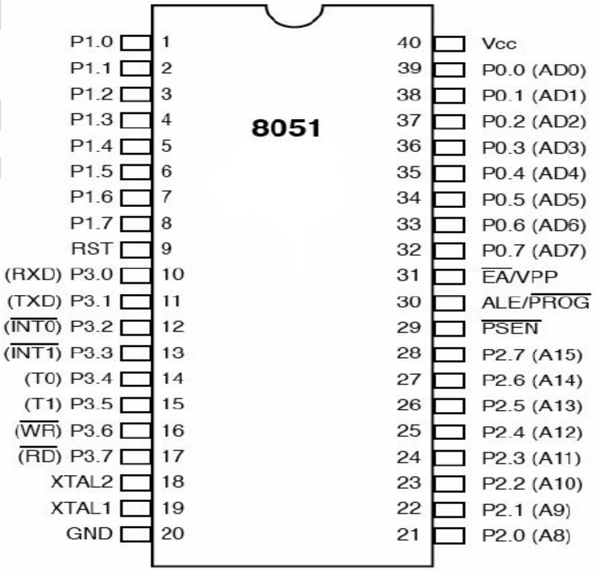
7	6	5	4	3	2	1	0
EA	—	ET2	ES	ET1	EX1	ET0	EX0

EX0 → $\overline{\text{INT0}}$ interrupt (External) enable bit
ET0 → Timer-0 interrupt enable bit
EX1 → $\overline{\text{INT1}}$ interrupt (External) enable bit
ET1 → Timer-1 interrupt enable bit
ES → Serial port interrupt enable bit
ET2 → Timer-2 interrupt enable bit
EA → Enable/Disable all
Setting '1' → Enable the corresponding interrupt
Setting '0' → Disable the corresponding interrupt

4.

Explain the functional pin diagram of 8051 microcontroller. (NOV/DEC'11) BTL2 **(13M)**
Answer: Page 5.13 - P.S.Manoharan

- Explain about the pin outs in detail and function of pins. (6 M)
- Diagram (7 M)



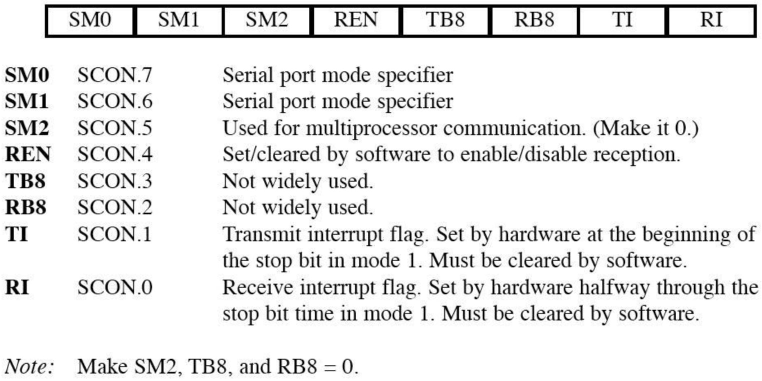
- Pin 40 provides supply voltage.
  - ✓ Pin 20 is the ground.
  - ✓ The 8051 has an on-chip oscillator - inputs XTAL1 (pin 19) and XTAL2 (pin 18).
  - ✓ Pin 9 is the RESET pin - active high (normally low).
  - ✓ EA which stands for "external access – pin 31
  - ✓ PSEN stands for "program store enable
  - ✓ ALE (address latch enable)

- ✓ The four ports PO, PI, P2, and P3 each use 8 pins

5. **Explain how serial communication is performed in 8051 microcontroller.**(**NOV/DEC'11**)BTL2 **(13M)**

Answer: Page 5.23 - P.S.Manoharan

- Explain about the serial communication (6 M)
- Explain about fully, half duplex (4 M)
- Diagram (3 M)



SM0	SM1	SM2	REN	TB8	RB8	TI	RI

SM0	SCON.7	Serial port mode specifier
SM1	SCON.6	Serial port mode specifier
SM2	SCON.5	Used for multiprocessor communication. (Make it 0.)
REN	SCON.4	Set/cleared by software to enable/disable reception.
TB8	SCON.3	Not widely used.
RB8	SCON.2	Not widely used.
TI	SCON.1	Transmit interrupt flag. Set by hardware at the beginning of the stop bit in mode 1. Must be cleared by software.
RI	SCON.0	Receive interrupt flag. Set by hardware halfway through the stop bit time in mode 1. Must be cleared by software.

Note: Make SM2, TB8, and RB8 = 0.

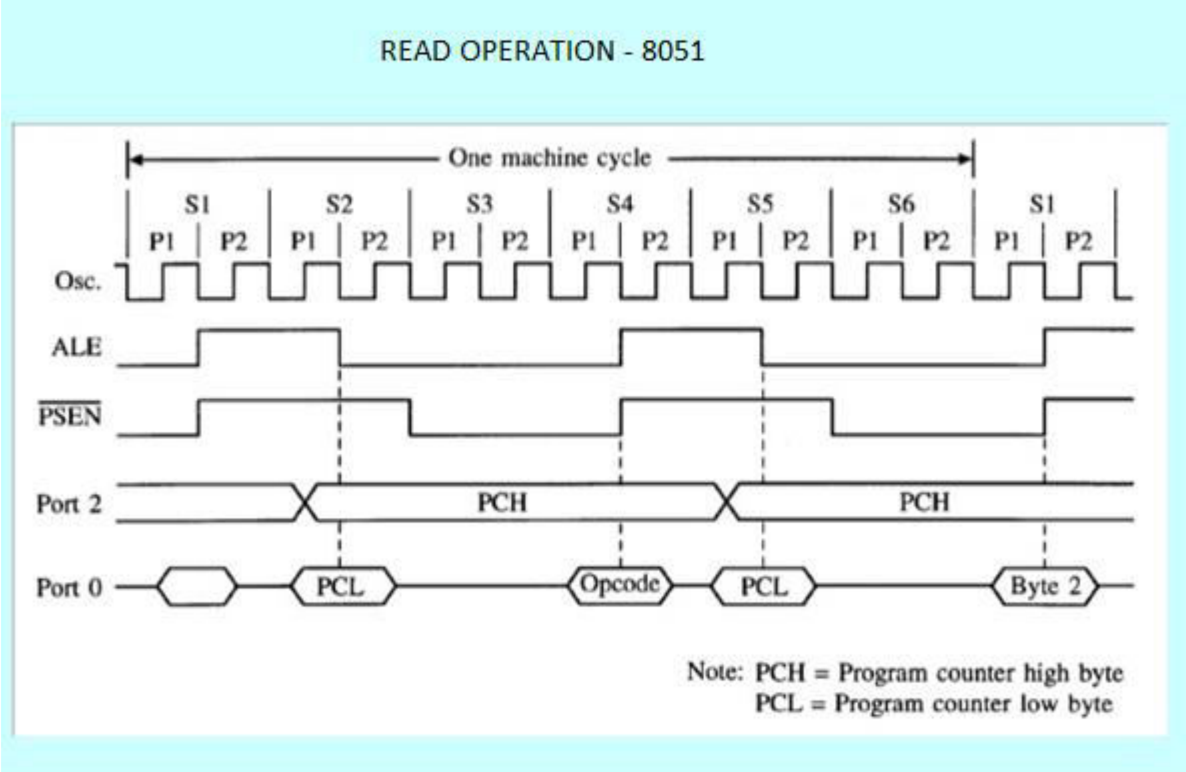
- ✓ SM0 and SM1 determine the mode
- ✓ only mode 1 – important
- ✓ For mode 1 SM0= 0, SM1=1
- ✓ compatible with the COM port of PCs
- ✓ each character a total of 10 bits are transferred - followed by 8 bits of data, and finally 1 stop bit
- ✓ REN (receive enable) - REN=1, allows 8051 to receive data on the RxD
- ✓ REN=0, the receiver is disabled
- ✓ TI (transmit interrupt) - transmits data serially via TxD
- ✓ RI (receive interrupt) - receives data serially via RxD

6. **Explain the different addressing modes of 8051 microcontroller.**BTL2 **(13M)**

Answer : Notes

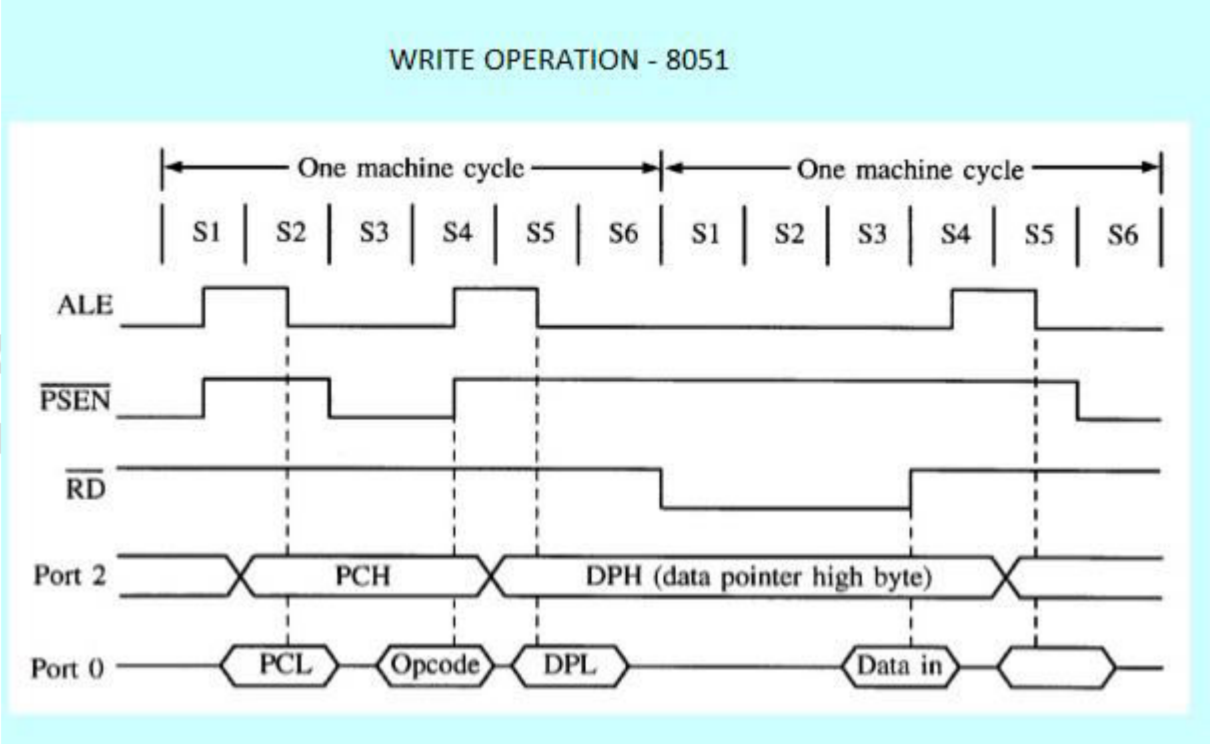
- Direct Addressing (3M)
  - ✓ Operand is specified by an 8-bit address field - the instruction
  - ✓ This address mode - possible only for addressing internal Data RAM and SFRs
- Indirect Addressing (2M)
  - ✓ The instruction specifies a register which contains the address of the operand
  - ✓ The address register for 8-bit addresses - R0 or R1 of the selected bank, or the Stack Pointer
  - ✓ The address register for 16-bit addresses can only be 16-bit "data pointer" register, DPTR
  - ✓ Both internal and external RAM can be indirectly addressed
- Register Instructions (2M)
  - ✓ Special instructions are used for accessing four register banks (containing R0 to R7)
  - ✓ This instructions have 3-bit register specification within the opcode
  - ✓ This way of accessing registers - much more efficient because of no need for the address byte
  - ✓ When such instruction - executed one of registers - selected ban - accessed

	✓ Register bank - selected by two bank select bits in PSW • Register-Specific Instructions (2M) ✓ instructions which - specific to a certain register ✓ don't need an address byte ✓ always operate with the same register • Immediate Constants (2M) ✓ The value of a constant follows the opcode ✓ MOV A, #10 – loads the Accumulator with the decimal number 10 • Indexed Addressing (2M) ✓ Only Program Memory can be accessed and it can be a read ✓ Used for reading look-up tables in Program Memory and "case jump" instruction.
7.	**Draw the timing diagram of 8051 and explain machine cycle with instruction cycle.** BTL2 **Answer: Notes 177 (13M)** • **Diagram** (5M) • **Microprocessor:** (2M) Programmable device : write ,read and fetch instruction • **Program:** Set of instruction in memory - a program **Instruction cycle**: (2M) ✓ Time taken to complete execution. ✓ It will fetch the instruction ✓ Decode the instruction ✓ Execute the instruction • **Machine cycle:** (2M) It consists of number of instruction cycle.12 oscillation period consists of 6 states, each state last for two clock periods ✓ Op code fetch machine cycle – 4T ✓ Memory read machine cycle-3T ✓ Memory write machine cycle-3T ✓ I/O read machine cycle-3T ✓ I/O write machine cycle-3T • **T-State:** (2M) One sub division of operation performed in one clock period 1 clock period = 1 T state



READ OPERATION - 8051

Note: PCH = Program counter high byte
PCL = Program counter low byte



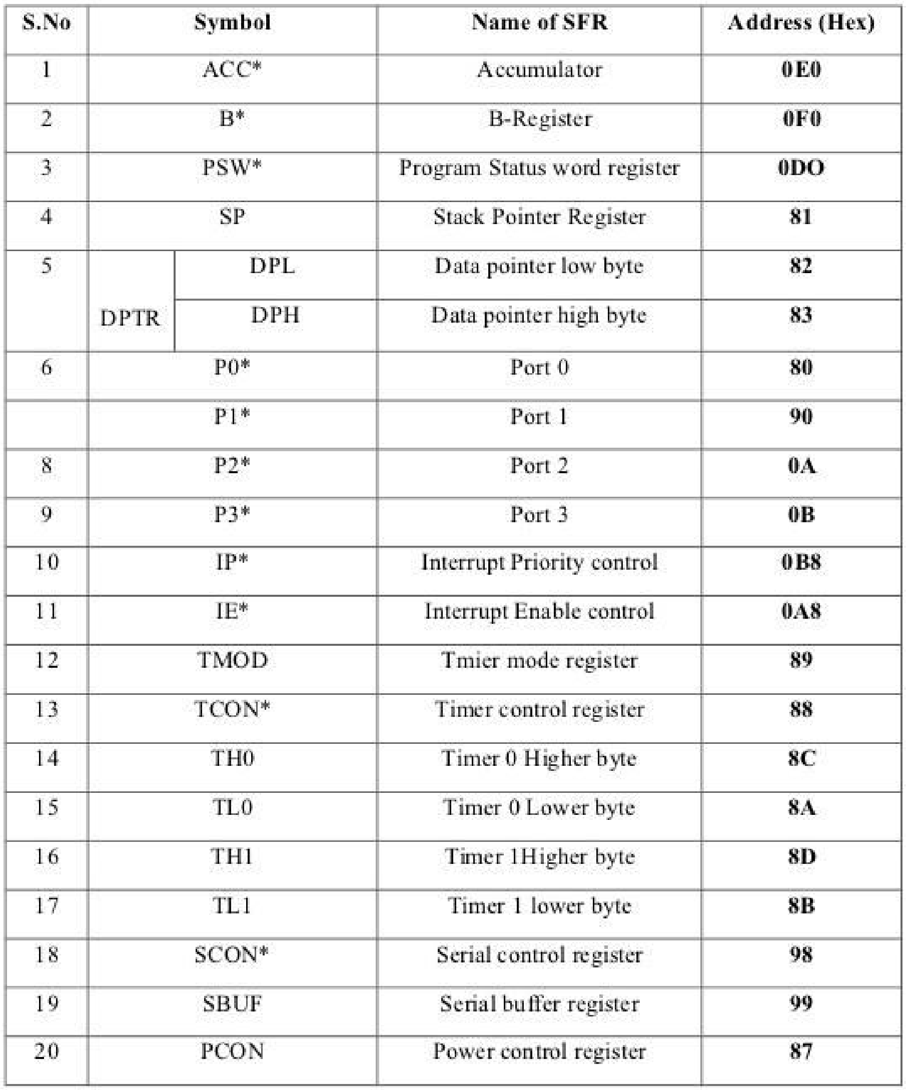
WRITE OPERATION - 8051

PART*C

Q.No.	Questions
1.	**Discuss the organization of internal RAM and special function registers of 8051 microcontroller in detail. (APRIL/MAY'11)**BTL2 **(15M)**

Answer: Page 5.16 - P.S.Manoharan

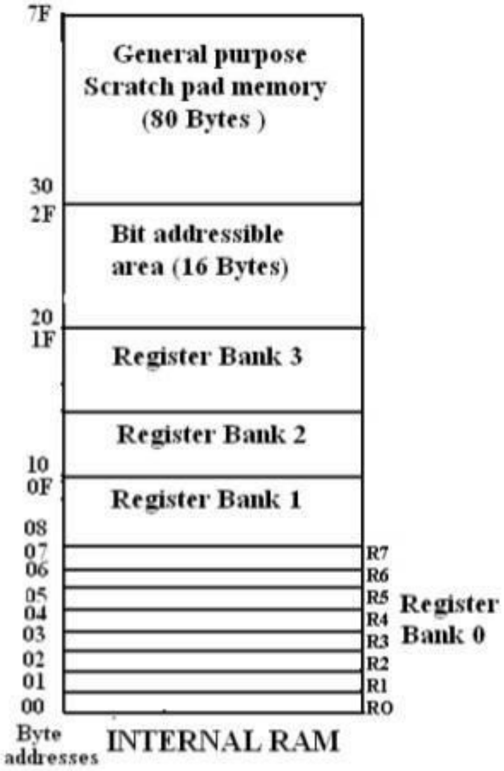
- Explain about Special function registers (15 m)



S.No	Symbol		Name of SFR	Address (Hex)
1	ACC*		Accumulator	**0E0**
2	B*		B-Register	**0F0**
3	PSW*		Program Status word register	**0DO**
4	SP		Stack Pointer Register	**81**
5	DPTR	DPL	Data pointer low byte	**82**
		DPH	Data pointer high byte	**83**
6	P0*		Port 0	**80**
	P1*		Port 1	**90**
8	P2*		Port 2	**0A**
9	P3*		Port 3	**0B**
10	IP*		Interrupt Priority control	**0B8**
11	IE*		Interrupt Enable control	**0A8**
12	TMOD		Tmier mode register	**89**
13	TCON*		Timer control register	**88**
14	TH0		Timer 0 Higher byte	**8C**
15	TL0		Timer 0 Lower byte	**8A**
16	TH1		Timer 1Higher byte	**8D**
17	TL1		Timer 1 lower byte	**8B**
18	SCON*		Serial control register	**98**
19	SBUF		Serial buffer register	**99**
20	PCON		Power control register	**87**

The * indicates the bit addressable SFRs

Table:SFRs of 8051 Microcontroller



- **SPECIAL FUNCTION REGISTERS (SFRs):**
  - ✓ some of them are related to I/O ports(P0,P1,P2 and P3)
  - ✓ some of them are meant for control operations (TCON, SCON,PCON)
  - ✓ remaining are the auxiliary SFRs

2. **Explain the program memory and memory structure of 8051.(Nov/Dec’11)** BTL2 **(15M)**

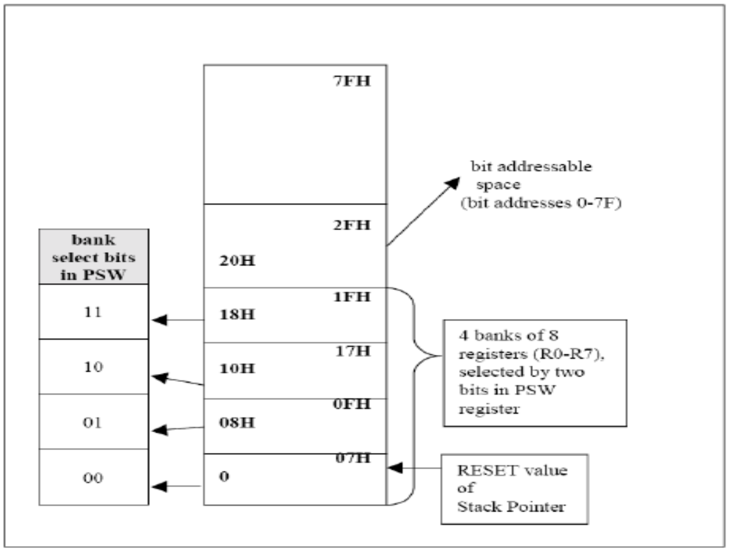
Answer: Page 5.9 - P.S.Manoharan

- Separate address spaces for Program (ROM) and Data (RAM) Memory (2 M)
- Allow Data Memory to be accessed by 8-bit addresses quickly and manipulated by 8-bit

CPU

- Program Memory (5 M)
- Data Memory (5 M)
- Diagram (3 M)

Internal Data Memory, 128 bytes



- **Program Memory**
  - ✓ Only be read, not written to
  - ✓ The address space is 16-bit, so maximum of 64K bytes Up to 4K bytes can be on-chip (internal) of 8051
  - ✓ core PSEN (Program Store Enable) - used for access to external Program Memory
- **Data Memory**
  - ✓ Includes 128 bytes of on-chip Data Memory which - more easily accessible directly by its instructions
  - ✓ No number of Special Function Registers (SFRs)
  - ✓ Internal Data Memory contains four banks of eight registers and a special 32-byte long segment which - bit addressable by 8051 bit-instructions
  - ✓ External memory of maximum 64K bytes - accessible by “movx”

3. **Explain how serial communication is performed in 8051 microcontroller. (Nov/Dec’11)** BTL2 **(15M)**

Answer: Page 5.23 - P.S.Manoharan

- Explanation (2 M)
  - ✓ The serial port of 8051 full duplex
  - ✓ it can transmit and receive simultaneously
  - ✓ The register SBUF is used to hold the data.
  - ✓ The special function register SBUF - physically two registers.
  - ✓ One - write-only and used to hold data to be transmitted out of the 8051 via TXD.
  - ✓ The other - read-only and holds the received data from external sources via RXD.
  - ✓ Both mutually exclusive registers have the same address 099H. (3 M)
- **Serial Port Control Register (SCON)** (5 M)
  - ✓ Register SCON controls serial data communication.
- **Address: 098H (Bit addressable)** (5 M)
  - ✓ SM2: multi processor communication bit

	✓ REN: Receive enable bit ✓ TB8: Transmitted bit 8 (Normally we have 0-7 bits transmitted/received) ✓ RB8: Received bit 8 ✓ TI: Transmit interrupt flag ✓ RI: Receive interrupt flag

UNIT 4 PERIPHERAL INTERFACING

Study on need, Architecture, configuration and interfacing, with ICs: 8255 , 8259 , 8254 , 8237 , 8251 , 8279 , A/D and D/A converters &Interfacing with 8085& 8051.

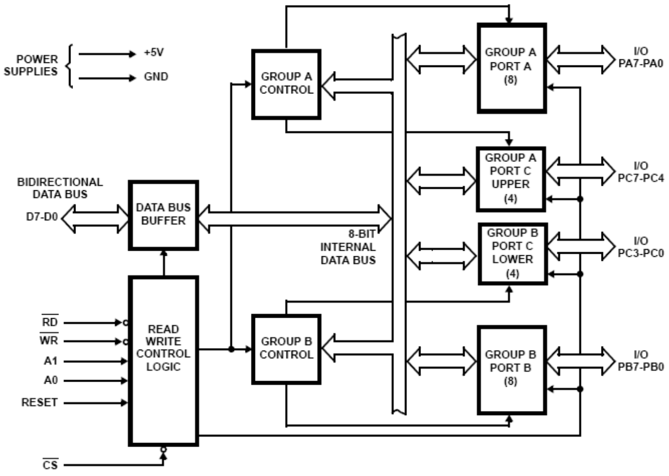
PART *A

Q.No.	Questions
1.	**What are the different ways to end the interrupt execution in 8259 PIC? (April/May'11)**BTL1 AEOI (Automatic End of Interrupt) mode the ISR bit is reset at the end of the second INTA pulse. Otherwise, the ISR bit remains set until the issue of an appropriate EOI command at the end of the interrupt subroutine.
2.	**What is the function of Scan section in 8279 programmable keyboard/Display controller? (April/May'11)**BTL1 Scan section which has two modes Encoded Mode and Decoded Mode Encoded Mode: In this mode, Scan counter provides a binary count from 0000 to 1111 the four scan lines (SC3 – SC0) with active high outputs. Decoded Mode: The internal decoder decodes the least significant 2 bits of binary count and provides four possible combinations on the scan lines (SC3- SC0) : 1110,1101,1011 and 0111.
3.	**State the use of ISR and PR registers in 8259 PIC. (Nov/Dec'11)**BTL1 ISR- Interrupt service Register Stores all the levels that are currently being serviced. PR– Priority Resolver determines the priorities of the bits set in the IRR (Interrupt Request register). The bit corresponding to the highest priority interrupt input is set in the ISR during the INTA input.
4.	**What are the salient features of INTEL 8259 Programmable interrupt controller? (May/June 14)** BTL1 • It manage eight Priority interrupt request. • The interrupt vector addresses are programmable. • The8259 are programmed to accept either the level triggered or edge triggered Interrupt request. • The interrupt can be masked or unmasked individually. • 5. 8259 helps to get the information of pending interrupts, in-service interrupts and masked interrupts
5.	**How data is transmitted in asynchronous serial communication?(May/June '14)** BTL4 Data is transmitted by setting transmission enable bit in the command instruction. When transmitter is enabled and CTS =0 the transmitter is ready to transfer data on Tx D line. The data bits is framed with one start bit and stop bits and then transmitted.

6.	**What are the applications of D/A converter interfacing with 8255? (May/June '12)** BTL1 Generating square, triangular and sine waveform, used in automatic process control.
7.	**What is keyboard interfacing?(May/June 12)** BTL1 Keyboard interfacing is interfacing an input device. Push button switches are used. in simple keyboard interface one input line is required to interface one key and this number will increase with number of keys. It is in the form of matrix with rows and columns and at the intersection a switch is present.
8.	**What are the different peripheral interfacing used with 8085 processor? (May/June 13)** BTL1 8255PPI, 8279 Keyboard and display controller, 8251 USART, 8259 PIC and 8254 - timer
9.	**What is the need for 8259 PIC?**BTL1 8259 PIC is necessary to solve multiple interrupt requests (more than five) we use an external device called a PIC. It is possible to increase the interrupt handling capacity of the microprocessor. When executing an interrupt an ISR can be serviced.
10.	**What are the basic modes of 8255? (Nov/Dec 2013)** BTL1 • BSR mode • I/O mode which is operated in mode 0, mode 1 and mode 2
11.	**What are the operating modes of IC 8253 / 8254 Timer?**BTL1 There are 6 operating modes in IC 8254 Timer they are Mode 0: Interrupt on Terminal Count Mode 1: Hardware – Triggered one shot Mode 2 – Rate Generator Mode 3 – Square wave generator Mode 4 – Software triggered strobe Mode 5 - Hardware triggered strobe
12.	**What is key de bouncing?**BTL1 The push button keys when pressed, bounces a few times, closing and opening the contact before providing a steady reading. The reading taken during the bouncing period may be wrong. Therefore, microprocessor must wait until the key reach to a steady state known as key de bounce.
13.	**What is the difference between A/D and D/A converters?**BTL1 Digital-to-analog is used to get a proportional analog voltage or current for the digital data given out by the microprocessor. An ADC converts the input analog voltage levels to the corresponding discrete digital signals.
14.	**Define the following terms for D/A converters.** BTL2 • Resolution: Resolution of a converter determines the degree of accuracy in conversion. It is equal to 1/2n. • Accuracy: Accuracy is the degree to which information on a map or in a digital database matches true or accepted values. Accuracy is an issue pertaining to the

	quality of data and thenumber of errors contained in a dataset or map. • Mono tonicity : If a clock has mono tonicity, then each successive time reading from that clock will yield a time further in the future than the previous reading. • Conversion time: The time required by an analog to digital converter to fully convert and analog input sample.
15.	**List the features of 8279.** BTL1 • It has built in hardware to provide key de bounce. • It provides two output modes for display interface : Left and Right entry • It provides three input modes for keyboard interface: Scanned keyboard Mode, Scanned sensor matrix mode and strobed input mode. • It provides multiplexed display interface with blanking and inhibit options.
16.	**How is DMA initiated?**BTL5 When the IO device needs a DMA transfer, it will send DMA request signal to the DMA controller. The DMA controller in turn sends a HOLD request to the processor. When the processor receives a HOLD request, it will drive its tri stated pins to high impedance state at the end for current instruction execution and send an acknowledge signal to the DMA controller. Now the DMA controller will perform DMA transfer.
17.	**What are the different types of DMA?**BTL1 Cycle stealing (or Single transfer) DMA, Block transfer (or Burst Mode) DMA and Demand transfer DMA.
18.	**What is Cycle stealing DMA?**BTL1 In Cycle stealing DMA, the DMA controller will perform one DMA transfer in between instruction cycles (i.e. in this mode, the execution of one processor instruction and one DMA data transfer will take place alternatively).
19.	**What is the function of the GATE signal in timer 8254?**BTL1 In timer 8254, the GATE signal acts as a control signal to start, stop or maintain the counting process. In modes 0, 2, 3, and 4 the GATE signal should remain high to start and maintain the counting process. In modes 1 and 5, GATE signal has to make low to high transitions to start the counting process and need not remain high to maintain the counting process.
20.	**What is meant by Baud rate? What is meant by doubling the baud rate in the 8051?**BTL1 The rate at which the serial data is being transferred is called Baud rate. We can double the baud rate in 8051 using two ways: • By doubling the crystal frequency. • By making SMOD bit in the PCON register from 0 to 1.
PART * B	
Q.No.	**Questions**
1.	**Draw and explain the functional block diagram of 8255 PPI**. **(13M) (May/June 2013) (April/May'11)** BTL6 **Answer:Page :4.18 - P.S.Manoharan** • Explain about block diagram (6 M)

- Diagram (7 M)

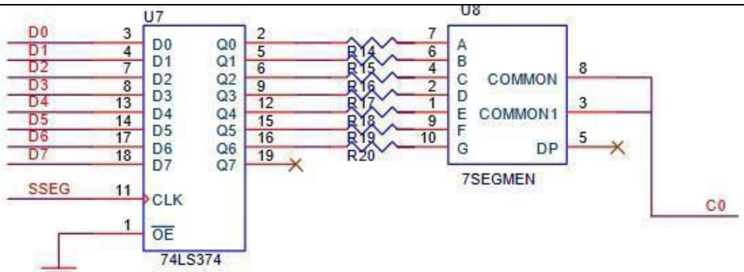


- **Data Bus buffer:**
  - ✓ It is a 8-bit bidirectional Data bus.
  - ✓ Used to interface between 8255 data bus with system bus.
  - ✓ The internal data bus and Outer pins D0-D7 pins are connected in internally.
  - ✓ The direction of data buffer is decided by Read/Control Logic.
- **Read/Write Control Logic:**
  - ✓ Getting the input signals from control bus and Address bus
  - ✓ Control signal are RD and WR.
  - ✓ Address signals are A0, A1, and CS.
  - ✓ 8255 operation - enabled or disabled by CS. Group A and Group B control:
  - ✓ Group A and B get the Control
  - ✓ Signal from CPU and send the command to the individual control blocks.
  - ✓ Group A send the control signal to port A and Port C (Upper) PC7-PC4.
  - ✓ Group B send the control signal to port B and Port C (Lower) PC3-PC0.
- **PORT A:-**
  - ✓ This is a 8-bit buffered I/O latch.
  - ✓ It can be programmed by mode 0, mode 1, and mode 2.
- **PORT B:-**
  - ✓ 8-bit buffer I/O latch.
  - ✓ It can be programmed by mode 0 and mode 1.
- **PORT C:-**
  - ✓ This is a 8-bit Unlatched buffer Input and an Output latch.
  - ✓ Split into two parts.
  - ✓ It can be programmed by bit set/reset operation.

2. **Design an interface circuit needed to connect DIP switch as an input device and display the value of the key pressed using 7 segment LED display. Using 8085 system, write a program to implement the same.(13M)**BTL6

Answer: Page :4.29 -P.S.Manoharan

- Program (5 M)
- Explanation (4 M)
- Diagram (4 M)



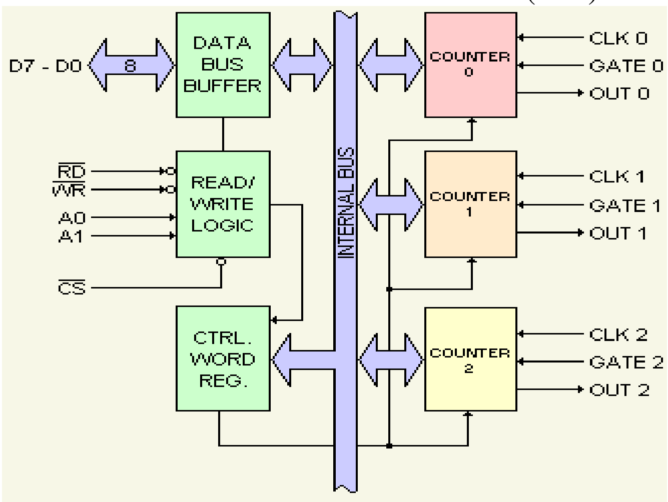
```
START: MVI A, 10H
OUT 01H
MVI A, DCH
OUT 01H
MVI 90H
OUT 01H
L2 MVI B, 08H
LXI H, 4200H
L1 MOV A, M
OUT OOH
CALL DELAY
INX H
DCR B
JNZ L1
JMP L2
DELAY LXI D, FFFFH
L3 DCX D
MOV A, D
ORA E
JNZ L3
RET
```

3.

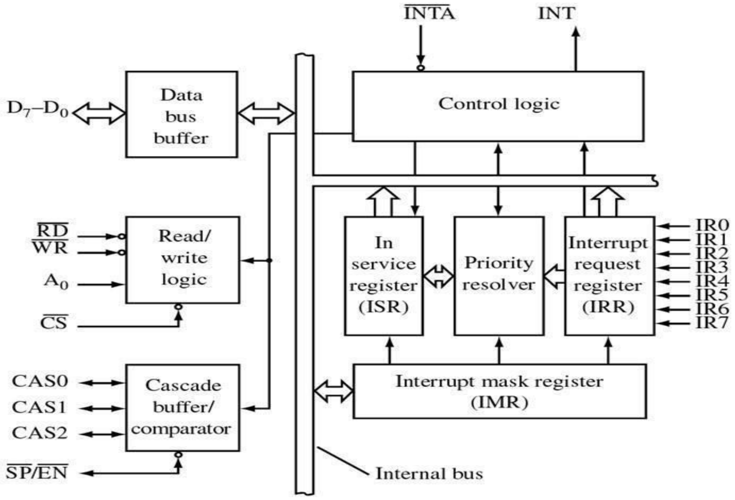
Explain the block diagram and modes of 8254/53 timer.(Nov/Dec'11)(13M)BTL2

Answer: Page :1.19 -P.S.Manoharan

- Explain about block diagram (6 M)
- Diagram (7 M)



	- **Data bus buffer** ✓ 3-state bi-directional ✓ 8-bit buffer - used to interface the 8254 to the system bus. - **Read/write logic** ✓ Read/Write Logic accepts inputs from the system bus and generates control signals for the other functional blocks of the 8254. ✓ A1and A0 select one of the three counters or the Control Word Register to be read from/written into. ✓ A ``low" on the RD input tells the 8254 that the CPU -reading one of the counters. ✓ Both RD and WR are qualified by CS, RD and WR- ignored unless the 8254 has been selected by holding CS low. - **Control word register** ✓ The Control Word Register - selected by the Read/Write Logic when A1, A0=11. ✓ If the CPU then does a write operation to the 8254, the data - stored in the Control Word Register and interpreted as a Control Word used to define the operation of the Counters. ✓ Control Word Register can only be written to; status information - available with the Read-Back Command. - **COUNTER 0, COUNTER 1, COUNTER 2** ✓ three functional blocks are identical in operation. ✓ The Counters - fully independent. ✓ Each Counter may operate in a different Mode. MODE 0: INTERRUPT ON TERMINAL COUNT MODE 1: HARDWARE RETRIGGERABLE MODE 2: RATE GENERATOR MODE 3: SQUARE WAVE MODE MODE 5: HARDWARE TRIGGERED STROBE (RETRIGGERABLE)
4.	**Write a neat functional block diagram, explain the functions of 8259 PIC. (13M)(May/June 2013)**BTL2 **Answer: Page :4.38 -P.S.Manoharan** - Explain about block diagram (6 M) - Diagram (7 M)



- **DATA BUS BUFFER**
  - ✓ It is an eight pin bidirectional data bus.
  - ✓ Control, Status and Interrupt vector information are transformed through this bus.
  - ✓ It allows 8259 to send interrupt code and address of interrupt service subroutine to the processor.
- **READ/WRITE LOGIC**
  - ✓ The function of this block is to accept Output commands from the CPU.
  - ✓ It contains the Initialization Command Word (ICW) registers
  - ✓ Operation Command Word (OCW) registers which store the various control formats for device operation.
  - ✓ This function block also allows the status of the 8259A to be transferred onto the Data Bus.
- **CONTROL LOGIC**
  - ✓ It has two pins**: INT as an output** which goes high if valid interrupt is asserted**.**
  - ✓ **INTA** an acknowledgement from processor to 8259.
- **CS (CHIP SELECT)**
  - ✓ A LOW on this input enables the 8259A. No reading or writing of the chip will occur unless the device is selected.
- **WR (WRITE)-** A LOW on this input enables the CPU to write control words (ICWs and OCWs) to the 8259A.
- **RD (READ)**
  - ✓ A LOW on this input enables the 8259A to send the status of the Interrupt Request Register (IRR)
  - ✓ In Service Register (ISR)
  - ✓ the Interrupt Mask Register (IMR)
  - ✓ Interrupt level onto the Data Bus.
- **A0**
  - ✓ used in conjunction with WR and RD signals to write commands into the various command registersas well as reading the various status registers of the chip.

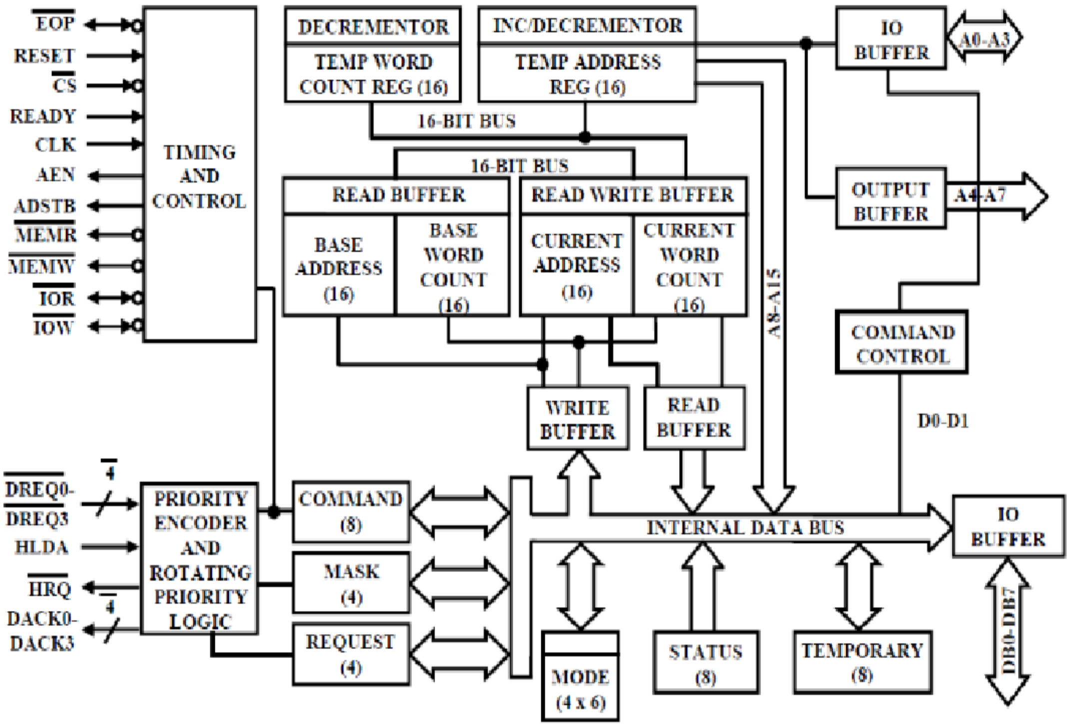
- ✓ This line can be tied directly to one of the address lines
- **INTERRUPT REQUEST REGISTER (IRR)**
  - ✓ It has 8 input lines **(IR0 – IR7)** for interrupts**.**
  - ✓ When these lines go high, the requestare stored in the register.
  - ✓ It registers a request only if the interrupt is unmasked**.**
- **IN SERVICE REGISTER (ISR)**
  - ✓ ISR keeps track of which interrupts are currently being serviced
  - ✓ the corresponding bit will be set in this register.
- **PRIORITY RESOLVER**
  - ✓ This logic block determines the priorities of the bits set in the IRR.
  - ✓ The highest priority - selected and stored into the corresponding bit of the ISR during INTA pulse.
- **INTERRUPT MASK REGISTER (IMR)**
  - ✓ The IMR stores the bits which mask the interrupt lines to be masked.
  - ✓ The IMR operates on the IRR.
  - ✓ Masking of a higher priority input will not affect the interrupt request lines of lower quality

5.

Draw the block diagram of DMA controller and explain each block. (13M) (April/May'11) (May/June 12)(May/June2013)BTL6

Answer: Page :4.51- P.S.Manoharan

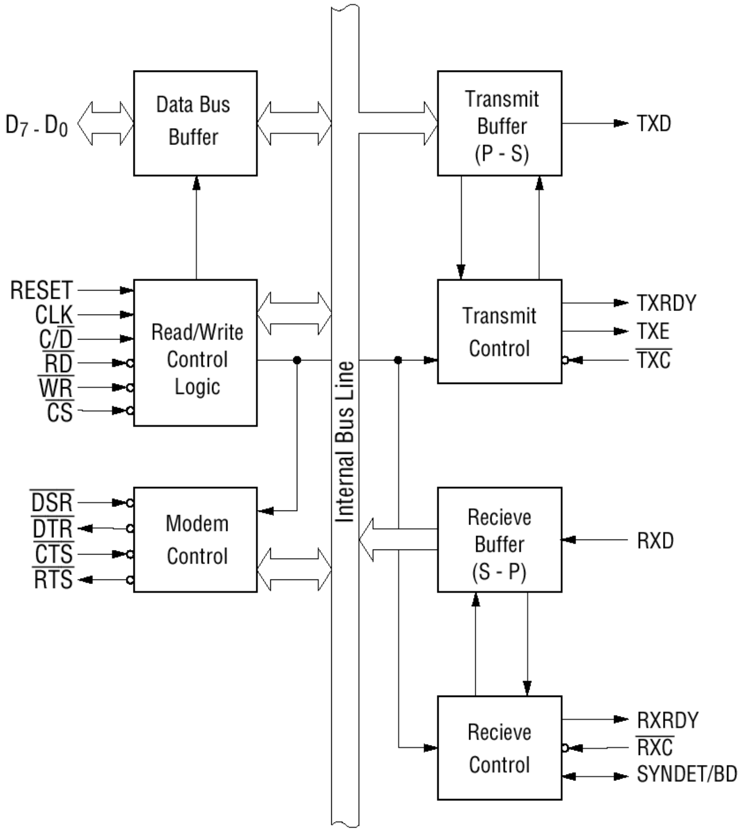
- Explain about the block diagram (6 M)
- Diagram (7 M)
- Explanation

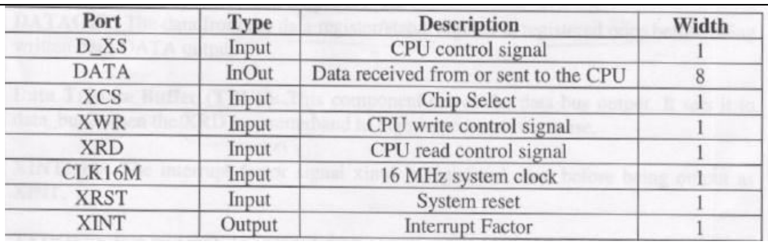


- ✓ peripheral to a CPU that is programmed to perform a sequence of data transfers on behalf of the CPU.

- ✓ DMA controller can directly access memory
- ✓ used to transfer data from one memory location to another- from an I/O device to memory and vice versa.
- ✓ DMA controller manages several DMA channels
- ✓ each of which can be programmed to perform a sequence of these DMA transfers.
- ✓ data that must be read (or devices that must output data and be written to) signal the DMA controller to perform
- ✓ a DMA transfer by asserting a hardware DMA request (DRQ) signal.
- ✓ A DMA request signal for each channel l - routed to the DMA controller.
- ✓ This signal - monitored and responded to in much the same way that a processor handles interrupts.
- ✓ When the DMA controller sees a DMA request, it responds by performing one or many data transfers from that I/O device into system memory - vice versa.

PART * C

Q.No.	**Questions**
1.	**With functional diagram, explain the operation and programming of 8251 USART in detail.(15M)**BTL2 **Answer: Page Notes 115** • Block diagram(6M) • Program (5 M) • Explanation(4M) 



Port	Type	Description	Width
D_XS	Input	CPU control signal	1
DATA	InOut	Data received from or sent to the CPU	8
XCS	Input	Chip Select	1
XWR	Input	CPU write control signal	1
XRD	Input	CPU read control signal	1
CLK16M	Input	16 MHz system clock	1
XRST	Input	System reset	1
XINT	Output	Interrupt Factor	1

PROGRAM :

TRANSMITTER

```
MOV SI, 1500
MOV AL, 36H
OUT 16H, AL
MOV AL, 40H
OUT 10H, AL
MOV AL, 01H
OUT 10H, AL
RELOAD: MOV CL, 05H
CHECK: IN AL, OAH
AND AL, 04H
JZ CHECK
MOV AL, [SI]
OUT 08H, AL
INC SI
CMP AL, 3FH
JNZ RELOAD
DEC CL
JNZ CHECK
INT 02
```

RECEIVER:

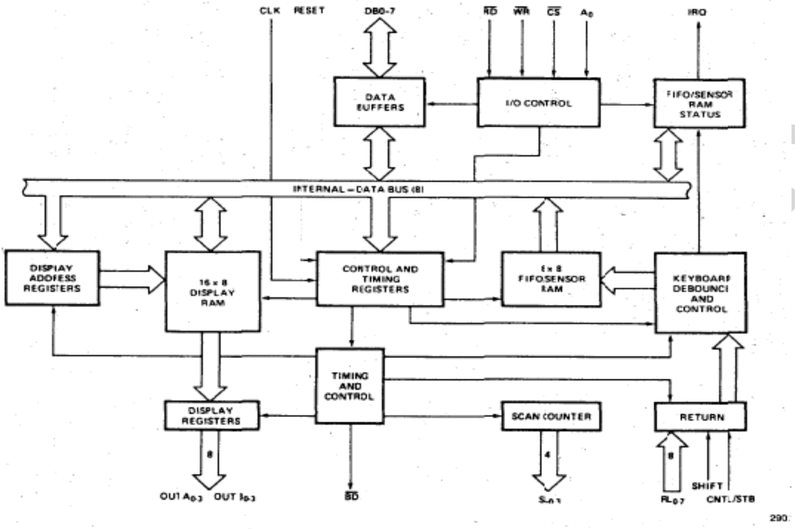
```
MOV SI, 1500
MOV AL, 36H
OUT 16H, AL
MOV AL, 40H
OUT 10H, AL
MOV AL, 01H
OUT 10H, AL
RELOAD: MOV CL, 05H
CHECK: IN AL, OAH
AND AL, 02H
JZ CHECK
IN AL, 08H
MOV [SI], AL
INC SI
CMP AL, 3FH
JNZ RELOAD
DEC CL
JNZ CHECK
INT 02
```

2.

Explain the block diagram, architecture and registers of the 8279 keyboard/display controller. (15M)(Nov/Dec'11) (May/June 13)BTL2

Answer: Page :4.29 - P.S.Manoharan

- Explain about block diagram (7 M)
- Diagram (8 M)



- **It consists 4 main section.**
  - ✓ CPU interface and control section.
  - ✓ Scan section
  - ✓ Keyboard Section
  - ✓ Display section.
- **CPU INTERFACE AND CONTROL SECTION:**
  - ✓ Data buffers
  - ✓ I/O control
  - ✓ Control and timing registers.
  - ✓ Timing and control logic.
- **Data Buffers**:
  - ✓ 8-bit bidirectional buffer.
  - ✓ Used to connect the internal data bus and external data bus.
- **I/O control:**
  - ✓ I/O control section uses the A0, CS, RD and WR signals to controls the data flow.
  - ✓ The data flow - enabled by CS=0otherwise it -the high impedance state.
  - ✓ A0=0 means the data - transferred.
  - ✓ A0=1 means status or command word - transferred.
- **Timing and control registers:**
  - ✓ Store the keyboard and display modes and others operating condition programmed by the CPU.
  - ✓ The modes are programmed by sending proper command A0=1.
- **Timing and control:**
  - ✓ It consist timing counter chain.
  - ✓ First counter is divided by N pre scalar that can be programmed to give an

internal frequency of 100 KHz.

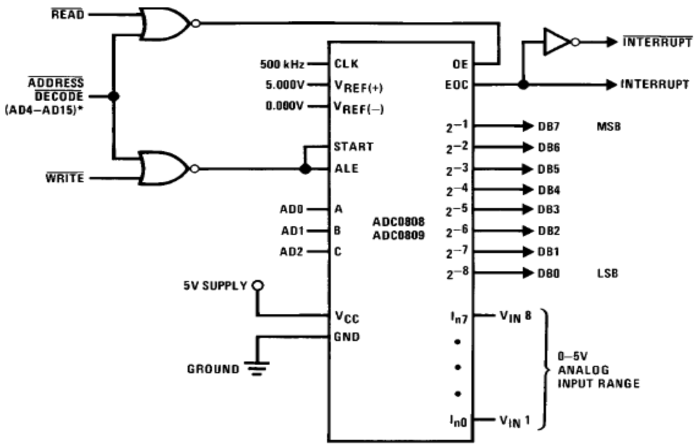
- **SCAN SECTION**
  - ✓ Encoded mode
  - ✓ Decoded mode.
- **ENCODED MODE:**
  - ✓ It provide binary count from 0000 to 1111 by four scan lines (SC3-SC0) by activehigh inputs.
  - ✓ It is externally decoded to provide 16 scan lines
  - ✓ Display use all 16 lines to interface 16 digit 7 segment display.
  - ✓ But keyboard use only 8 scan lines out of 16 lines.
- **DECODED MODE:**
  - ✓ In this mode, the internal decoder decodes the least 2 significant bits.
  - ✓ It is provide four possible combination from (SC0-SC3) such as 1110, 1101, 1011 and 0111.
  - ✓ This four active low outputs line is used to directly to interface 4 –digit 7-segment display ,8*4 matrix keyboard
- **KEYBOARD SECTION**
  - ✓ Return buffers.
  - ✓ Keyboard denounce control.
  - ✓ FIFO / sensor RAM.
  - ✓ FIFO / sensor RAM status.

3.

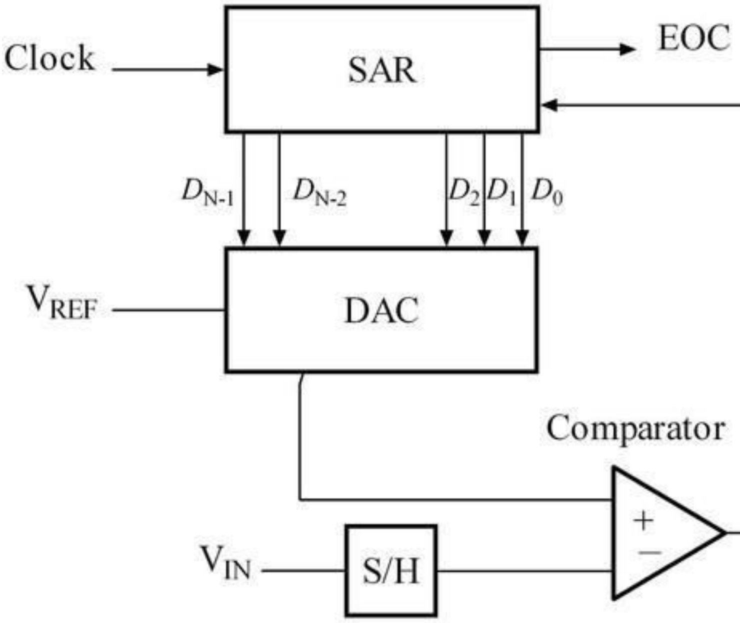
Explain with a neat sketch the ADC interfacing with 8085 microprocessor.(15M) (April/May’11)BTL2

Answer: Page :5.40 - P.S.Manoharan

- Explain the working of block diagram (8 M)
- Diagram (7 M)



- Explanation:
  - ✓ The successive approximation circuit typically consists of four block:
  - ✓ sample and hold circuit to acquire the input voltage (VIN).
  - ✓ An analog voltage comparator that compares Vin to the output of the internal DAC
  - ✓ outputs the result of the comparison to the successive approximation register (SAR).
  - ✓ A successive approximation register block designed to supply an approximate digital code of Vin to the internal DAC.
  - ✓ An internal reference DAC that supplies the comparator with an analog voltage

	equivalent of the digital code output of the SAR for comparison with Vin. 

UNIT 5MICRO CONTROLLER PROGRAMMING & APPLICATIONS	
Data Transfer, Manipulation, Control Algorithms& I/O instructions – Simple programming exercises key board and display interface – Closed loop control of servo motor- stepper motor control -Washing Machine Control.	
PART *A	
Q.No.	**Questions**
1.	**What are the applications of 8051 Microcontroller ? (May/June 2012)**BTL1 • Washing Machine control • Traffic Light control • Servo Motor control • Stepper motor control • DC motor control.
2.	**Give the PSW setting for masking register bank 2 as default register bank in 8051 Microcontroller.((Nov/Dec 2016)** BTL1 Selecting one of the 4 banks is done by setting or clearing the 2 bank select bits RB0 and RB1 in the PSW register. Registers are called R0 to R7 by default BTL1
3.	**Mention the interrupts of 8051 microcontroller. (Nov/Dec 2013)** BTL1 INT0, TF0, INT1, TF1, R1 & T1
4.	**Give an example for DA instruction of 8051 microcontroller. (Nov/Dec 2012)** BTL1 ADD A, #1 DAA (Adding a data with accumulator data)
5.	**State the functions performed by JBC and CJNE instructions in 8051 microcontroller.(May/June 2014)** BTL1 **JBC:** SYNTAX: JBC bit addr, reladdr Jump if Bit Set and Clear Bit. JBC will branch to the address indicated by reladdr if the bit indicated by bit addr is set. Before branching to reladdr the instruction will clear the indicated

	bit. If the bit is not set program execution continues with the instruction following the JBC instruction. **CJNE:** SYNTAX: CJNE operand1, operand2, reladdr. Compare and Jump If Not Equal. CJNE compares the value of operand1 and operand2 and branches to the indicated relative address if operand1 and operand2 are not equal. If the two operands are equal program flow continues with the instruction following the CJNE instruction.
6.	**What is Program Status Word? (May/June 2014) (Nov/Dec 2015,2016)** BTL5 The current state of the processor is stored in a register called Processor Status Word (PSW).The PSW contains bits which indicate such things as whether the previous arithmetic operations produced a positive, negative or zero result.
7.	**What are the operations of washing machine?** BTL1 Fill, Agitate, Soak, Drain, and Spin.
8.	**What are the control signals from 8051 microcontroller required for washing machine control? (May/June 2015)** BTL1 Fill, Agitate, Drain and spin operation signals are the control given through microcontroller.

9.	**How pulse is generated using 8051 microcontroller. (May/June 2015)** BTL1
	MOV TMOD, #01 ; Timer 0, mode 1(16-bit)
	HERE: MOV TL0, #0F2H ; Timer value = FFF2H
	MOV TH0, #0FFH
	CPL P1.5
	ACALL DELAY
	SJMP HERE

10.	**List the difference between MOV and MOVX instructions. (Nov/Dec 2015)** BTL1 MOV copies the value of operand 2 into operand 1. The value of operand 2 is not affected. Both operand 1 and operand 2 must be in internal RAM. Eg: MOV A, R0 MOVX moves a byte to or from external memory into or from the accumulator. Eg: MOVX @R0, A
11.	**Mention any four data transfer instructions of 8051 microcontroller. (Nov/Dec 2016)** BTL1 MOVX,MOV,MOV DPTR,MOVX A.
12.	**Explain DAA instruction of 8051.** BTL2 Decimal adjust accumulator for addition bytes.
13.	**Name different types of jump instructions.** BTL1 There are three forms of jump. They are LJMP (Long jump)-address 16; AJMP (Absolute Jump)- address 11; SJMP (Short Jump)-relative address.
14.	**Explain the addressing modes of 8051.** BTL2 • Register addressing • Direct byte addressing • Register indirect addressing • Immediate addressing • Register specific addressing • Index addressing • Bit addressing
15.	**Explain PUSH and POP instructions in 8051.** BTL2 PUSH-The stack pointer is incremented by one. The contents of the indicated variable are then copied into the internal RAM location addressed by the stack pointer. POP - Reverse of PUSH

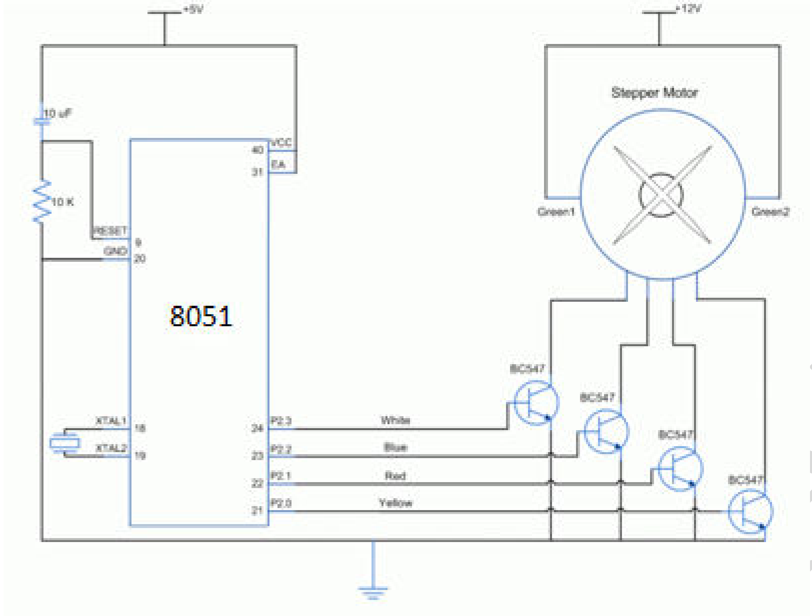
	operation.

16.	**Give the PSW setting for making register bank 2 as default register bank in 8051 microcontroller.** BTL1
	MOV PSW, #10 ; SELECT BANK 2
	MOV A, R0 ; (A) ‹— (R0) FROM BANK 2
	MOV PSW, #00 ; SELECT BANK 0
	CLR C ; CLEAR CARRY
	SUBB A, R1 ; A ‹— A- (R1) FROM BANK 0
	The above program is to subtract the contents of R1 of BANK0 from the contents of RO Of Bank 2.

17.	**What are the use of PWM in motor control using microcontroller?** BTL1 The speed of the dc motor depends on the applied voltage. The average applied dc voltage and power can be varied using a technique called pulse width modulation. In this technique the dc power supply is not a voltage of fixed amplitude ie it is a pulsating DC voltage. By changing the pulse width we can change the applied power.
18.	**What is the output of the program?** BTL1 MOV R0, A XRL A, # 3F H XRL A, R0 The contents of A register will be 3F H and the contents of R0 will be the initial contents of A
19.	**Write a program to find the 2's complement using 8051.** BTL6 MOV A, R0 CPL A INC A

20.	**Write the instuction to load accumulator, DPH, &DPL using 8051.**BTL6
	MOV A,#30
	MOV DPH, A
	MOV DPL, A

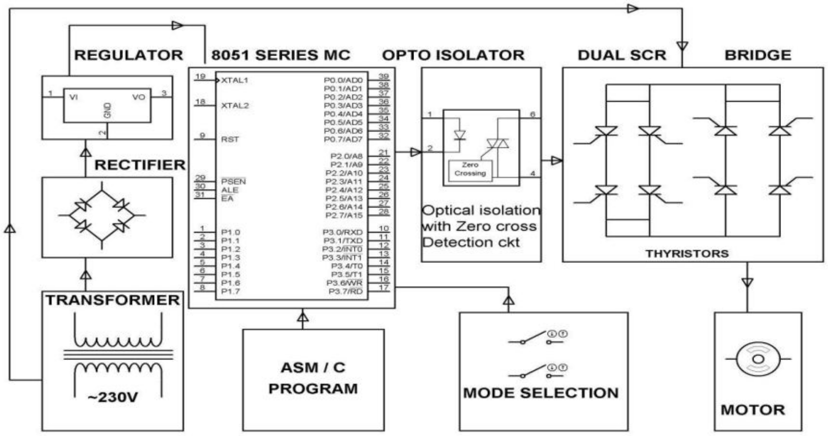
	PART * B
Q.No.	**Questions**
1.	**Draw the schematic for interfacing a stepper motor with 8051 microcontroller and write 8051 ALP for changing speed and direction of motor. (13M) (May/June 12)** BTL6 **Answer :Page : 4.57 - P.S.Manoharan** • Example Program (6 M) • Explanation and diagram(7 M) **Full Step Drive:** ✓ In this method two coils are energized at a time. ✓ here two opposite coils are excited at a time. **Half Step Drive:** ✓ In this method coils are energized alternatively. ✓ it rotates with half step angle ✓ In this method, two coils can be energized at a time or single coil can be energized.



PROGRAM TO RUN THE STEPPER MOTOR:

```
ORG 0H
MOV A,#66H
MOV R1,#48
MAIN:
H1: ACALL
ROTATE_R DJNZ R1,H1
AJMP M
ROTATE_R: MOV P1,A RR A
ACALL DELAY RET
DELAY: MOV R2,#10
 H2: MOV R3,#200
H3: MOV R4,#250
 H4: DJNZ R4,H4
DJNZ R3,H3
DJNZ R2,H2
 RET
M: SJMP
$ END
```

2.	**Explain the working of a washing machine and how it is controlled by the 8051microcontroller. (13M) (NOV/DEC'11) (MAY/JUNE 12)** BTL2 **Answer :Refer : NOTES** • Block diagram (7 M) • Explanation (6 M)

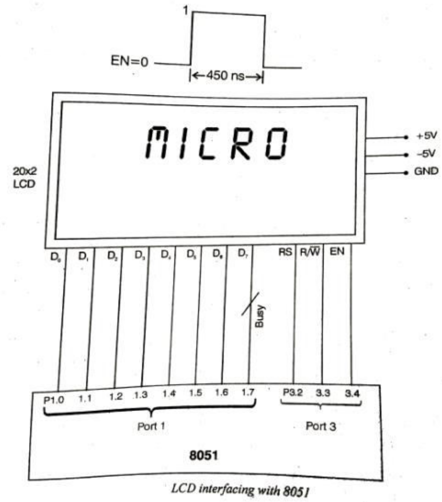


- **Fill**
  - ✓ Fill the water in three level- high , medium and low
  - ✓ Select nob – used to select mode
- **Agitate**
  - ✓ Operation – heavy, normal and low
  - ✓ Select nob – used to select mode
- **Drain**
  - ✓ Water removal – with dirt
- **Spin**
  - ✓ Removing water droplets and lower the humidity
- During normal mode, the machine operates on the following steps:
  - ✓ The clothes are washed for a specified time which is set by the controller
  - ✓ The detergent water is drained
  - ✓ The fresh water is put through pump
  - ✓ The clothes are rinsed for a specified time which is set by the controller.
  - ✓ The water is drained and the moisture is absorbed from clothes.

3. **Write short notes on LCD interface . (13M) (May-2009)** BTL1

Answer: Page :5.37 - P.S.Manoharan

- Explain about block diagram (7 M)
- Diagram (6 M)



LCD interfacing with 8051

LCD COMMAND CODE

CODE (HEX)	COMMAMD
01	Clear display screen
02	Return hoe
04	Decrement cursor(shift cursor to left)
05	Shift display right
06	Increment cursor(shift cursor right)
07	Shift display left
08	Display off cursor off
0A	Display off cursor on
0C	Display on cursor off
0E	Display on cursor on
0F	Display on cursor blinking
10	Shift cursor position to left
14	Shift cursor position to right
18	Shift the entire display to left
1C	Shift the entire display to right
80	Force cursor t beginning of 1st row
C0	Force cursor to beginning of 2nd row
38	2 lines and 5*7 matrix

PART * C

Q.No.	Questions
1.	**Write an assembly language program based on 8051 microcontroller instruction set to perform four arithmetic operations on 2, 8 bit data (15M) (April/May’11)** BTL6

Answer: Refer Notes 158

8 BIT ADDITION (IMMEDIATE ADDRESSING) (3M)

```
CLR C //Clear the PSW
MOV A, # data1 //Load 1st number in the        accumulator
ADDC A, # data2 //Add the two numbers
MOV DPTR, #4500 //Load destination address in
the DPTR
MOVX @ DPTR, A //Store sum in destination address
L1: SJMP L1 //Terminate the program
```

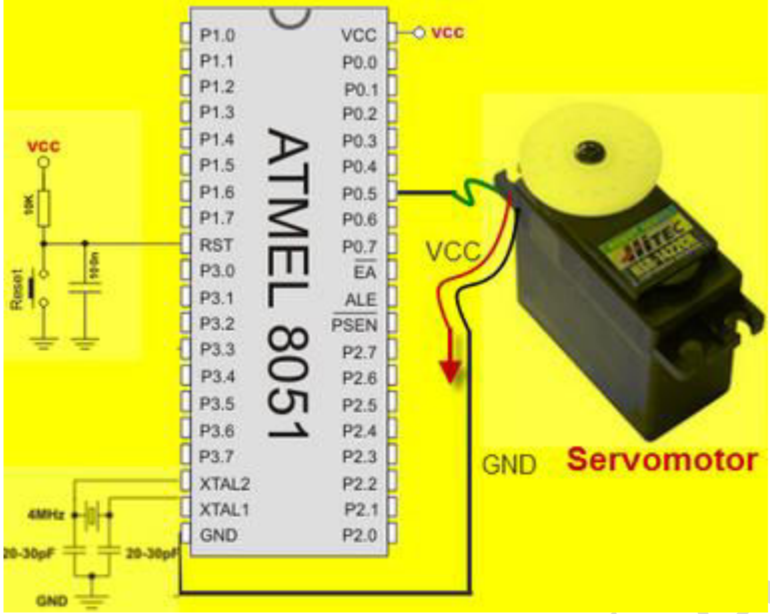
(2)8 BIT SUBTRACTION (IMMEDIATE ADDRESSING) (4M)

```
CLR C //Clear the PSW
MOV A, # data1 //Load 1st number in accumulator
SUBB A, # data2 // Subtract data1 from data2
MOV DPTR, #4500 // Load destination address in DPTR
MOVX @ DPTR, A //Store difference
L1: SJMP L1 //Terminate the program
```

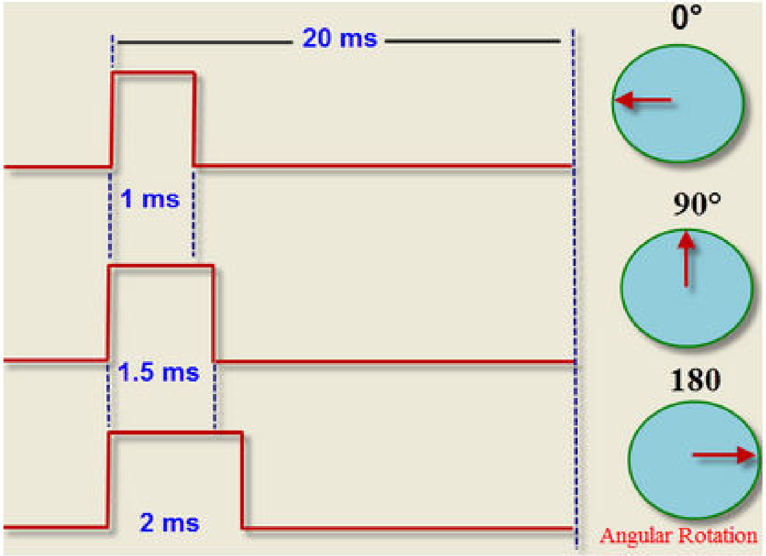
(3) 8 BIT MULTIPLICATION (4M)

```
MOV A, #data1 //Load A register with data1
MOV B, #data2 //Load B register with data2
```

	MUL AB //Multiply A &B MOV DPTR, # 4500H //Initialize destination address MOVX @ DPTR, A //Store lower order product INC DPTR //Increment DPTR MOV A,B //Move higher order product to A MOVX @ DPTR, A //Store higher order product STOP: SJMP STOP //Terminate the program **(4) 8 BIT DIVISION (4 M)** MOV A, #data1 //Load A register with data1 MOV B, #data2 //Load B register with data2 DIV AB //Divide A &B MOV DPTR, # 4500H //Initialize destination address MOVX @ DPTR, A //Store quotient INC DPTR //Increment the data pointer MOV A,B //Move remainder to reg A MOV @ DPTR, A //Store remainder STOP: SJMP STOP //Terminate the program
2.	**Explain the servomotor control using 8051 microcontroller ? (15) (APRIL/MAY'11)**BTL1 **Answer Refer :Notes 160** • Diagram(8M) • Explanation (7M) ✓ Servo motor – interfaced with 8051 microcontroller ✓ Microcontroller – specific function ✓ Speed control – enabled ✓ For specific rotation for application ✓ Supply and ground- connected with 8051 ✓ Controller – mechanical device and mechanical load



- ✓ Servo motors are self-contained mechanical devices
- ✓ That are used to control the machines with great precision.
- ✓ Found in many applications from toys to industrial automation.
- ✓ Servo motors - especially designed for specific angular position to control the machines.
- ✓ Usually the servo motor is used to control the angular motion among from 0° to 180° and 0° to 90°.

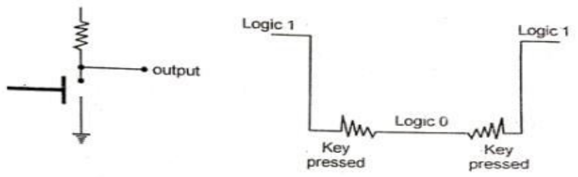


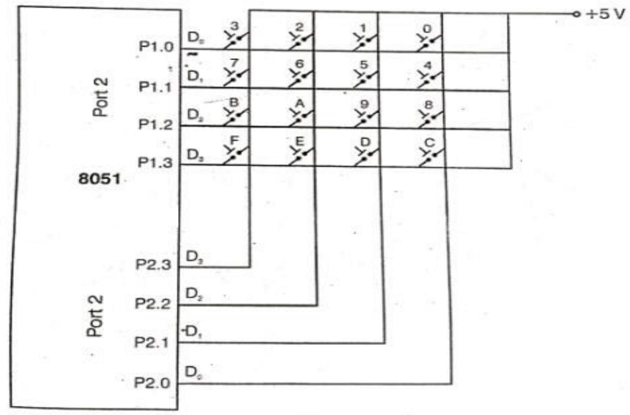
3. **Explain the interfacing of Keyboard/Display with 8051 microcontroller? (April/May'11)(BTL2) (15M)**

Answer: Page : 5.34 - P.S.Manoharan

- Explain about block diagram (6 M)
- Diagram (5 M)

- Program (4 M)





Matrix Keyboard

- ✓ 8051 – interfaced with keyboard display
- ✓ Programmer – programmed in 8051
- ✓ After execution the output will be displayed in interfaced device
- ✓ Port 1 and port 2 - employed for interfacing
- ✓ Form a matrix for output correlation
- ✓ Controller will control the operation
- ✓ Function of ports – related with interrupt and delay signals

Program for keyboard:

```
MOV P2 #FF H
MOV P,@ 00H
L2:MOV A,P2
ANL A,#0F H
CJNE A,#0F H,OVER
SJMP L2
OVER:ACALL DELAY
MOV A,P2
ANL A,#0FH
CJNE A,#0FH,OVER1
SJMP L2
OVER1:MOV P1,#0FEH
MOV A,P2
ANL A,#0F H
CJN A,#0F H,ROW_0
MOV P1,#0FD H
MOV A,P2
ANL A,0F H
CJNE A,#0F H,ROW_1
MOV P1,#0FB H
```

	MOV A,P2 ANL A,#0F H CJNE A,#0F H,ROW_2 MOV P1,#0F7 H MOV A,P2 ANL A,#0F H CJNE A,#0F H ,ROW_3 ROW_0:MOVE DPTR,KEY0 SJMP FIND

EE6503 POWER ELECTRONICS L T P C 3 0 0 3

OBJECTIVES:

- To get an overview of different types of power semiconductor devices and their switching characteristics.
- To understand the operation, characteristics and performance parameters of controlled rectifiers
- To study the operation, switching techniques and basics topologies of DC-DC switching regulators.
- To learn the different modulation techniques of pulse width modulated inverters and to understand harmonic reduction methods.
- To study the operation of AC voltage controller and various configurations.

UNIT I POWERSEMI-CONDUCTORDEVICES 9

Study of switching devices, Diode, SCR, TRIAC, GTO, BJT, MOSFET, IGBT-Static and Dynamic characteristics - Triggering and commutation circuit for SCR- Design of Driver and snubber circuit.

UNIT II PHASE-CONTROLLEDCONVERTERS 9

2-pulse,3-pulse and 6-pulseconverters– performance parameters –Effect of source inductance-Gate Circuit Schemes for Phase Control–Dual converters.

UNIT III DCTODCCONVERTER 9

Step-down and step-up chopper-control strategy–Forced commutated chopper–Voltage commutated, Current commutated, Load commutated, Switched mode regulators- Buck, boost, buck- boost converter, Introduction to Resonant Converters.

UNIT IV INVERTERS 9

Single phase and three phase voltage source inverters (both120^0modeand180^0mode)–Voltage& harmonic control--PWM techniques: Sinusoidal PWM, modified sinusoidal PWM - multiple PWM – Introduction to space vector modulation –Current source inverter.

UNIT V AC TO AC CONVERTERS 9

Single phase and Three phase AC voltage controllers–Control strategy- Power Factor Control – Multistage sequence control -single phase and three phase cycloconverter converters.

TOTAL:45 PERIODS

OUTCOMES:

Ability to understand and analyse, linear and digital electronic circuits.

TEXT BOOKS:

1. M.H.Rashid, 'Power Electronics: Circuits, Devices and Applications', Pearson Education, PHI Third Edition, New Delhi, 2004.
2. P.S.Bimbra "Power Electronics" Khanna Publishers, third Edition, 2003.
3. L. Umanand, " Power Electronics Essentials and Applications", Wiley, 2010.

REFERENCES:

1. Joseph Vithayathil,' Power Electronics, Principles and Applications', McGraw Hill Series, 6th Reprint, 2013.
2. Ashfaq Ahmed Power Electronics for Technology Pearson Education, Indian reprint, 2003.

3. Philip T. Krein, “Elements of Power Electronics” Oxford University Press, 2004 Edition.
4. Ned Mohan, Tore. M. Undel and, William. P. Robbins,‘ Power Electronics: Converters, Applications and Design’, John Wiley and sons, third edition,2003.
5. Daniel.W.Hart, “Power Electronics”, Indian Edition, Mc Graw Hill, 3rd Print, 2013.

UNIT I – POWER SEMI-CONDUCTOR DEVICES

Study of switching devices, Diode, SCR, TRIAC, GTO, BJT, MOSFET, IGBT-Static and Dynamic characteristics - Triggering and commutation circuit for SCR- Design of Driver and Snubber circuit.

PART * A

Q.No **Questions**

1. **Specify the basic feature of IGBT .(NOV/DEC-2016)** (BTL1)
   - Lower on state power loss
   - Lower switching losses
   - Used for high power applications
   - Smaller snubber circuit requirements
   - Lower gate drive requirements

2 **What is the use of snubber circuit? (NOV/DEC-2008,MAY/JUNE-2009, NOV/DEC-2016)** (BTL1)

Snubber circuit consists of a series combination of a resistor and a capacitor in parallel with the thyristors. It is mainly used for dv /dt protection.

3 **What is meant by commutation process of SCR? List out its types.(APRIL/MAY-2017)** (BTL2)

Commutation is defined as the process of turning OFF of a thyristor.

Two types:
- Natural commutation
- Forced commutation.

4 **What are the advantages of GTO over SCR?(APRIL/MAY-2017, NOV/DEC-2015)** (BTL2)
- Elimination of commutation of commutating components in forced commutation, resulting in reduction in cost, weight and volume.
- Reduction in acoustic noise and electromagnetic noise due to elimination of commutation chokes.
- Faster turn-off, permitting high switching frequencies.
- Improved efficiency of the converters.

5 **What are the difference between power diode and signal diode? (NOV/DEC-2013)** (BTL4)

S.No.	**Power diode**	**Signal diode**
1.	Constructed with n-layer, called drift region between p+ layer and n+ layer.	Drift region is not present.
2.	The voltage, current and power ratings are higher.	The voltage, current and power ratings are lower
3.	Power diodes operate at high speeds.	It Operates at higher switching speed.

6 **What is Latching current? (NOV/DEC-2013)** (BTL1)

The latching current is defined as the minimum value of anode current which it must attain during turn on process to maintain conduction when gate signal is removed

7 **What are the parameters involved in Switching losses of power device?(APRIL/MAY-2011)** (BTL4)

- Forward conduction losses
- Loss due to leakage current during forward and reverse blocking.
- Switching losses at turn-on and turn-off.
- Gate triggering loss.

8 **What are the methods of turn on the SCR? (APRIL/MAY-2011)** (BTL2)

- Forward voltage triggering
- Gate triggering
- dv/dt triggering
- Temperature triggering
- Light triggering

9 **Define voltage ripple factor. (JAN-2006)** (BTL1)

Voltage ripple factor is defined as the ratio of the net harmonic content of the output voltage to the average output voltage.

10 **What are the factors influenced in the turn off time of a thyristor? (NOV/DEC-2010)** (BTL2)

There are Two main factors that influence in the turn off time of a thyristor. 1.Recovery Process and 2.Recombination process

11 **How SCR differs from TRIAC?(MAY/JUNE-2009)** (BTL4)

SCR	**TRIAC**
It is a unidirectional device	It is a Bidirectional device
SCR can be triggered by positive polarity voltage	TRIAC can be triggered by positive or negative polarity voltage
High dv/dt rating	Low dv/dt rating
Reliability is more	Reliability is less
Symbol	Symbol

12 **State the advantages of IGBT over MOSFET.(NOV/DEC-2008)** (BTL4)

- Lower on state power loss
- Lower switching losses
- Used for high power applications
- Smaller snubber circuit requirements
- Lower gate drive requirements

13 **Enumerate the applications of IGBT. (Jan-2008)** (BTL4)

IGBT are widely used in medium power applications such as DC & AC motor drives, UPS systems, power supplies and drive for solenoids, relays and contactors.

14 **Define the term pinch off voltage of MOSFET.(NOV/DEC-2007)** (BTL1)

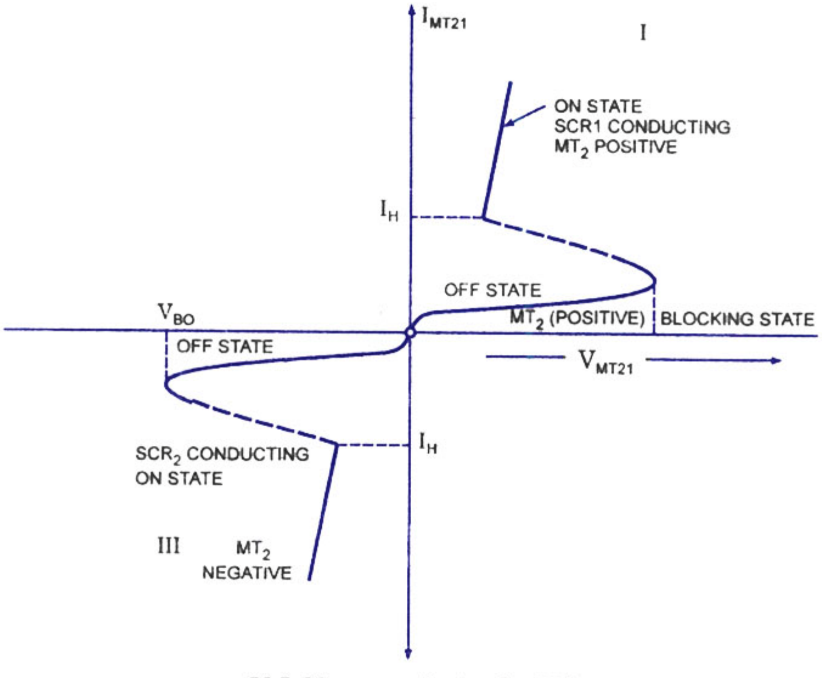
If the gate source voltage Vgs is made negative enough, the channel will be completely depleted, offering a high value of Rds and there will be no flow of current from drain to source. Ids=0,the value of Vgs is called pinch off voltage

15 **Define Holding current and latching current in SCR.(NOV/DEC-2015)** (BTL1)

The latching current is defined as the minimum value of anode current which it must attain during turn on process to maintain conduction when gate signal is removed.

The holding current is defined as the minimum value of anode current below which it must fall to for turning off the thyristor.

16 **Enumerate the application of IGBT.(JAN-2008)** (BTL4)

	• DC to DC motor Drives • UPS system(Power supplies) • Drive for solenoid, relay and contractors.
17	**What are the classifications of Diode?** (BTL2) • General purpose diode • Fast recovery diode • Schottky diode
18	**What are the different types of thyristor?(JAN-2008)** (BTL2) SCR,TRIC,DIAC,SCS and GTO
19	**List the basic features of power MOSFET.(DEC-2006)** (BTL2) • Power MOSFET is a voltage controlled device • Unipolar device • It has high input impedance • Do not have secondary breakdown
20	**What is meant by gate Drive Circuit?** (BTL1) The gating circuit is an integral part of a power converter that consists of power semiconductor devices. The output of the converter is depends on how the gating drive switching device.
	PART * B (13 Marks)
1	**Describe the Static (VI) Characteristics of TRIAC. 13 Marks (NOV/DEC-2008)** (BTL2) **Answer Page 2.35 - J.GNANAVADIVEL** • **Definition of Traic** (2m) Bidirectional device conduct both directions • Draw the VI characteristics of TRIAC & Explain (6m)  *V-I Characteristic of a Triac* • **Explain modes of operation (5m)** Mode 1 – MT2 positive, positive gate current Mode 2 - MT2 positive, negative gate current

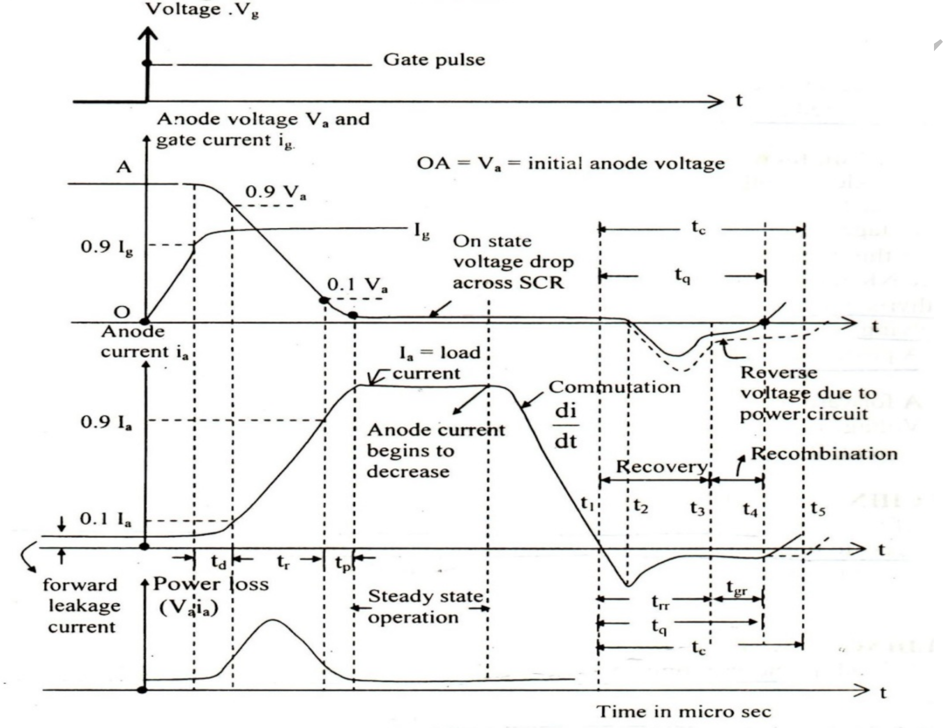
Mode 3 - MT2 negative, positive gate current
Mode 4 - MT2 negative, negative gate current

2

Explain about the Dynamic (Switching or Transient) Characteristics of SCR. (BTL2) **13M (APRIL/MAY-2017)**

Answer Page :2.13 – J. GNANAVADIVEL

- **Define SCR** (2m)
  1. Silicon controlled rectifier , latching device
  2. Turned on by gate terminal,
- Draw the transient characteristics of SCR (5m)



  1. Turn on time , ton=td+ tr+tp
  2. Turn off time , tq= trr+tgr
- Explain its turn on and turn off process (6m)
  1. Turn-on: Time during which it changes from forward blocking state to final on state.
  2. Turn off: Time changes from conduction state to forward blocking state.

3

Elaborate the Triggering methods (Turn ON methods) in SCR. 13 M (NOV/DEC-2012) (BTL1)

Answer Page: 2.10 J.GNANAVADIVEL

- Define scr (3m)
  Scr - unidirectional device, blocks the current flow from cathode to anode.
- Types of turn on methods and explain (10m)
  1. Forward voltage triggering
  2. Gate triggering
  3. dv/dt triggering
  4. Temperature triggering
  5. Light triggering

4

Draw the Two transistor model of SCR and derive the expression for anode current. 13 M (NOV/DEC-2012) (BTL3)

Answer Page: 2.18 J.GNANAVADIVEL

- Draw the two transistor model diagram (7m)
  Bisecting two middle layers, as two separate halves
- Explain its operation (6m)
  1. SCR operated- two transistor models.
  2. Transistor model obtained bisecting two middle layers two separate halves.
- Working peak-off state forward voltage- maximum instantaneous value of reverse voltage
- Repetitive peak-off state forward voltage- transient voltage thyristor OFF state.
- Block repeatedly forward directions.
- Non-repetitive peak off state forward voltage- maximum instantaneous value of any non repetitive transient OFF state voltage.

5

Explain about the snubber circuit of SCR and MOSFET. 13 M (BTL 2)

Answer Page: 2.30& 2.60 J.GNANAVADIVEL

Snubber circuit:

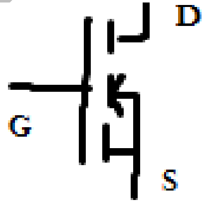
- Snubber circuit used protection circuit
- Draw the circuit diagram for snubber circuit (4m)
- Explain its operation (9m)
  1. The snubber circuit used di/dt protection.
  2. Consists series combination resistance Rs, Capacitance Cs parallel SCR.
  3. Switch S closed sudden voltage appears across circuit.
  4. Capacitance behaves short circuit.
  5. Due to this voltage across SCR is zero.
  6. With passage time, voltage across capacitance builds slow rate dv/dt across Cs.
  7. Thyristor less specified maximum dv/dt rating power semiconductor device.

6

What is operation of MOSFET? 13 M (NOV/DEC-2016) (BTL1)

Answer Page: 2.47 - J.GNANAVADIVEL

- Draw its symbol (4m)



- Working operation and its types (9m)
  1. Enhancement type 2. Depletion type
  1. Power mosfet voltage controlled device output current(drain current) controlled gate-source voltage (Vgs).
  2 .Power MOSFET three terminals drain D, source S, gate G.
  3. Power Mosfet unipolar device flow of majority carriers only.
  4. Very high input impedances -order 10^9 ohm.

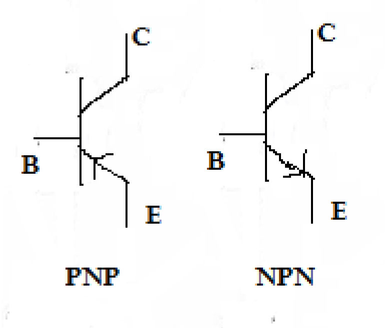
7

Differentiate MOSFET and BJT. 10 M (MAY/JUNE-2009) (BTL4)

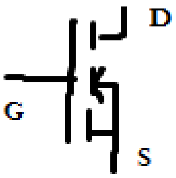
Answer Page: 2.52 by J.Gnanavadivel

- Define and draw the symbol of MOSFET and BJT (4m)

BJT



MOSFET



- Features , advantages & disadvantages , differentiate MOSFET & BJT(6m)
  1. BJT current controlled device, MOSFET voltage controlled device
  2. BJT higher switching losses , mosfet lower switching losses
  3. BJT unipolar device MOSFET is bipolar device
  4. BJTs available ratings 1200V, Mosfet available ratings upto 500V, 140A

8

Differentiate MOSFET and IGBT. (10 M)

Answer Page: 2.73 & 2.74- J.Gnanavadivel (BTL4)

- Features , advantages & disadvantages of MOSFET & IGBT (10m)

IGBT

- Lower switching losses.
- High power applications
- High cost
- Lower gate drive requirements
- Less snubber circuit requirements

MOSFET:

- Higher switching losses
- Low power applications
- Less cost
- High gate drive requirements
- More snubber circuit

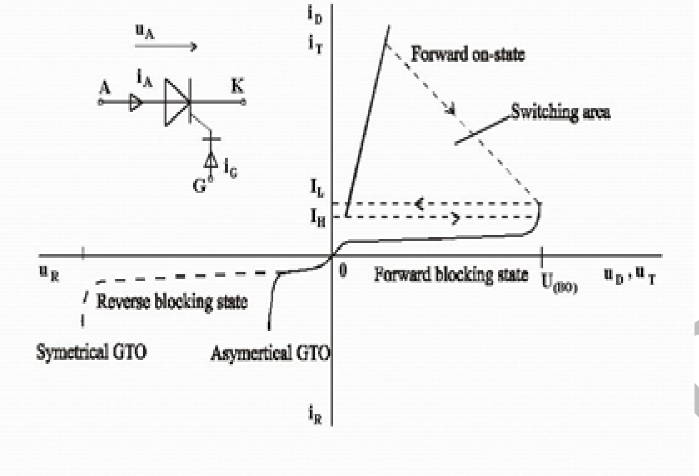
9

Describe the Static (VI) Characteristics and Dynamic (Switching) Characteristics of GTO. 13 M

Answer Page: 2.61- J. Gnanavadivel (BTL2)

GTO- Gate turn off thyristor

- VI characteristics of GTO (7m)



- Explain its operation (6m)

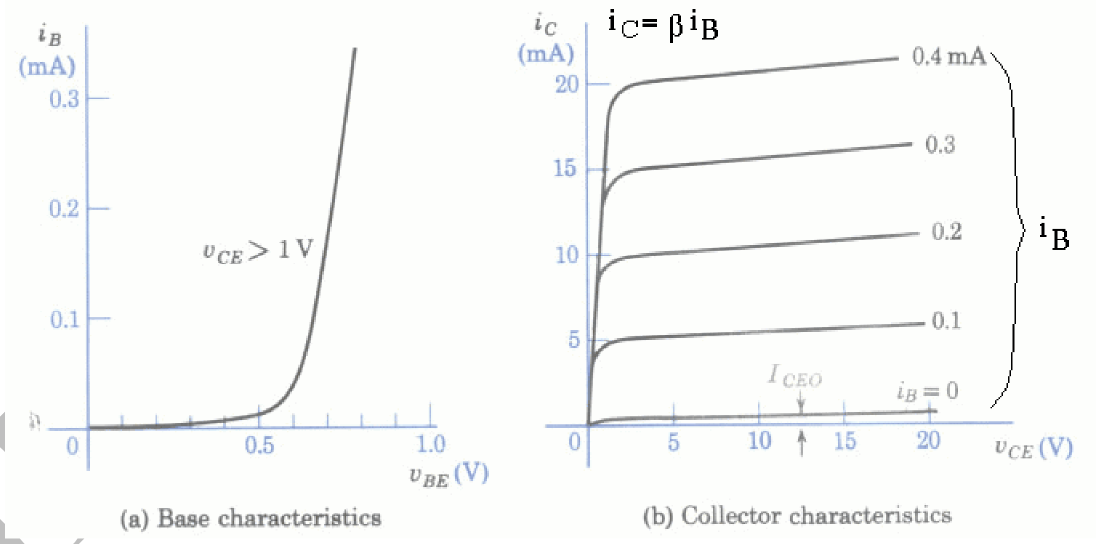
  1. Gate turn off thyristor pnpn device, turned on like ordinary SCR pulse positive gate current.
  2. Inverter chopper circuits, scr turned off forced commutation.
  3. Applications GTO easily turned off negative gate pulse appropriate amplitude.
  4. Turning off GTO, turn-off circuit capable output high peak current.

10

Describe the Static (VI) Characteristics and Dynamic (Switching) Characteristics of BJT and also define SOA. 13 M (NOV/DEC-2007) (BTL2)

Answer Page: 2.43 & 2.45 – J.Gnanavadivel

- Draw the VI characteristics of BJT and explain (7m)



(a) Base characteristics (b) Collector characteristics

- Explain its operation (6m)

  1. Power BJT three layer, two junction npn or pnp semiconductor device.
  2. Term 'bipolar' indicates current flow consists movement both holes electrons.
  3. BJT three terminals named collector C, Emitter E and base B.

- Switching Characteristics:

  1. Turn on process: Transistor cannot be turned on instantly because internal capacitances value.
  2. Turn on time transistor sum of delay time, rise time.
  3. Turn off process: Turn off process transistor sum of storage time,fall time.

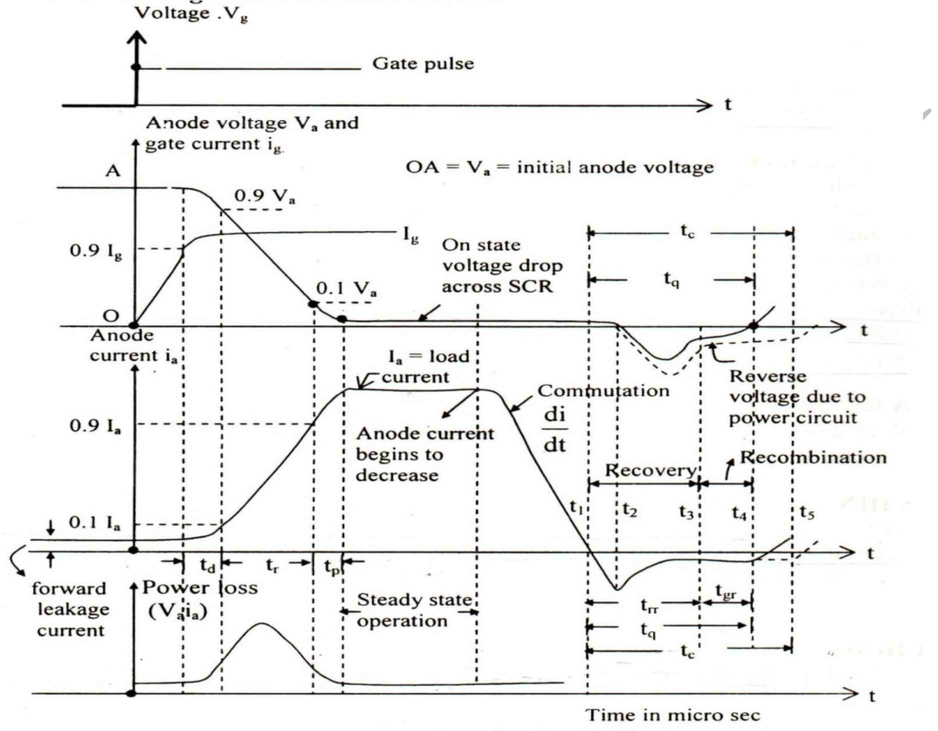
PART * C (15 Marks)

1 **What is SCR? Describe the Static (VI) Characteristics and Dynamic (Switching) Characteristics of SCR. 15 M (MAY/JUNE-2009, NOV/DEC-2010)** (BTL2)

Answer Page :2.87 & 2.13 - J.GNANAVADIVEL

Silicon controlled rectifier:

- Unidirectional device, triggered by positive gate voltage
- Draw the VI & Transient characteristics, explain it (8m)



- Explain turn on and turn off process with neat waveform (7m)
  1. Turn on period defined time during changes forward blocking state final on state.
  2. Dynamic process SCR from conduction state, forward blocking state called turn off process.

2 **Explain types of Commutation Methods in SCR. 15M (NOV/DEC-2010)**

Answer Page :2.26 - J.GNANAVADIVEL (BTL2)

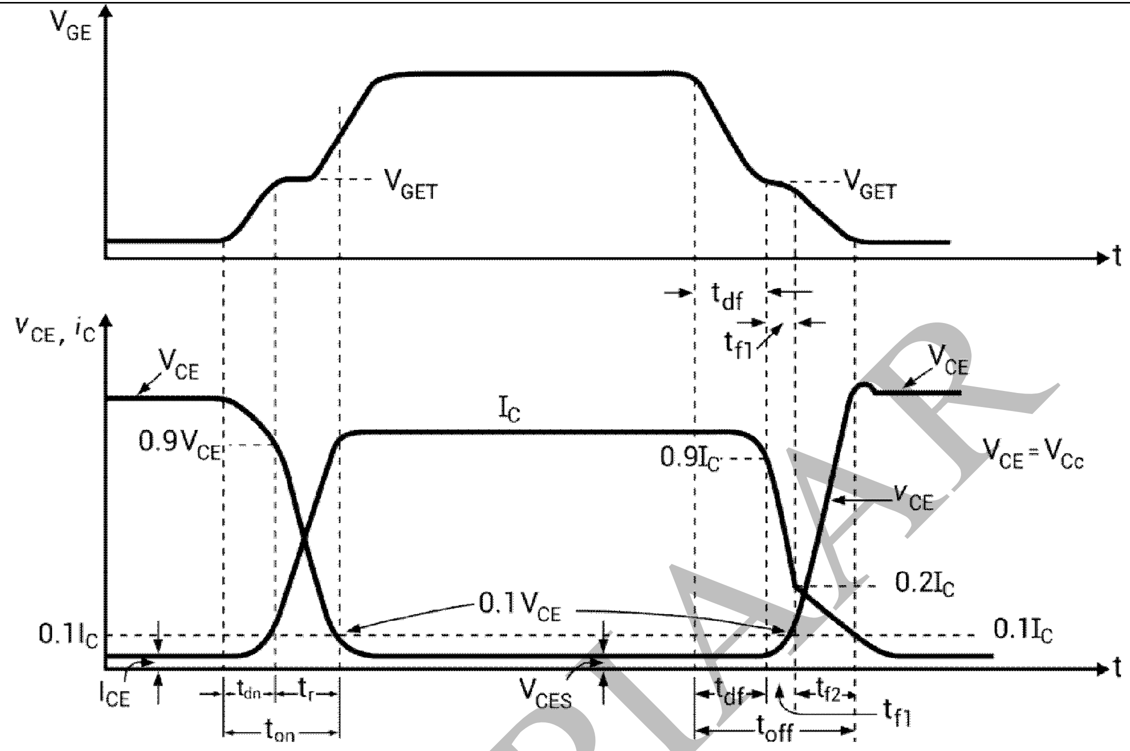
- Define commutation (3m)
  Process turning off thyristor
- Types with neat diagram and explain (12m)
  1. Line commutation:
     Current passes through natural zero, no external circuit required
  2. Forced commutation
     Forward current thyristor forced zero by additional circuit

3 **Describe the Static (VI) Characteristics and Dynamic (Switching) Characteristics of IGBT. 15 M (MAY/JUNE-2009) (NOV/DEC-2010)** (BTL1)

Answer Page: 2.52 - J.GNANAVADIVEL

IGBT:

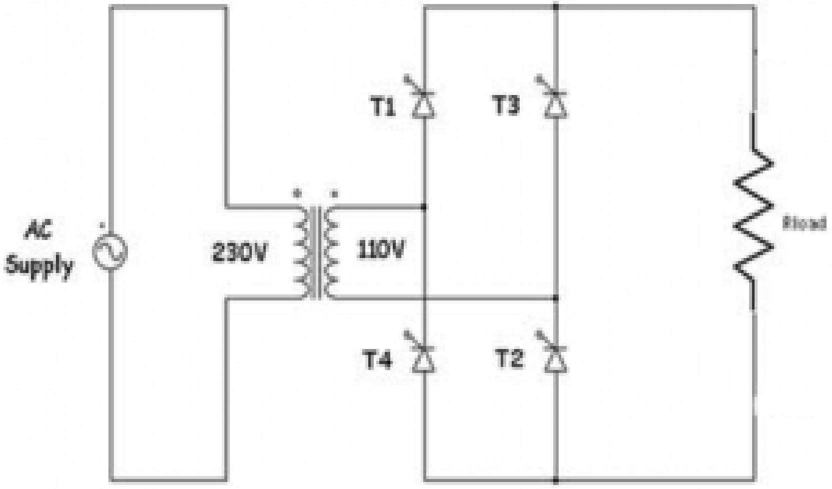
- Device combines advantage of MOSFET & BJT, free from secondary breakdown voltage. (8 M)
- Draw the VI graph and switching characteristics of IGBT, explain (7m)

	 • Typs: 1. Non punch through IGBT 2. Punch through IGBT • Working operation: 1. IGBT new development area Power MOSFET technology. 2. Device combines advantages both MOSFET & BJT. 3. IGBT high input impedances MOSFET, low on state power loss as BJT. 4. Free secondary breakdown problem present BJT. 5. IGBT also metal oxide insulated gate transistor (MOSFET) conductively-modulated field effect transistor (COMFET) , gain modulated FET(GEMFET).

UNIT II – PHASE-CONTROLLED CONVERTERS	
2-pulse, 3-pulse and 6-pulseconverters– performance parameters –Effect of source inductance— Gate Circuit Schemes for Phase Control–Dual converters.	
PART * A	
Q.No	**Questions**
1.	**What is meant by phase controlled rectifier?** BTL1 • Rectification is the process of converting alternating current(AC) or voltage into DC or voltage. It converts fixed ac voltage into variable dc voltage.
2	**Mention some of the applications of controlled rectifier. (NOV/DEC-2012)** BTL4 • Steel rolling mills, printing press, textile mills and paper mills employing dc motor drives. • DC traction • Electro chemical and electro-metallurgical process

	• Portable hand tool drives • Magnet power supplies • HVDC transmission system
3	**Write the function of freewheeling diodes in controlled rectifier.(APRIL/MAY-2017) (NOV/DEC-2016)** BTL2 • It serves two processes. • It prevents the output voltage from becoming negative. • The load current is transferred from the main thyristors to the freewheeling diode, thereby allowing all of its thyristors to regain their blocking states.
4	**State the advantages of freewheeling diodes in a controlled in a controlled rectifier.** BTL4 • Input power factor is improved. • Load current waveform is improved and thus the load performance is better.
5	**What is meant by delay angle and phase angle control? (APRIL/MAY-2017) (NOV/DEC-2007)** BTL2 • The delay angle is defined as the angle between the zero crossing of the input voltage and the instant the thyristor is fired controlling the firing angle is called phase angle control.
6	**What are the advantages of single phase bridge converter over single phase mid-point converter**? BTL4 • SCRs are subjected to a peak-inverse voltage of 2Vm in a fully controlled bridge rectifier. Hence for same voltage and current ratings of SCRs, power handled by mid-point configuration is about. In mid-point converter, each secondary winding should be able to supply the load power. As such, the transformer rating in mid-point converter is double the load rating.
7	**What is meant by commutation angle or overlap angle?** BTL1 • The commutation period when outgoing and incoming thyristors are conducting is known as overlap period. The angular period, when both devices share conduction is known as the commutation angle or overlap angle.
8	**What are the different methods of firing circuits for line commutated converter?** BTL2 • UJT firing circuit. • The cosine wave crossing pulse timing control. • Digital firing schemes.
9	**Give an expression for average voltage of single phase semi converters.** BTL3 Average output voltage $V_{dc} = (V_m / n) (1 + \cos a)$.
10	**What is meant by input power factor in controlled rectifier?** BTL1 • The input power factor is defined as the ratio of the total mean input power to the total RMS input volt-amperes. • Power Factor = (V_1 I_1 cos 9_1) / ($V_{rms.}I_{rms}$) where V_1 = phase voltage, I_1 = fundamental component of the supply current, $\wedge_1$ = input displacement angle, I_{rms} = supply rms current.
11	**Write the advantages of six pulse converter.** BTL4 • Commutation is made simple. • Distortion on the ac side is reduced due to the reduction in lower order harmonics. • Inductance reduced in series is considerably reduced.
12	**What is meant by commutation?** BTL1 • It is the process of changing the direction of current flow in a particular path of the circuit.

	This process is used in thyristors for turning it off.
13	**Mention the types of commutation**? BTL2 • Natural commutation • Forced commutation
14	**What is meant by natural commutation? (NOV/DEC-2012)** BTL1 • Here the current flowing through the thyristor goes through a natural zero and enable the thyristor to turn off.
15	**What is meant by forced commutation?** BTL1 In this commutation, the current flowing through the thyristor is forced to become zero by external circuitry.
16	**Define Harmonic factor (or) THD of the input current. (MAY-2004,NOV/DEC-2008)** BTL1 The harmonic factor of the input current is defined as the ratio of the total harmonic content to the fundamental component. $THD = \frac{\sqrt{Is^2 - Is1^2}}{Is1}$
17	**Define Displacement factor. (MAY-2007,MAY-2005)** BTL1 The input displacement factor is defined as the cosine of the input displacement factor.
18	**What is meant by full converter?(DEC-2004)** BTL1 A fully controlled converter or full converter uses thyristors only and there is a wider control over the level of DC output voltage. It is also known as two Quadrant Converter.
19	**Define voltage ripple factor. (NOV/DEC-2010,JAN-2006)** BTL1 Voltage ripple factor is defined as the ratio of the net harmonic content of the output voltage to the average output voltage
20	**State the invention mode of rectifier. (NOV/DEC-2009,MAY-2009)** BTL1 In a single phase full converter, $\alpha > 90^\circ$, the voltage at the DC terminal is negative. Therefore Power flows from load to source and the converter acts as line commutated inverter, Source voltage is negative source current is positive This is called inversion mode or synchronous inversion
	Part-B
1	**Explain the operation of 1ϕ full wave rectifier with R-load with suitable waveforms. Derive the expression for Average load voltage, Average load current. (13 M) (NOV/DEC-2010)** BTL2 **Answer :Page: 3.23- J.GNANAVADIVEL** • Draw the single phase full wave circuit diagram using R- Load.(3M)



- Draw its corresponding waveform(5M)
- Derive its expression for average load voltage and current. (5M)

Vdc= Vm/∏[1+ cosα}]
Idc= Vm/∏R[1+ cosα}]

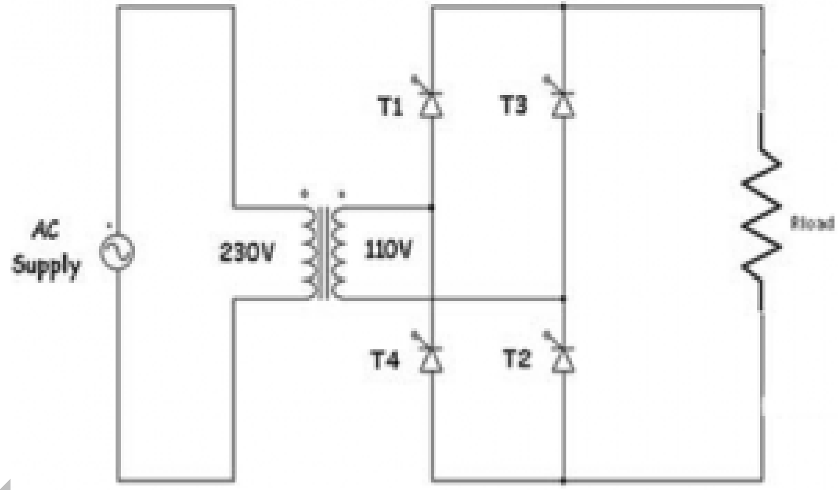
2

Derive Performance Parameter of 1ϕ full wave (Two pulse) converter. (13M) BTL4

Answer :Page: 3.66 - J.GNANAVADIVEL

<u>1ϕ full wave (Two pulse) converter:</u>

- Draw the circuit diagram of 1ϕ full wave converter (4M)



- Using the formula of 1ϕ full wave converter derive the formula of a_n & b_n (9M)

For a pure sinusoidal input current and voltage, power factor is defined as the cosine of the load angle Φ

where the voltages and currents are stated in rms values and VA is

$$VA=\sqrt{P_R^2+P_Q^2}$$

For a rectifier circuit, the input power factor is given by

$$=\frac{V_{Fund}I_{Fund}}{V_{RMS}I_{RMS}}\cos\phi_1$$

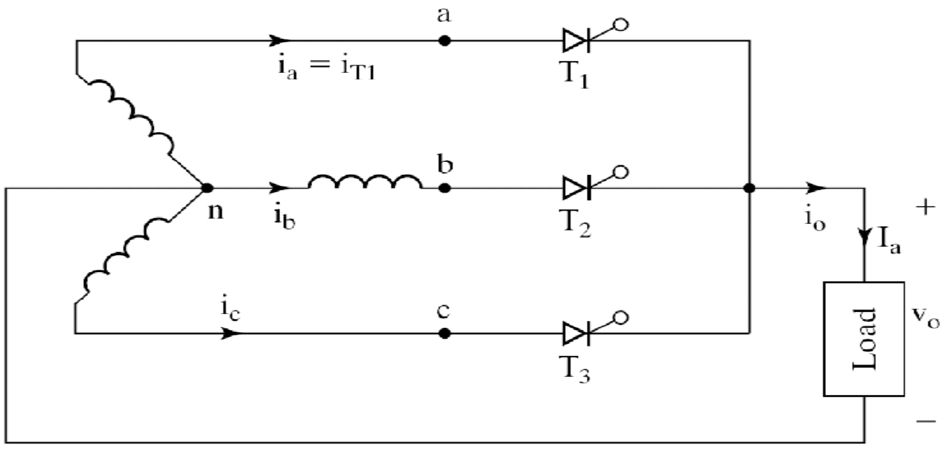
3

Explain the operation of 3ϕ half wave (Three Pulse) rectifier with R-load with suitable waveforms. (13 M) BTL2

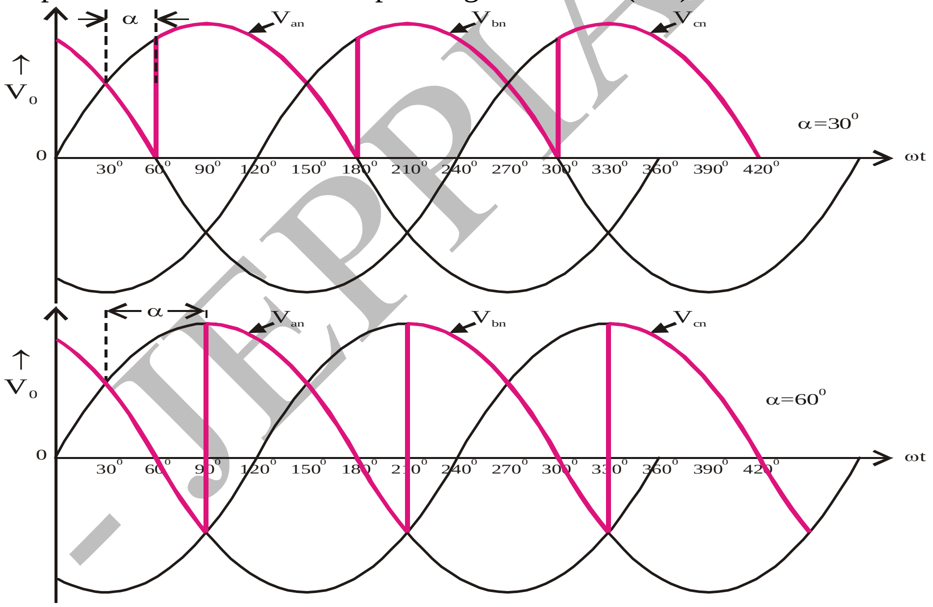
Answer :Page: 3.74 - J.GNANAVADIVEL

<u>3ϕ half wave (Three pulse) converter:</u>

- Draw the three phase half wave circuit diagram using R- Load. (4M)



- Explain its operation & draw its corresponding waveform (5M)



- Derive its expression for average load voltage and current. (4M)
  Vdc =3 (3)1/2/ 2 π[Vmcosα]

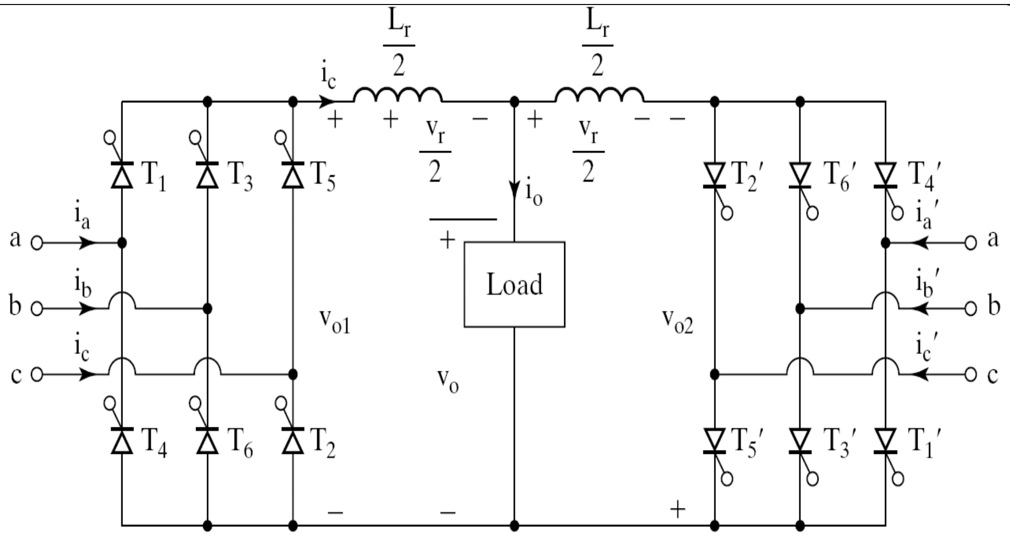
4

Explain the operation of 3ϕ full wave (six pulse) rectifier with R-load with suitable waveforms. (13M) BTL2

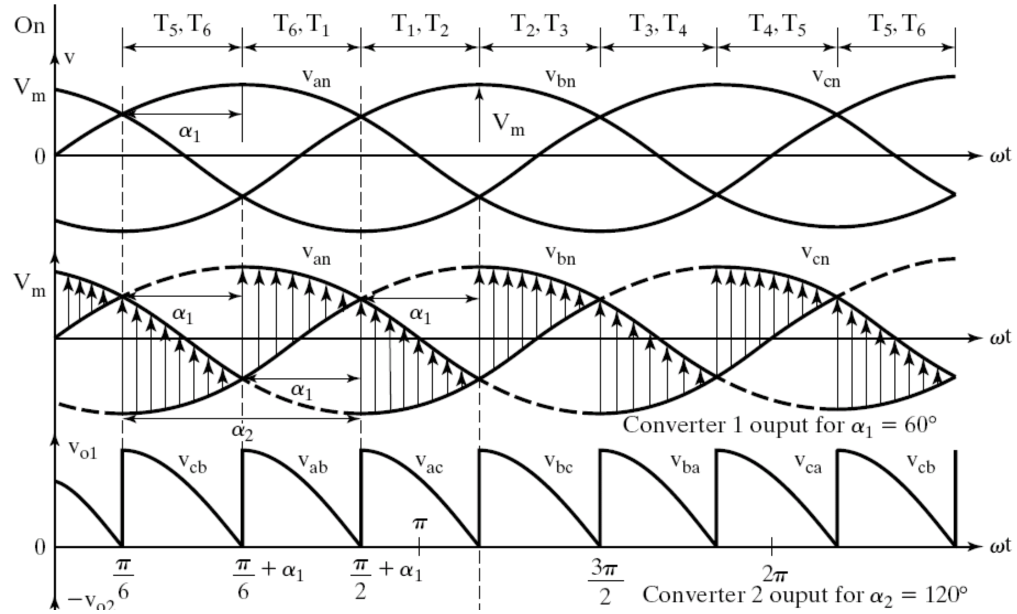
Answer Page: 3.74- J.GNANAVADIVEL

<u>3ϕ full wave (Six pulse) converter:</u>

- Draw the three phase full wave circuit diagram using R- Load. (4M)



- Draw its corresponding waveform (5M)



- Derive its expression for average load voltage and current. (4M)

Phase voltage:

Van= Vmsinwt
Vbn= Vmsin(wt-120)
Vcn= Vmsin(wt-240)

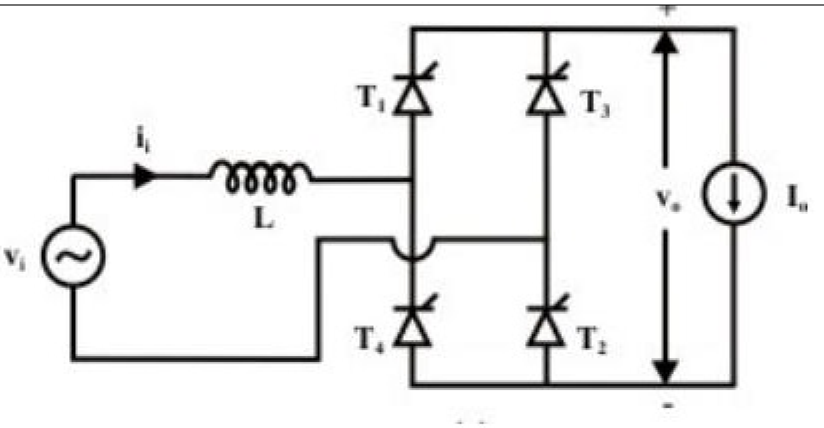
5

Explain the effect of source inductance in 1ϕ rectifier with neat diagram and waveform. (NOV/DEC-2008) (13M) BTL1

Answer Page: 3.91- J.GNANAVADIVEL

<u>Effect of source inductance in 1ϕ rectifier:</u>

- Draw the 1ϕ source inductance circuit diagram (2M)



- Explain its working (5M)
  1. Inductance & Resistance present input source, time required current change takes place.
  2. Period during both outgoing and incoming thyristors conducting, known overlap period.
  3. Due source impedance average output voltage should reduced
  4. Reduce displacement factor
- Derive its output voltage equation (6M)

  Vdc= Vm/∏ (cos α +cos (α+μ))

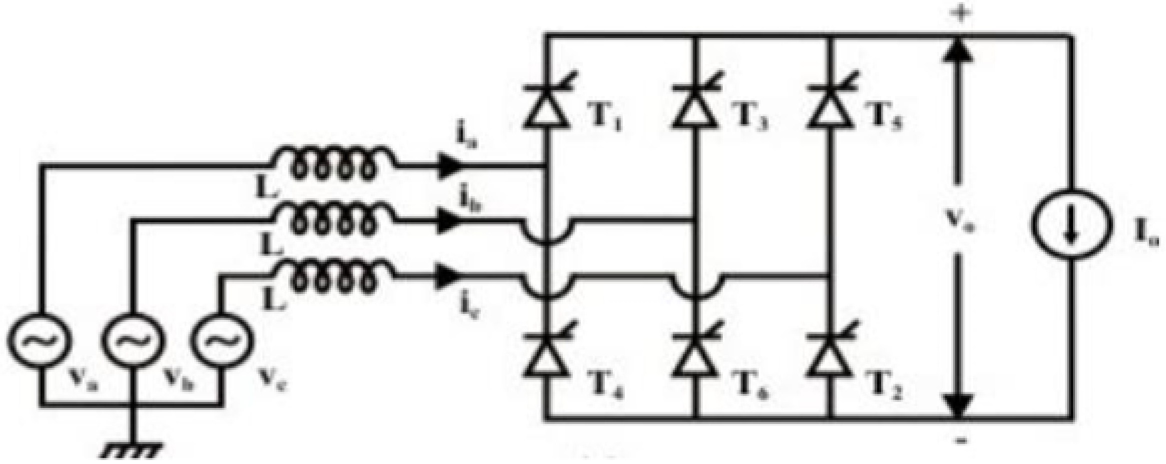
6

Explain the effect of source inductance in 3ϕ rectifier with neat diagram and waveform. (13M) BTL2

Answer :Page :3.96- J.GNANAVADIVEL

<u>Effect of source inductance in 3ϕ rectifier</u>

- Draw the 3ϕ source inductance circuit diagram(3M)



- Explain its working(4M)
  1. Load current assumed constant.
  2. SCRs T3,T5 conduct up to wt= 30˚.
  3. SCRs T1, T5 conducts wt=30˚ to 90˚.
  4. At wt= 90˚ to 150˚ SCRs T1,T6 conducts.
  5. Period during both outgoing and incoming thyristors conducting, known overlap period.
  6. Angle which both devices share conduction called commutation angle.
- Derive its output voltage equation(6M)

  Vdc= 3wLs/π * Io

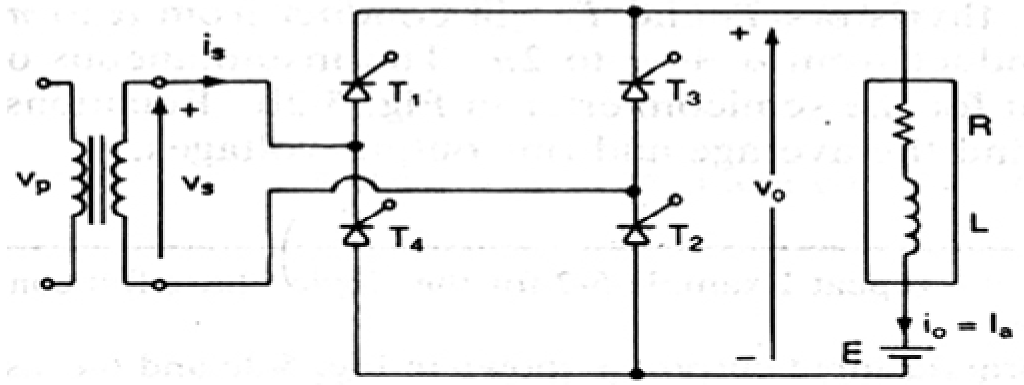
7

What is Phase angle control in rectifier and applications of rectifier? 13M BTL2

Answer Page: 3.33- J.GNANAVADIVEL

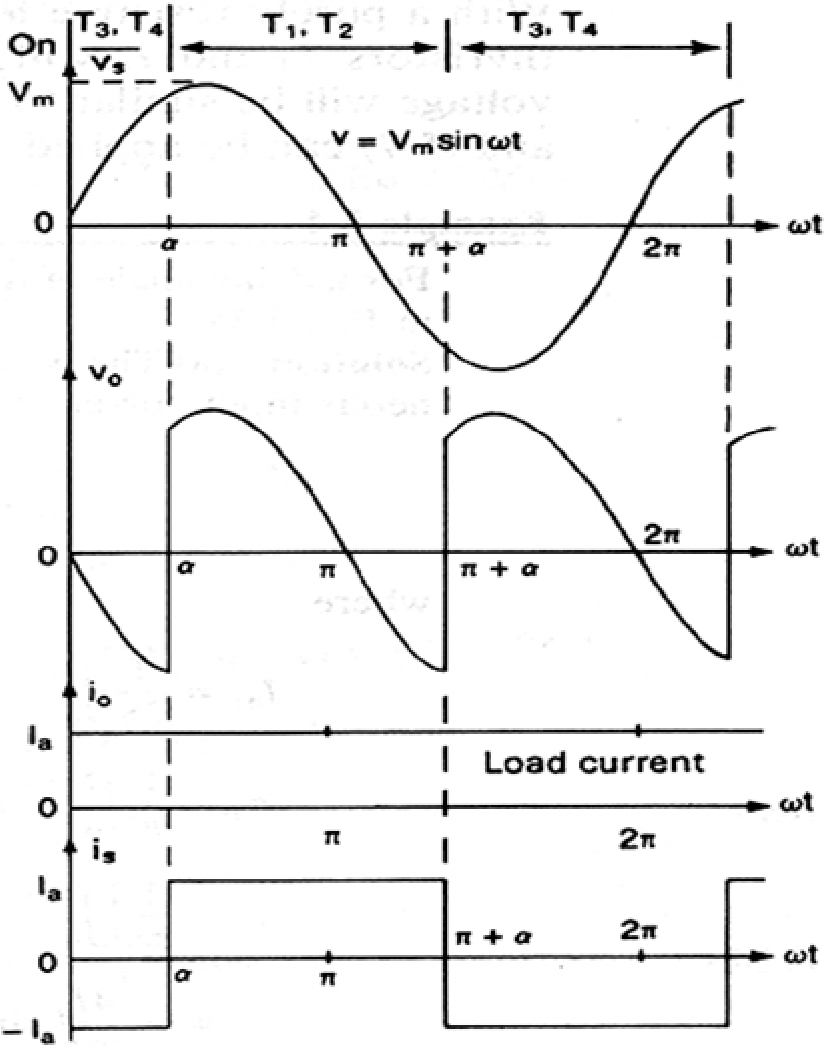
Phase angle control in rectifier:

- Explain phase angle control in rectifier(4M)



(a) Circuit

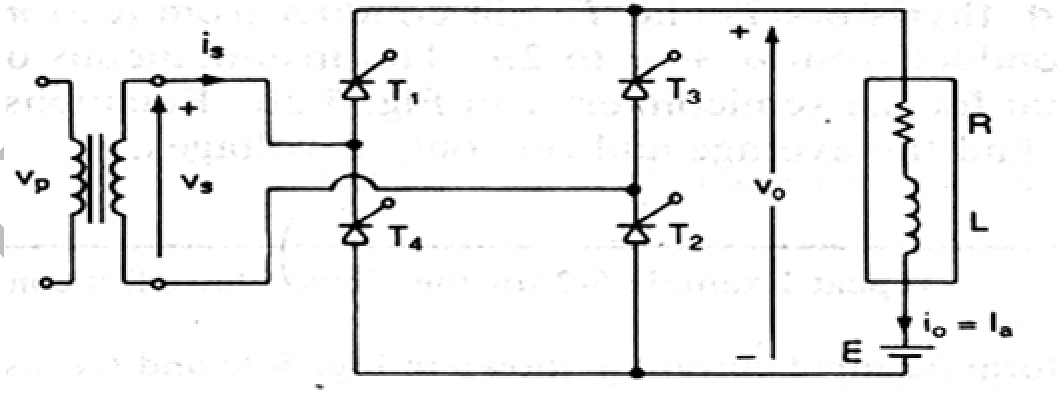
- Draw its waveform and explain its operation(9M)



8 **A 1ϕ half wave rectifier is used to supply power to a load of impedance 10 Ω from 230 V,50 Hz AC Supply at the firing angle of 30◦.calculate the load current. (13 M) (DEC-2003)**

BTL3

Answer Page: 3.12 - J.GNANAVADIVEL

	- Calculate output voltage using 1ϕ half wave rectifier formula (6M) Average output voltage Vdc: Vdc= Vm/2π (1 + cos α) Average output current, Idc: Idc= Vdc/R - Find output current (7M) Vdc= 96.6V Idc = 9.66A
9	**A single phase full converter delivers power to RLE load with R=0.5Ω, L=6.5mH and E=10 V. The ac supply voltage is 230V, 50 Hz. For the continuous conduction, determine the average Output voltage & load current at delay angle α=60◦. (13 M) (Jun-2016)** BTL3 **Answer Page: 3.42- J.GNANAVADIVEL** - Mention Given data(2M) R= 0.5Ω L= 6.5mH E= 10V Vs= 230V α = 60˚ - Write its relevant formula (2M) Vdc= 2Vm/π(cos α) Vdc= E+ Idc R - Calculate output voltage and load current at continuous conduction mode(9M) Vdc= 103.53V Idc=187.06A
	Part-C
1	**Explain the operation of 1ϕ full wave rectifier with RL-load with suitable waveforms. Derive the expression for Average load voltage, Average load current. (15M) (APRIL/MAY-2017)(NOV/DEC-2016)** BTL2 **Answer: Page:3.27 - J.GNANAVADIVEL** - Draw the single phase full wave circuit diagram using RL- Load.(4M)  (a) Circuit - Draw its corresponding waveform & explain (8M)

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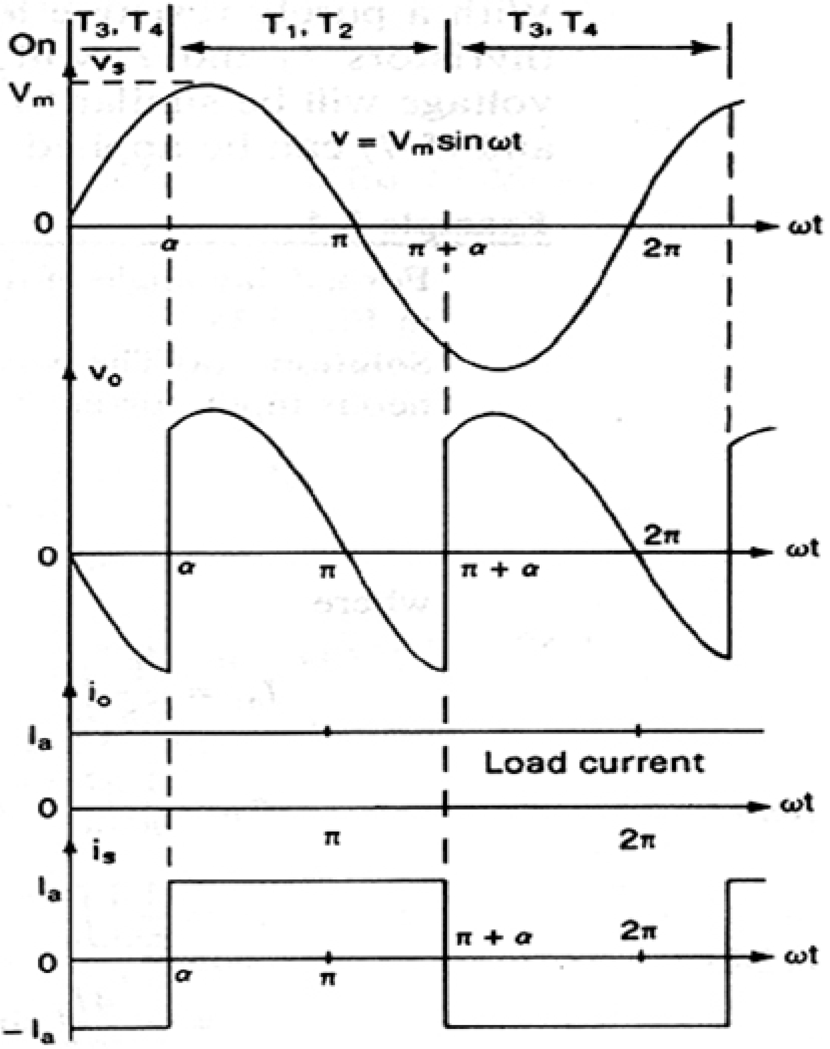

- Derive its expression for average load voltage and current(3M)

Vdc= 2Vm/π (cosα)
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Explain the Dual converter in detail. (15 M) (APRIL/MAY-2017, NOV/DEC-2016)

BTL2

Answer :Page: Appendix-c - J.GNANAVADIVEL

- Draw the circuit diagram of dual converter(4M)
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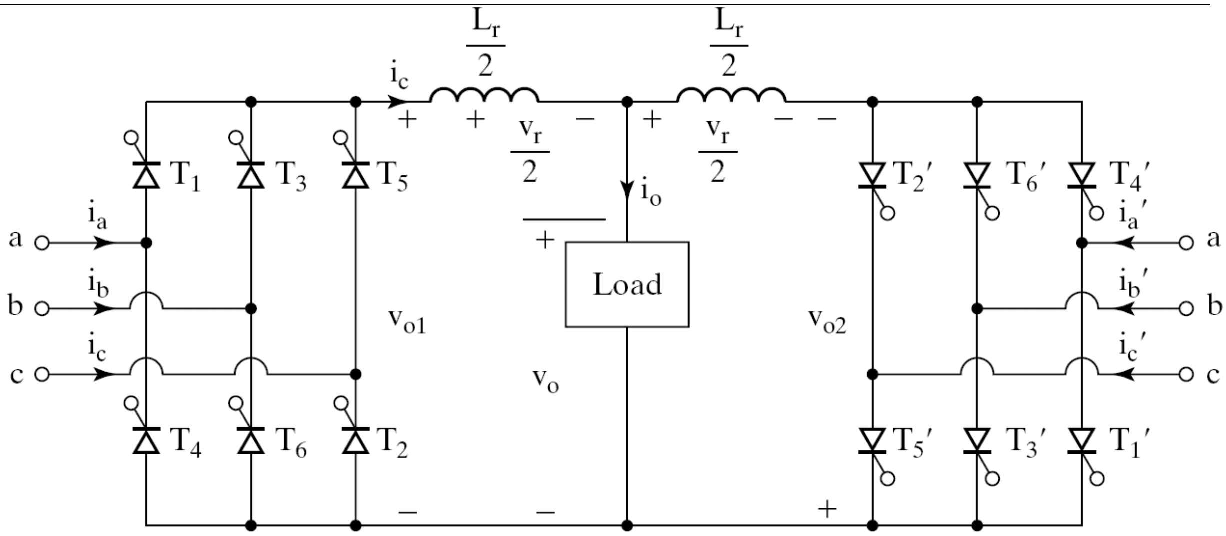
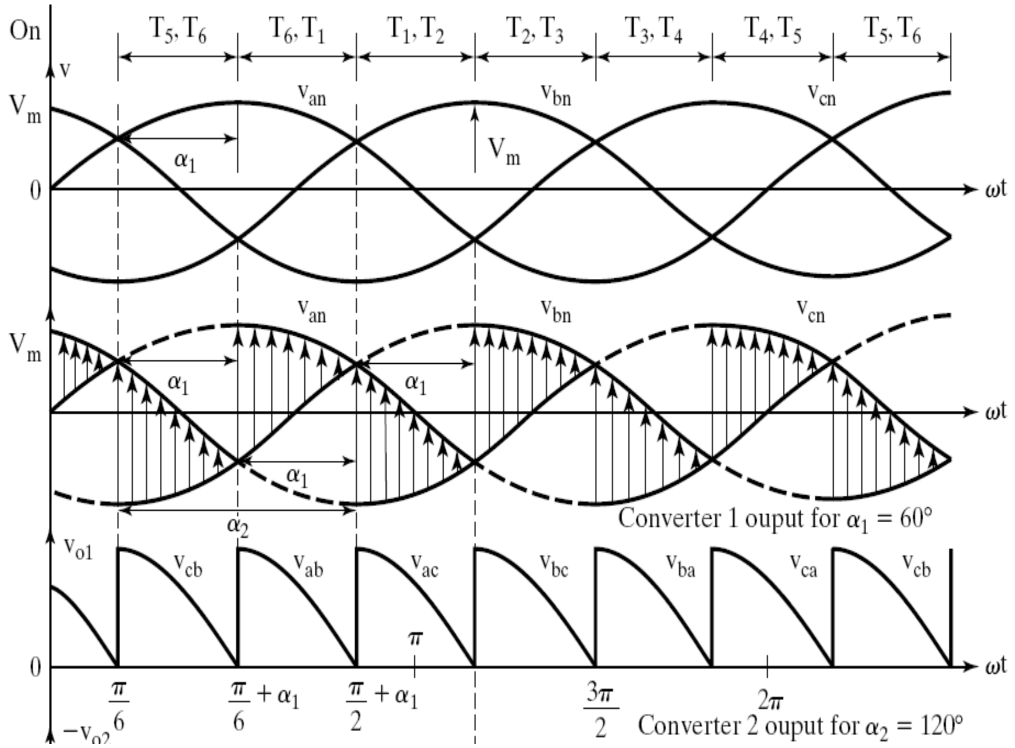


- Explain its operation (11M)



3

A single phase full converter is supplied from 230 V, 50 Hz source. The load consists of R=10Ω and a large inductance so as to render the load current constant. For a firing angle delay of 30◦ Determine 1.Average output voltage 2.Average output current 3.Average and rms value of thyristor currents and 4.Power factor. (MAY-2004,DEC-2011) (15 M) BTL3

Answer Page:3.43 - J.GNANAVADIVEL

- Given data & formula (4M)

VS= 230V

R = 10Ω

α = 30˚

	• Calculate output voltage, current, power factor (11M) $Vdc= 2Vm/\pi (\cos\alpha)$ $= 179.33V$ $Idc= Vdc/R$ $= 17.933A$ $ITA= Idc/2$ $= 8.966A$

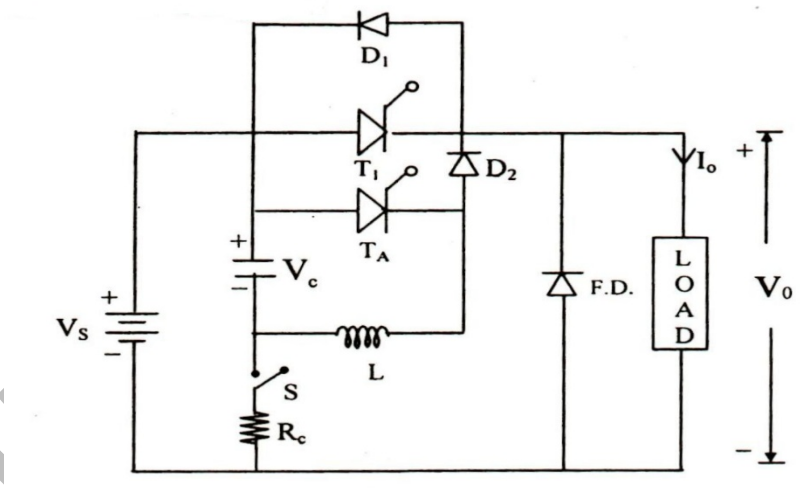
UNIT III - DC TO DC CONVERTER

Step-down and step-up chopper-control strategy–Forced commutated chopper–Voltage commutated, Current commutated, Load commutated, Switched mode regulators- Buck, boost, buck- boost converter, Introduction to Resonant Converters.

PART * A

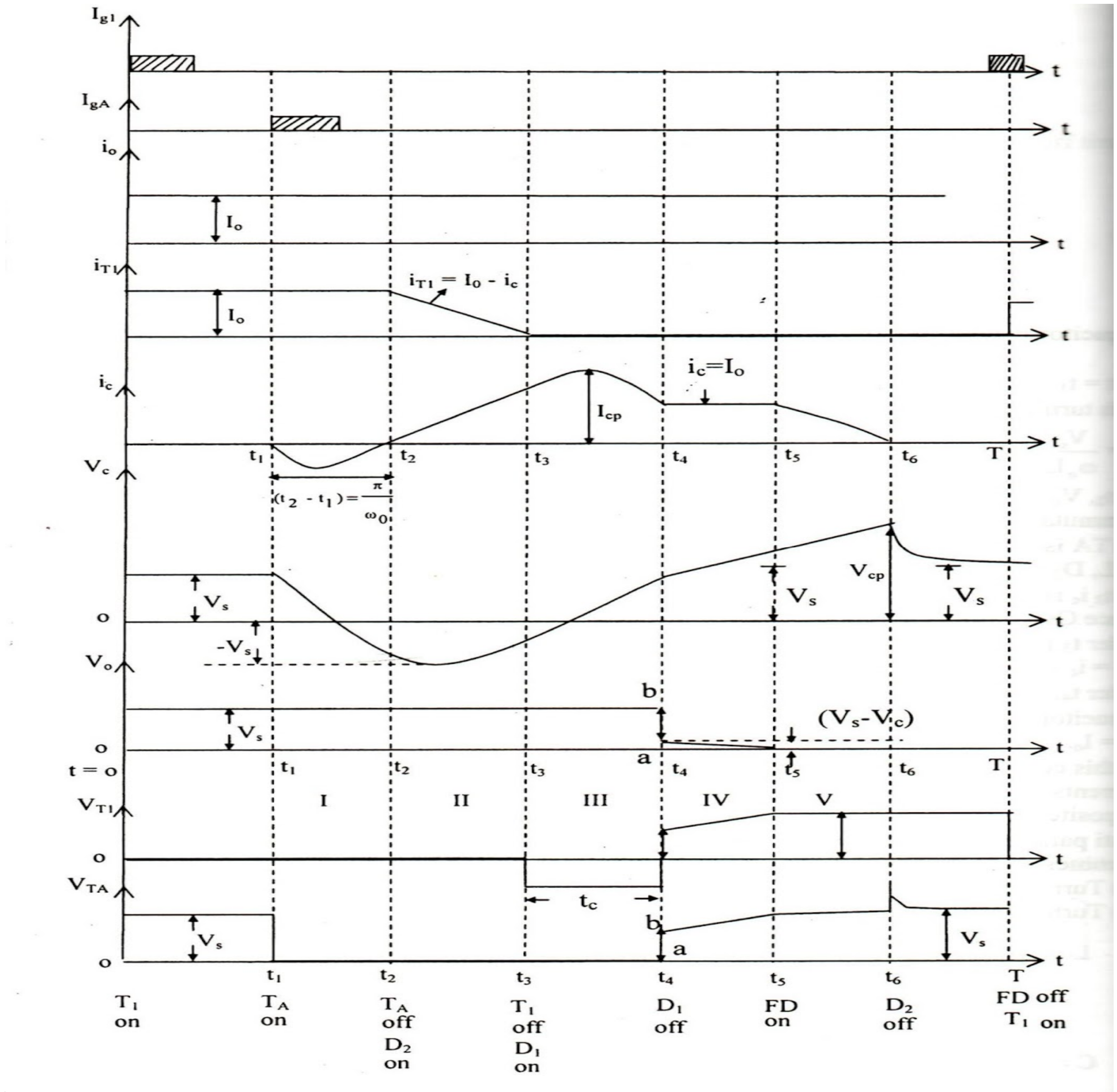
Q.No.	Questions
1.	**What are the advantages of dc chopper?** (BTL4) Chopper provides • High efficiency • Smooth acceleration • Fast by name response • Regeneration
2	**Write the applications of dc chopper.(APRIL/MAY-2017, MAY 2007, DEC 2008)** **(**BTL4) • Battery operated vehicles • Traction motor control in electric traction • Trollycars • Marine hoists • Mine haulers
3	**What is Resonant converter? (APRIL/MAY-2017)** **(**BTL1) A converter operates with LC resonant is called resonant converter. There are ZVS resonant converter resonant converters.
4	**What are the classification of DC chopper depends on direction of voltage and current?(NOV/DEC-2016**) (BTL2) • First Quadrant chopper • Second Quadrant chopper • Two Quadrant chopper(I and II,I and IV) • Four Quadrant chopper
5	**Write the two types of control strategies. (NOV/DEC-2016)** **(**BTL2) • Time Ratio Control(TRC) a. Constant frequency control b. Variable frequency control • Current Limit Control method (CLC)
6	**What is step-up and step-down chopper? (NOV/DEC-2012)** **(**BTL1) • In a step- down chopper or Buck converter, the average output voltage is less than the input voltage. • In a step-up chopper or Boost converter, the average output voltage is more than the input

	voltage.
7	**What is meant by PWM control in dc chopper**? **(NOV/DEC-2012)** **(**BTL1) • In this control method, the on time Ton is varied but chopping frequency is kept constant. The width of the pulse is varied and hence this type of control is known as Pulse Width Modulation (PWM).
8	**Mention any two disadvantages of frequency modulation control strategy. (NOV/DEC-2010)** **(**BTL4) • The chopping frequency has to be varied over a wide range for the control of output • voltage. • The filter design is very difficult • It generates harmonics at un predictable rage which produces interference in signaling and telephone line. • Large OFF time will make the load discontinuous.
9	**What are the advantages of ZVS when compared to ZCS? (NOV/DEC-2010)** **(**BTL4) • ZVS is preferred for high frequency applications because of the following reason a. Switching losses in the power semiconductor devices are zero. b. Maximum current through the semiconductor devices is small c. Electromagnetic interference is reduced during transition d. It can with stand short circuit condition e. Efficiency is high
10	**What is the principle of current limit control of DC chopper?(APRIL/MAY-2011)** **(**BTL1) The chopper is switched ON and OFF so that the current in load is maintain between two limits(I_{max} and I_{min}).It is possible either in constant frequency or variable frequency. it is used only when the load has energy storage element.
11	**State TRC. (NOV/DEC-2008)** **(**BTL1) In TRC, the value of T_{on}/ T is varied in order to change the average output voltage. Two types a. Constant frequency control b. Variable frequency control.
12	**What is duty-cycle? (NOV/DEC-2007)** (BTL1) Duty cycle is defined as the ratio of the on time of the chopper to the total time period of the chopper.
13	**Define DC chopper. (NOV/DEC-2007**) (BTL1) DC chopper is a high speed static switch used to obtain variable DC from Constant DC. It is Equivalent to AC transformer. Like transformer it can step-up and step-down DC voltage.
14	**What are the basic topologies of switching regulators?(JAN 2006)** **(**BTL4) • Buck converter • Boost converter • Buck Boost converter • Cuk converter
15	**What is meant by FM control in a dc chopper?** (BTL1) In frequency modulation control, the chopping frequency f (the chopping period T) is varied. Here two controls are possible. • On-time $T_{on}$is kept constant • Off period $T_{off}$is kept constant
16	**What are the different types of chopper with respect to commutation process?** **(**BTL4)

	• Voltage commutated chopper. • Current commutated chopper. • Load commutated chopper.
17	**State voltage commutation.** (BTL1) In this process, a charged capacitor momentarily reverse biases the conducting thyristor and turn it off.
18	**What is meant by current commutation?** **(**BTL1) In this process, a current pulse is made to flow in the reverse direction through the conducting thyristor and when the net thyristor current becomes zero, it is turned off.
19	**What is meant by load commutation?** **(**BTL1) In this process, the load current flowing through the thyristor either becomes zero or is transferred to another device from the conducting thyristor.
20	**What are the advantages of load commutated chopper?** (BTL4) • Commutating inductor is not required. • It is capable of commutating any amount of load current. • It can work at high frequencies in the order of kHz.
	Part-B
1	**Explain about the current commutation in chopper. (13M) (NOV/DEC-2012)** **(** BTL2) **Answer:Page:A.9- J.GNANAVADIVEL** • Draw the circuit diagram (3M)  • Explain its operation (4M) 1. Capacitor charged to Vs, main thyristor T1 fired at t = 0. So that load voltage Vo = Vs. 2. At t = t1, auxiliary thyristor turned on to commutate main thyristor. 3. With turning on of TA, an oscillatory current set up in circuit. $$i_c = \frac{V_s}{\omega_o L} \sin\omega_o t = V_s\sqrt{\frac{C}{L}} \sin \omega_o t.$$ 4. At t2, Vc = - Vs and ic tends to reverse in the auxiliary thyristor TA, it gets naturally commutated.

5. As TA reverse biased and turned off at t2. Oscillatory current ic begins flow through C, L, D2 and T1

- Draw & explain about output voltage and current waveform (6M)

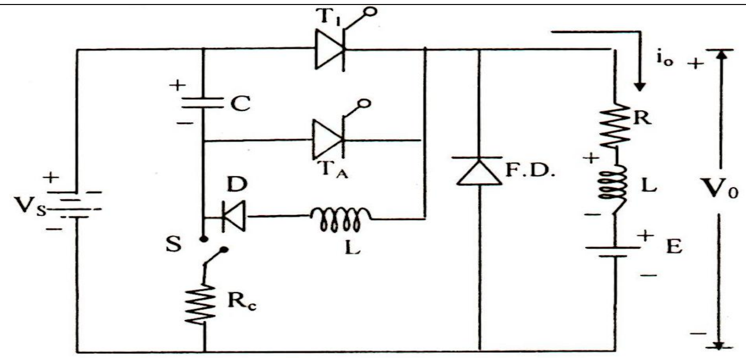


2

Explain the working principle of voltage commutated chopper showing the current and voltage waveform across each device. (13M) (NOV/DEC-2016) **(** BTL2)

Answer: Page:A.3 -J.GNANAVADIVEL

- Draw the circuit diagram (2M)



- Explain its operation (5M)

  1. Voltage commutated thyristor circuit, voltage source impressed across the SCR be turned off, mostly an auxiliary SCR.

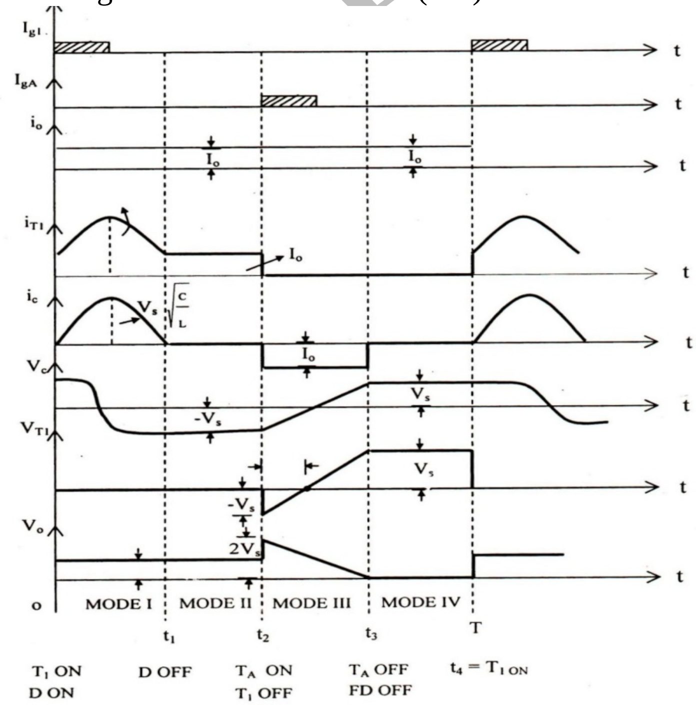
  2. Voltage comparable magnitude operating voltages. Current conducting SCR immediately quenched.

  3. Reverse-biasing voltage maintained period greater than required for device to turn-off.

  4. Large reverse voltage turning it off, device offers the fastest turn-off time obtainable that particular device.

  5. It exposition of 'hard' turn-off reverse biasing stress maximum. T1 is the main SCR and T2 is the Auxiliary.

- Draw the output voltage and current waveform(6M)

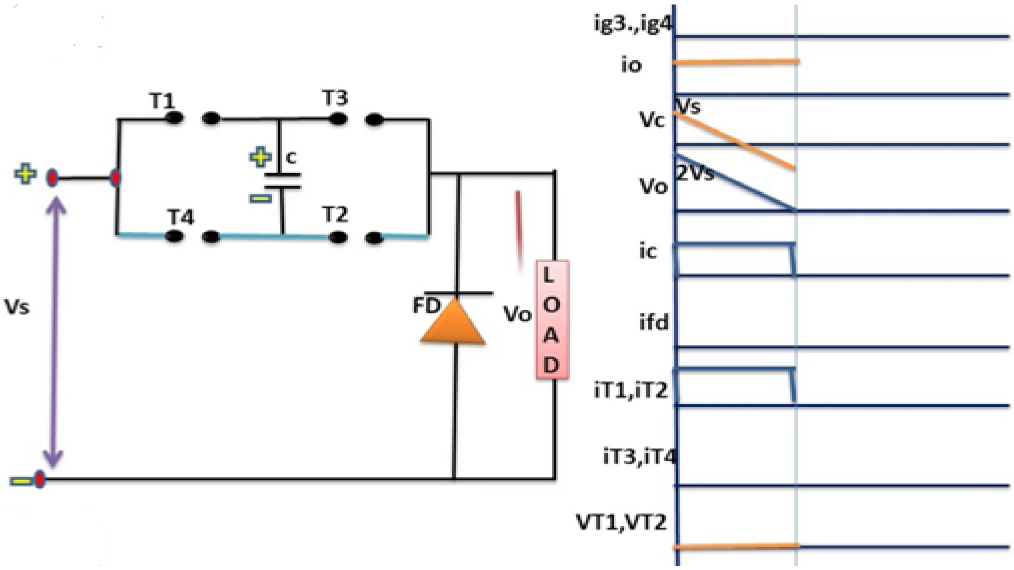
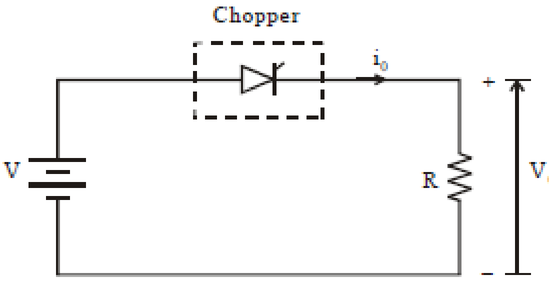


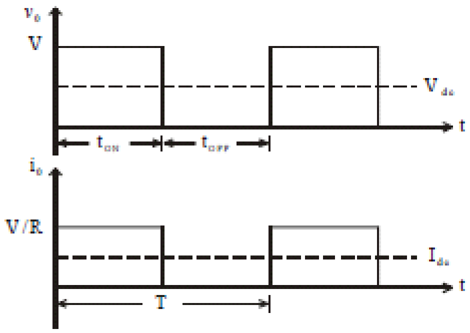
3

What is load commutation in chopper? (13M) **(** BTL2)

Answer: Page:A.16- J.GNANAVADIVEL

- Draw the circuit diagram & output voltage waveform (8M)

	 - Explain its operation (5M) 1. Commutating inductor not required. 2. Capable of commutating any amount load current. 3. Work high frequencies order kHz. 4. Filtering requirements minimal
4	**Elaborate Step down chopper with neat diagram and waveform. (13M) (NOV/DEC-2010)(NOV/DEC-2008)** (BTL2) **Answer: Page: 4.12- J.GNANAVADIVEL** - Draw step down chopper diagram (4M)  - Draw its waveform & explain (9M)



1. Thyristor circuit acts as switch.
2. When thyristor ON, supply voltage appears across load
3. When thyristor OFF, the voltage across load will zero.

The average output voltage is given as,

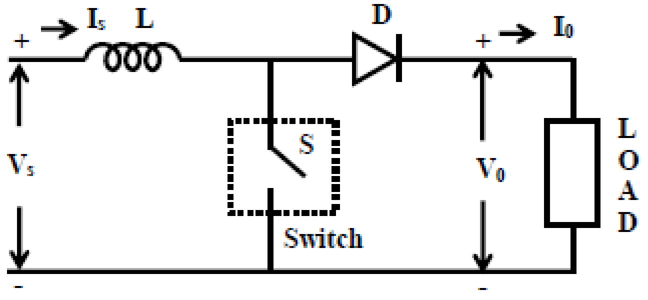
$$V_O = \frac{1}{T}\int_O^{T_{ON}} V_s\, dt$$
$$= \frac{V_s T_{ON}}{T}$$
$$= DV_s$$

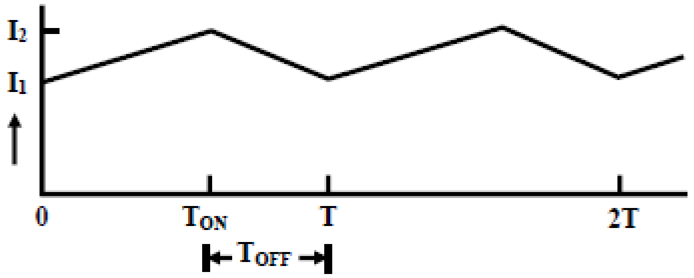
5

Explain Step up chopper with neat diagram and waveform. (13M) (NOV/DEC-2012)

Answer: Page: 4.22 - J.GNANAVADIVEL (BTL2)

- Draw step up chopper diagram (4M)

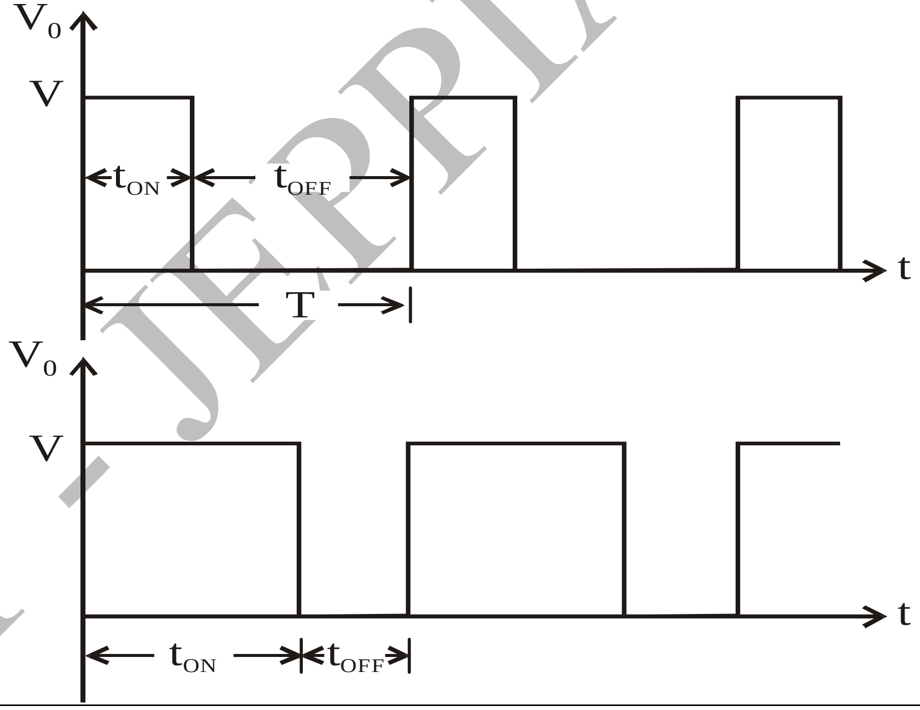




- Draw & explain its waveform (9M)
  1. Step-up chopper used obtain load voltage higher input voltage V. 2.Values L and C chosen depending requirement output voltage, current. 3. When chopper ON, the inductor L connected across supply. Inductor current ‘I’ rises the inductorstoresenergyduringONtimechopper.

<table>
<tr><td></td><td>
4. When the chopper is off, the inductor current I is forced to flow through the diode D and loadforaperiod,t_{OFF}.
5. Current tends decrease resulting reversing polarity induced EMF in L. Therefore voltage across load . $V_0 = V + L\frac{dI}{dt}$
</td></tr>
<tr><td>6</td><td>
Explain the control strategies of chopper. (13M) (APRIL/MAY-2017) (BTL1)
Answer :Page:4.28- J.GNANAVADIVEL

- Mentions its types of control strategies (3M)
  1. Time ratio control 2. Current limit control
- In time ratio control value of duty ratio, K =TON /T is changed.
- ‘K’ is the duty cycle.
- Two ways to achieve time ration control, namely **variable frequency and constant frequency operation.**
- Current value varies between maximum as minimum level of constant voltage.
- DC to DC converter is turned ON & then OFF confirm current preserved constantly.
- Explain each with neat diagram and waveform (10M)



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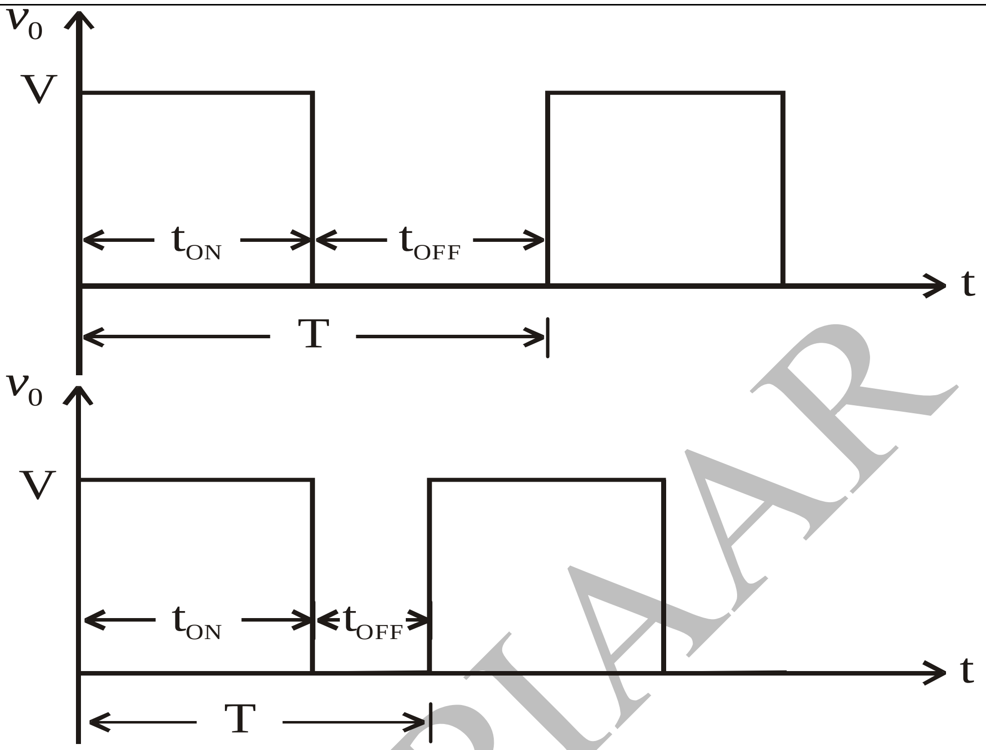
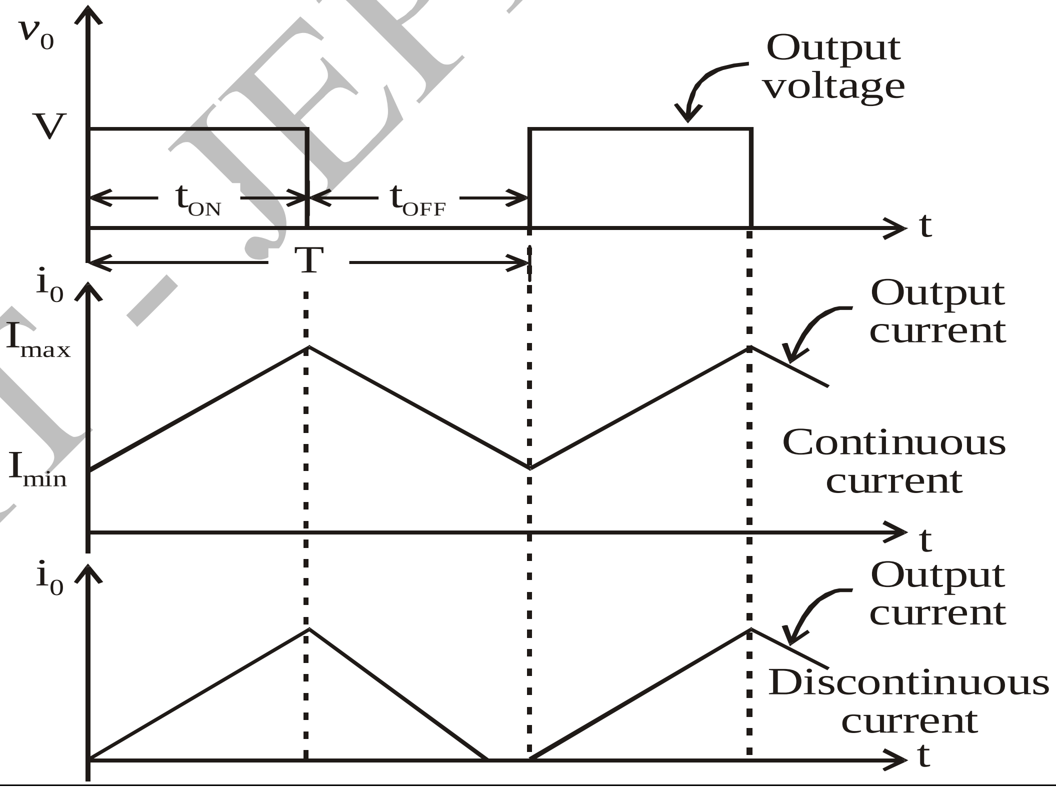
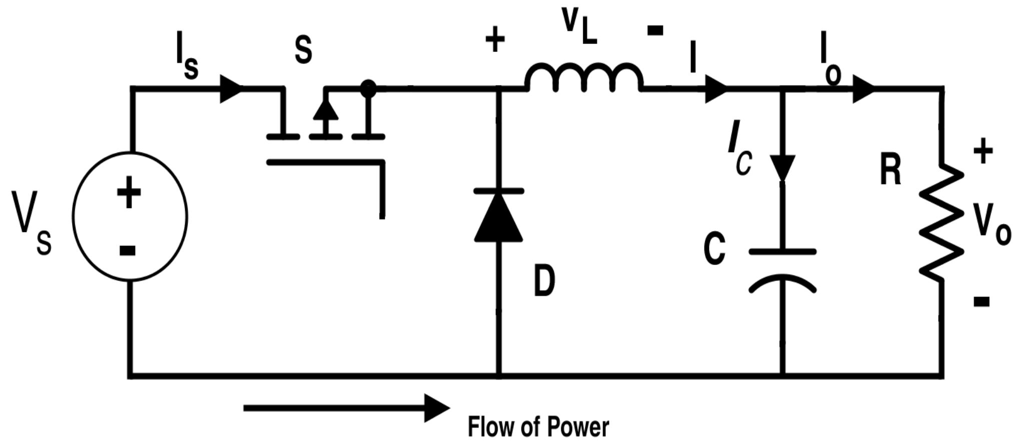
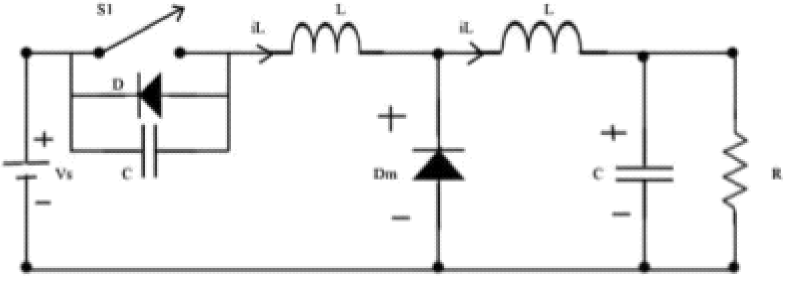
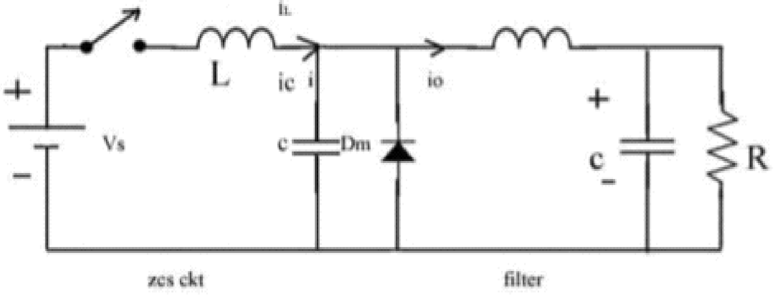
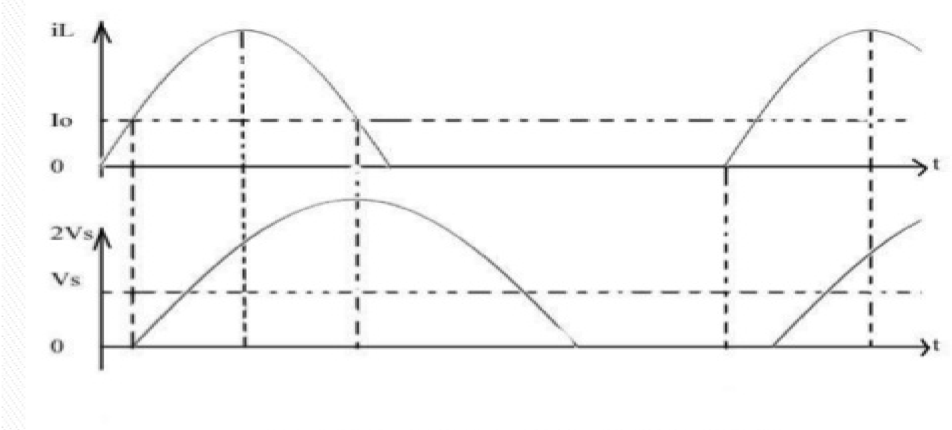
</table>

	 Constant Frequency Operation Current limti control 
7	**Explain about buck converter in chopper. (13M) (NOV/DEC-2007)** BTL2 **Answer :Page:4.40- J.GNANAVADIVEL**

	- Draw the buck converter circuit diagram (3M)  - Derive its expression for output voltage (10M) Vo= α Vs Io= α Io
8	**Explain the principle of operation of resonant converter. (13M)** BTL2 **Answer :Page:4.66- J.GNANAVADIVEL** - Draw the circuit diagram and explain operation (9M)  ZVS Circuit  ZCS Circuit - Draw the output voltage and current waveform (4M)



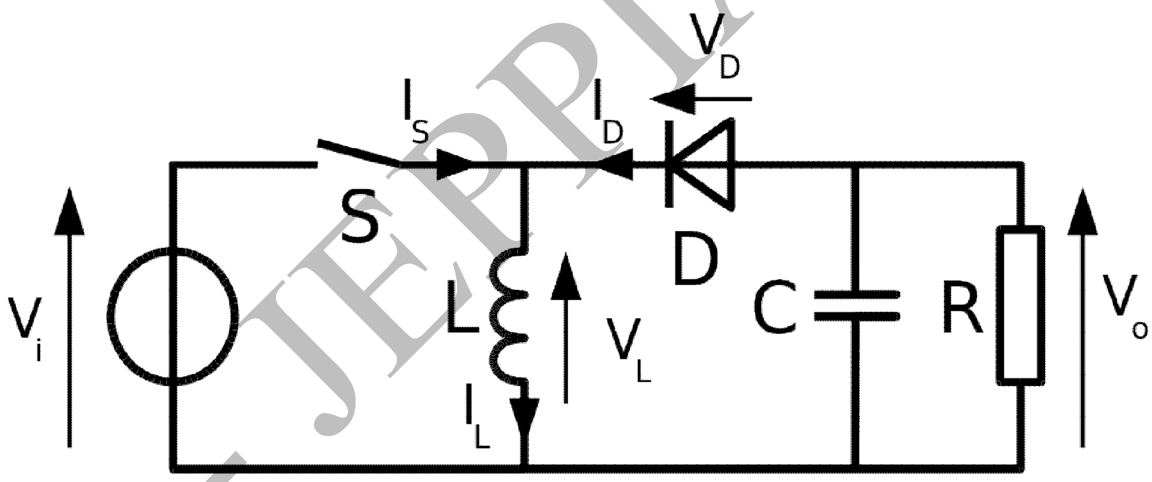
Wave form Dig of ZCS

9

Explain about buck-boost converter in chopper.(13M) (MAY/JUNE-2009) BTL2

Answer : Page:4.53- J.GNANAVADIVEL

- Draw the buck-boost converter circuit diagram (4M)



- Derive its expression for output voltage (9M)

Vo= - α/1-α * Vs

10

A chopper is connected to an inductive load with a resistance of 5Ω. On time and off time of the chopper is 20ms and 10ms respectively. The DC supply voltage is 300V. Estimate i) Duty cycle, ii) Chopping Frequency iii) Average load voltage iv) Average load current. (13M) BTL3

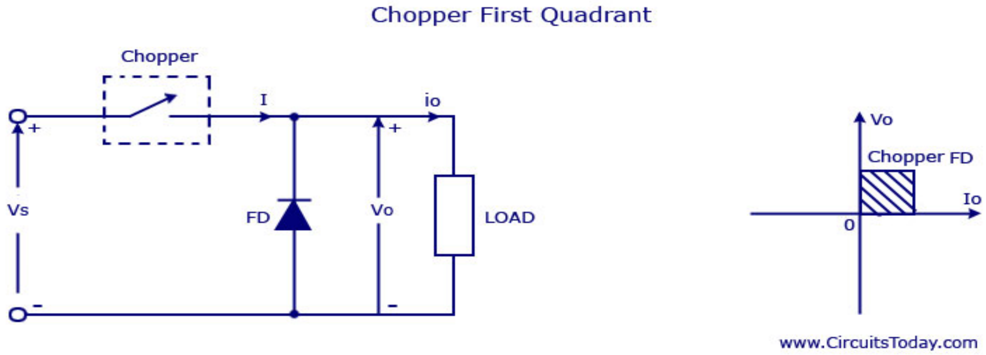
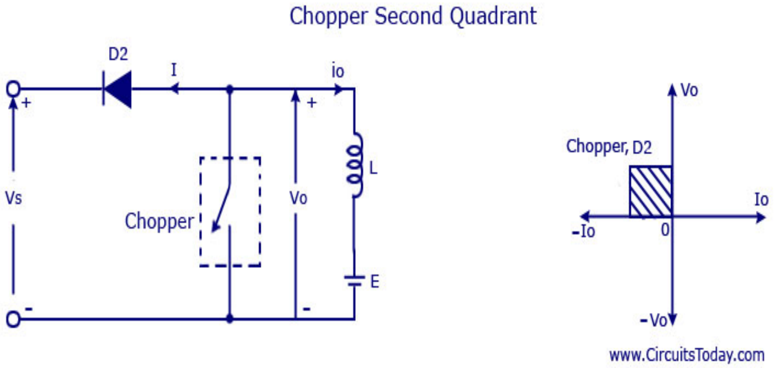
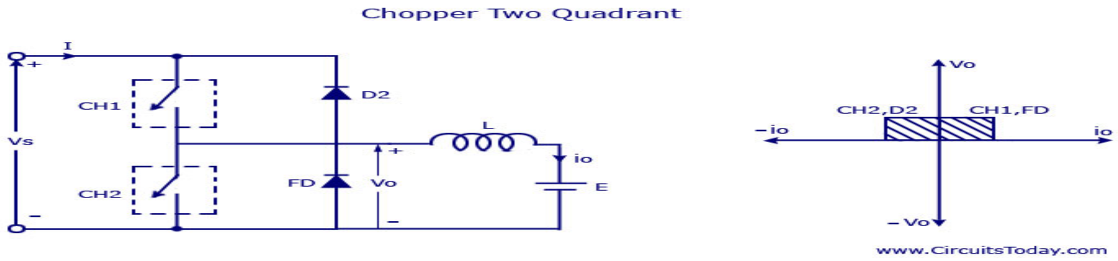
Answer: Page:4.8- J.GNANAVADIVEL

- Find the duty ratio (3M)
- Chopping frequency (3M)
- Average load voltage (3M)
- Average load current (4M)

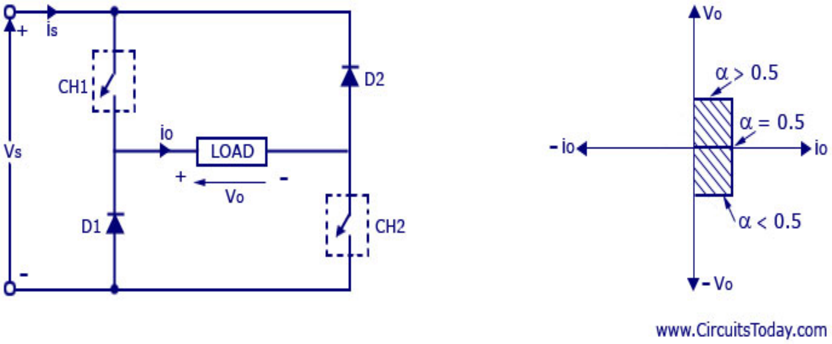
Duty ratio , α= Ton/T= 0.666

Chopping frequency, f= 1/T= 33.33Hz

Average load voltage= V0= Vs.α= 199.8 V

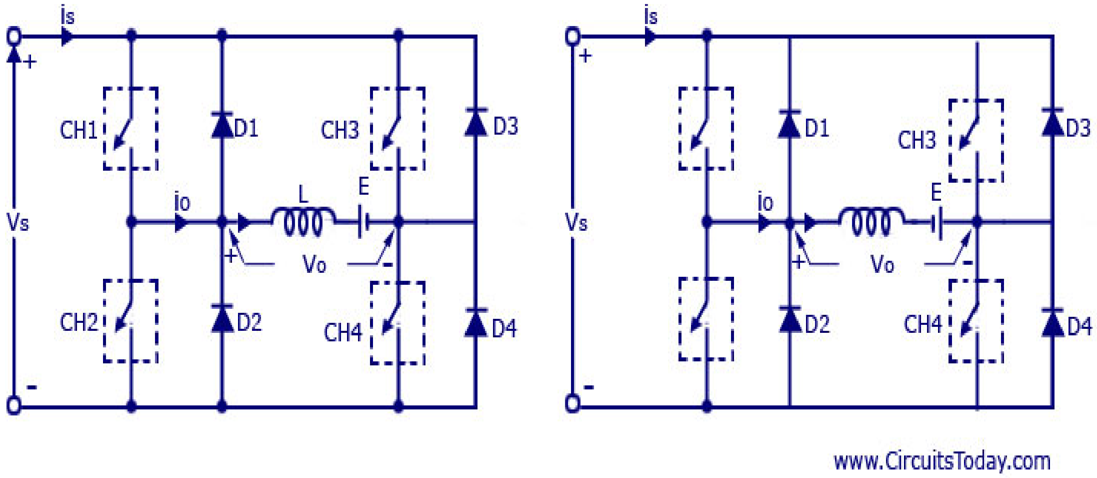
	Average Load current = Io= 39.96A
	Part-C (15 Marks)
1	**Explain about Types of commutation in chopper. (15M)(NOV/DEC-2013) BTL2** **Answer:Page:A.2- J.GNANAVADIVEL** - Mention its different types (4M) - Explain each type with neat diagram (11 M) 1. Type-A  2. Type-B  3. Type-c  4. Type-d

Two Quadrant Type B-chopper or D-chopper Circuit



5. Type-e

E-type Chopper Circuit Diagram With Load emf E and E Reversed



2

What is Switched mode regulator? Explain any two types of Switched mode regulator. (15M)(MAY/JUNE-2009) BTL2

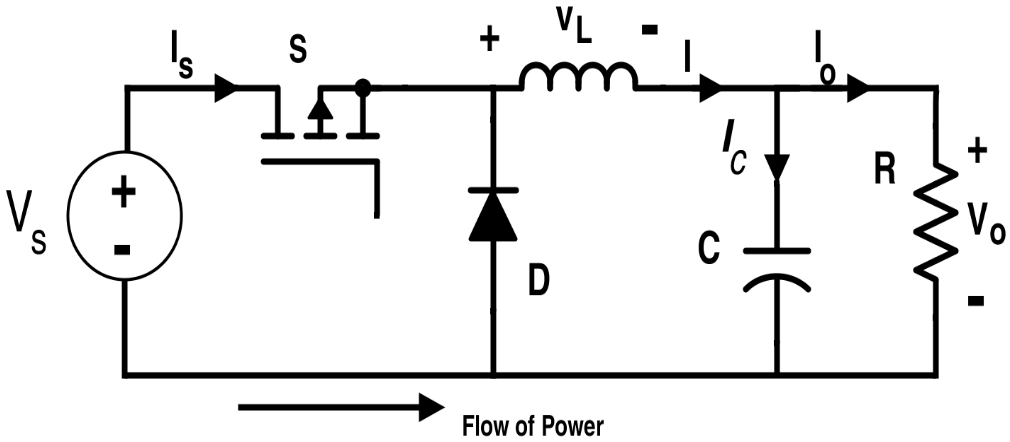
Answer: Page:4.39 - J.GNANAVADIVEL

- Define switched mode regulator (2M)

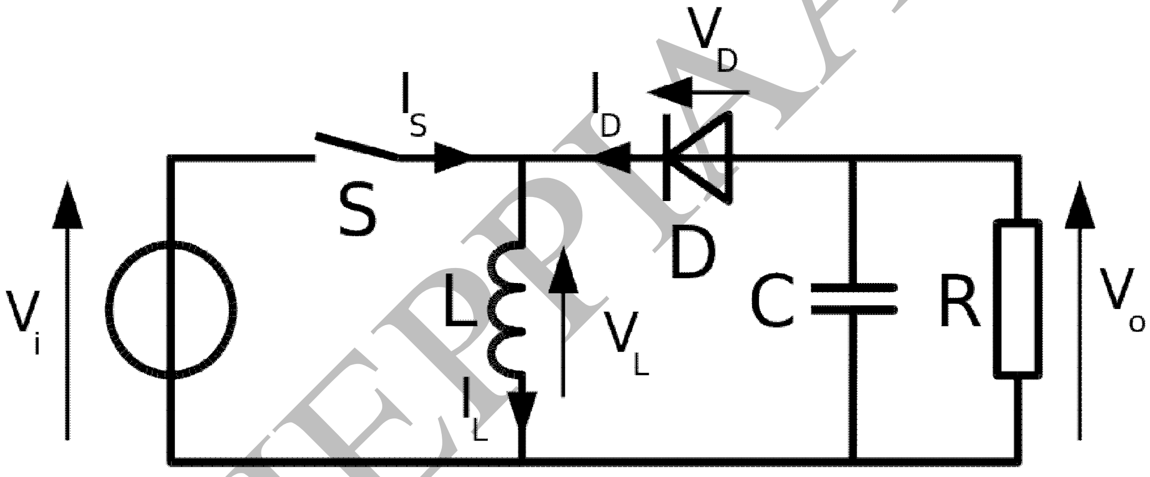
Switching mode regulators convert unregulated dc input voltage to a regulated dc output voltage.

- Block diagram (4M)
- Types of switched mode regulator and explain each (7M)

1. Buck converter 2. Boost regulator 3. Buck-Boost Regulator



[a] Buck converter



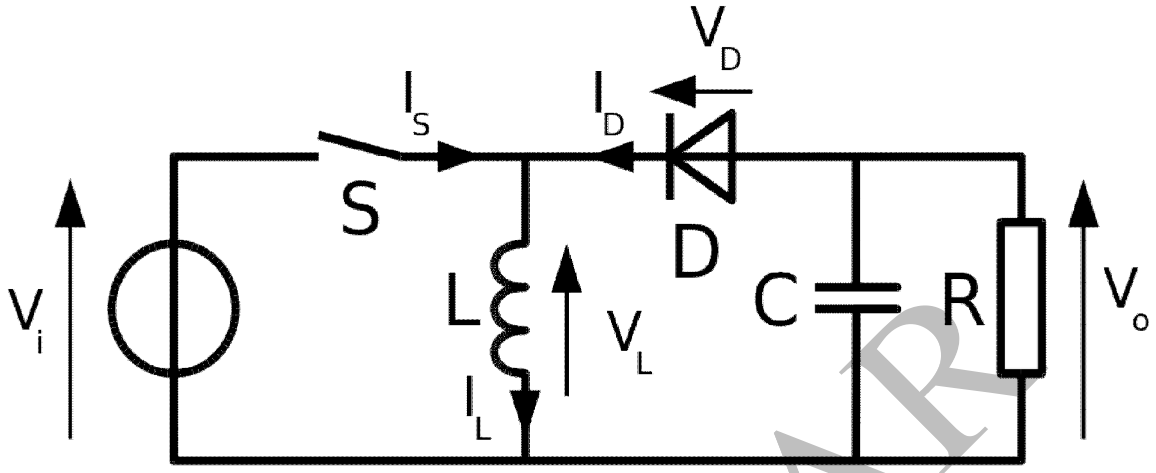
[b] Buck-Boost converter

3

Derive the expression for voltage gain in a dc-dc boost converter and explain the modes of operation with relevant waveforms. (15M) (NOV/DEC-2016,MAY/JUNE-2009) BTL2

Answer: Page:4.46- J.GNANAVADIVEL

- Draw the boost converter circuit diagram (3M)

	 • Derive its expression for output voltage (10M) Vo= 1/1-α* Vs

UNIT IV – INVERTERS	
Single phase and three phase voltage source inverters (both120^{0}modeand180^{0}mode)–Voltage& harmonic control--PWM techniques: Sinusoidal PWM modified sinusoidal PWM - multiple PWM – Introduction to space vector modulation –Current source inverter.	
PART * A	
Q.No.	**Questions**
1.	**What is meant by inverter?** (BTL1) A device that converts dc power into ac power at desired output voltage and frequency is called an inverter.
2	**What are the applications of an inverter?(MAY-2004)** (BTL1) ➢ Adjustable speed drives ➢ Induction heating ➢ Stand-by aircraft power supplies ➢ UPS ➢ HVDC transmission
3	**Write the main classification of inverter.** **(**BTL2) ➢ Voltage Source Inverter ➢ Current Source Inverter
4	**Why thyristors are not preferred for inverters?** (BTL1) Thyristors require extra commutation circuits for turnoff which results increased complexity of the circuit. For these reasons thyristors are not preferred or inverters.
5	**How output frequency is varied in case of a thyristor?** (BTL1) The output frequency is varied by varying the turn off time of the thyristors in the inverter circuit, i.e. the delay angle of the thyristors is varied.
6	**Give two advantages of CSI. (DEC-2006)** (BTL4) ➢ CSI does not require any feedback diodes. ➢ Commutation circuit is simple as it involves only thyristors.

7	**Why diodes should be connected in anti parallel with the thyristors in inverter circuits?** (BTL4) For RL loads, load current will not be in phase with load voltage and the diodes connected in anti parallel will allow the current to flow when the main thyristors are turned off. These diodes are called feedback diodes.
8	**What is meant by series inverter?** (BTL1) An inverter in which the commutating elements are connected in series with the load is called a series inverter.
9	**What is meant by parallel inverter?** (BTL1) An inverter in which the commutating elements are connected in parallel with the load is called a parallel inverter.
10	**What are the applications of a series inverter?** (BTL3) The thyristor is series inverter produces an approximately sinusoidal wave format a high output frequency, ranging from 200 Hz to 100 kHz. It is commonly used for fixed output applications such as ➢ Ultrasonic generator. ➢ Induction heating. ➢ Sonar Transmitter
11	**How the inverter circuit classified based on commutation circuitry?** (BTL1) ➢ Line commutated inverters. ➢ Load commutated inverters. ➢ Self commutated inverters. ➢ Forced commutated inverters.
12	**What is meant by McMurray inverter?** (BTL2) It is an impulse commutated inverter which relies on LC circuit and an auxiliary thyristor for commutation in the load circuit.
13	**Write the applications of a CSI.** (BTL4) ➢ Induction heating ➢ Lagging VAR compensation ➢ Speed control of ac motors ➢ Synchronous motor starting.
14	**What is meant by PWM control?(MAY-2005**) (BTL1) In this method, a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is the most popular method of controlling the output voltage and this method is termed as PWM control.
15	**What are the advantages of PWM control**? (BTL4) ➢ The output voltage can be obtained without any additional components. ➢ Lower order harmonics can be eliminated or minimized along with its output voltage control. As the higher order harmonics can be filtered easily, the filtering requirements are minimized.
16	**Write the disadvantages of the harmonics present in the inverter system.** (BTL4) ➢ Harmonic currents will lead to excessive heating in the induction motors. This will reduce the load carrying capacity of the motor. ➢ If the control and the regulating circuits are not properly shielded, harmonics from power ride can affect their operation and malfunctioning can result. ➢ Harmonic currents cause losses in the ac system and can even sometime producer on the system. Under resonant conditions, the instrumentation and metering can be affected.

- On critical loads, torque pulsation produced by the harmonic current can be useful.

17

What are the methods of reduction of harmonic content.? BTL1)

- Transformer connections
- Sinusoidal PWM
- Multiple commutation in each cycle
- Stepped wave inverters

18

Compare CSI and VSI . (DEC-2007,2006) (BTL4)

S. No.	VSI	CSI
1.	Input voltage is maintained constant	Input current is constant but adjustable
2.	The output voltage does not depend on load	The output current does not depend on the load

19

What are the disadvantages of PWM control? (BTL1)

SCRs are expensive as they must possess low turn-on and turn-off times.

20

What are the performance parameter of PWM inverter?(DEC-2009) **(**BTL1)

- Harmonic factor
- Total harmonic distortion
- Distortion factor
- Lower order harmonic

Part *B

1

Discuss the operation of 1 phase full bridge inverter, with the neat sketch and output waveforms. (13M) (NOV/DEC-2010) BTL2

Answer : Page : 5.5 - J.GNANAVADIVEL

- Draw the neat circuit diagram of 1 phase full bridge inverter (4M)

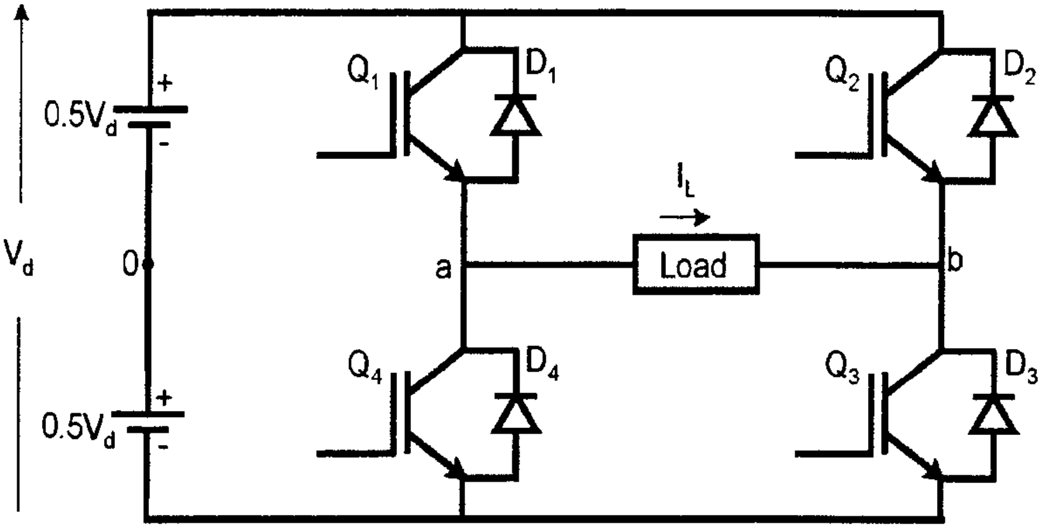
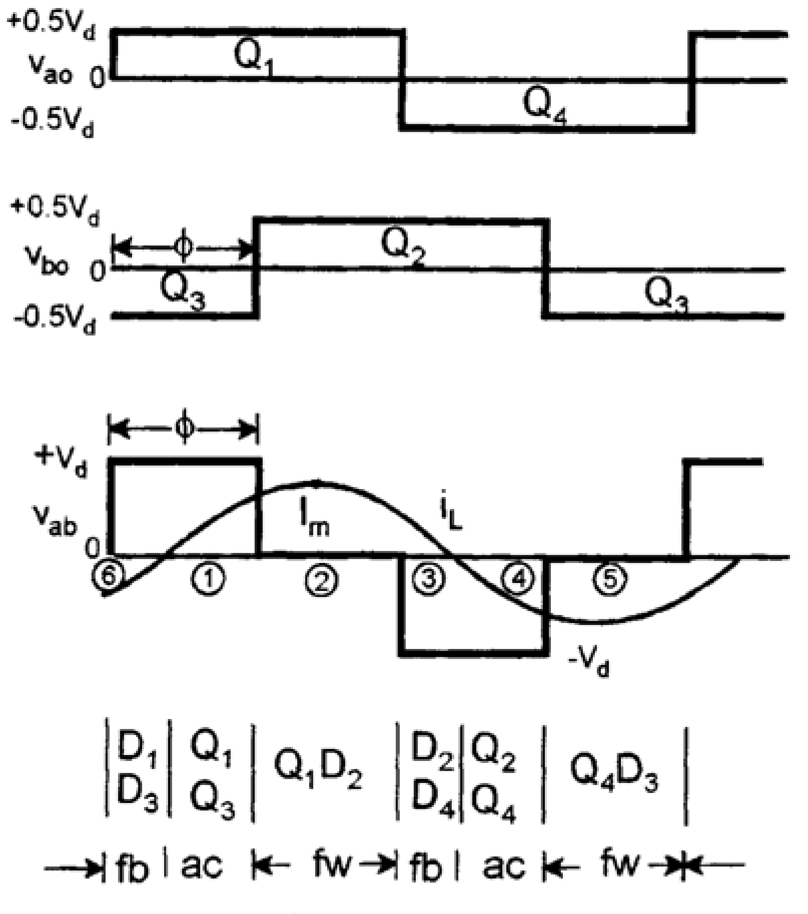


Figure 5.3 Single-phase bridge (H-bridge) inverter

- Explain its operation with waveform (9M)



Waveforms for phase-shift control of output voltage

2

Explain any three methods to reduce the harmonic content in the inverter. (13M) (NOV/DEC-2016) BTL2

Answer : Page : 5. 46 - J.GNANAVADIVEL

- Mention the types to reduce harmonics (3M)
    1. single pulse width modulation
    2. Transformer connections
    3. stepped wave inverters
- Explain in brief about each types (10M)

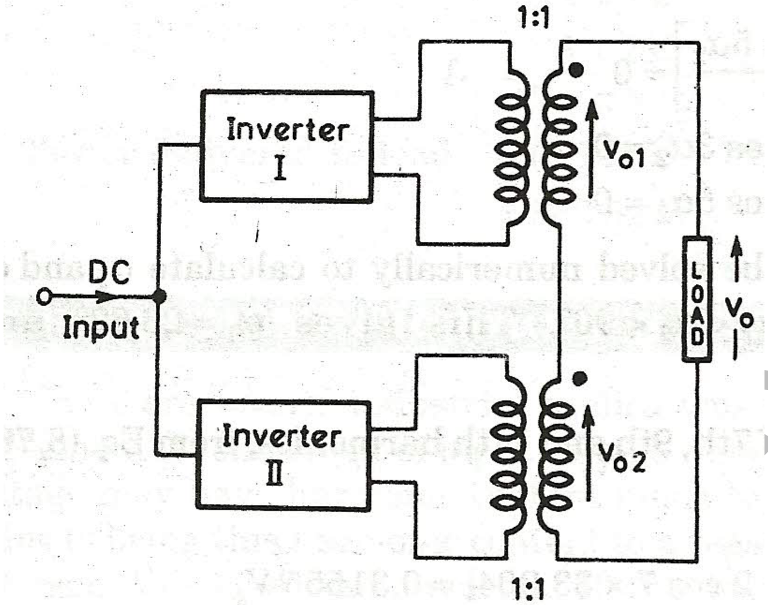
1. single pulse width modulation (3m)

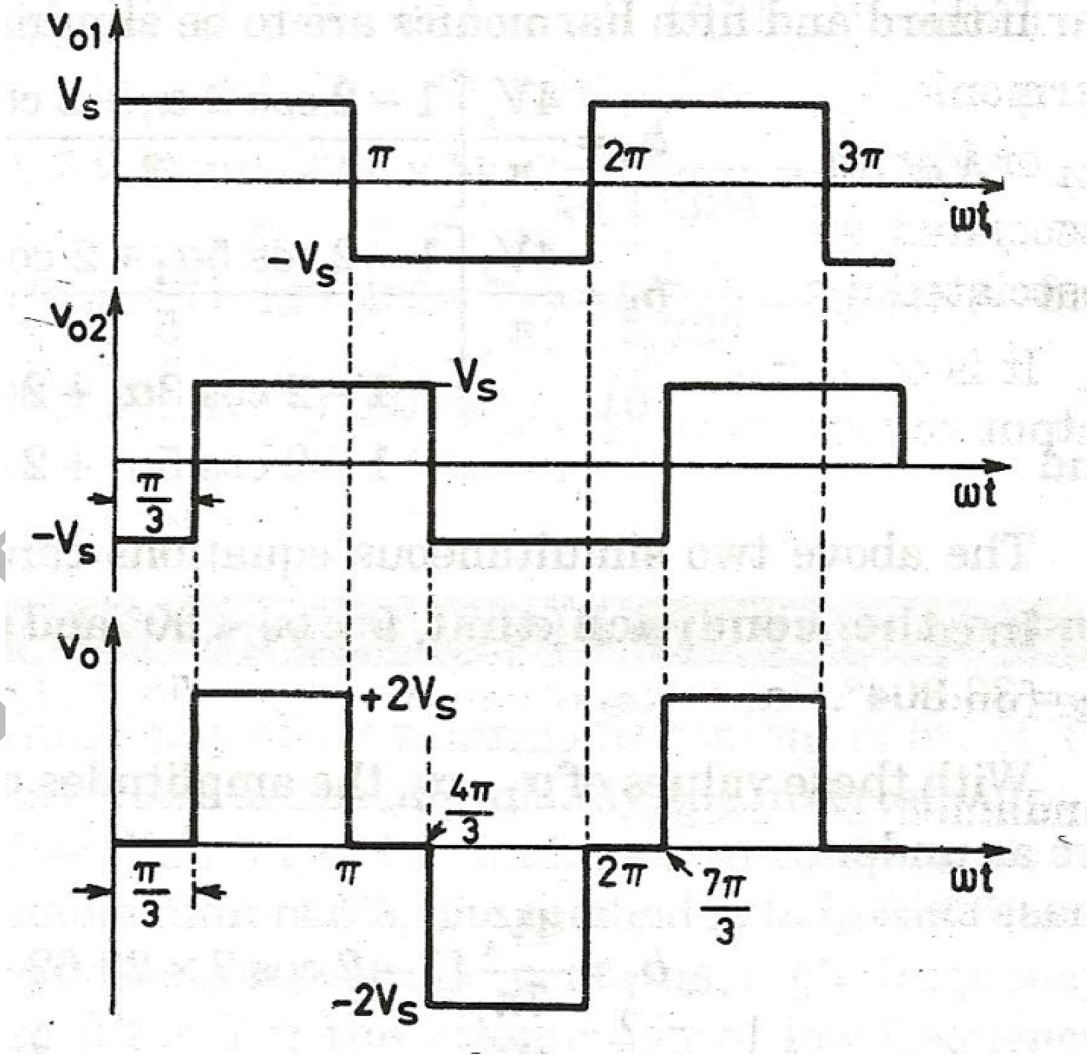
In the case of single pulse width modulation, the width of the3pulse is adjusted to reduce the harmonics.

$$V_{LN} = 4Vs/ (2n\pi)^{1/2} \sin nP/2$$

Where P is the width of the pulse, P=120˚, 72˚ to eliminate 3rd & 5th harmonics.

2. Transformer connection (3m)





3. stepped wave inverters (4m)

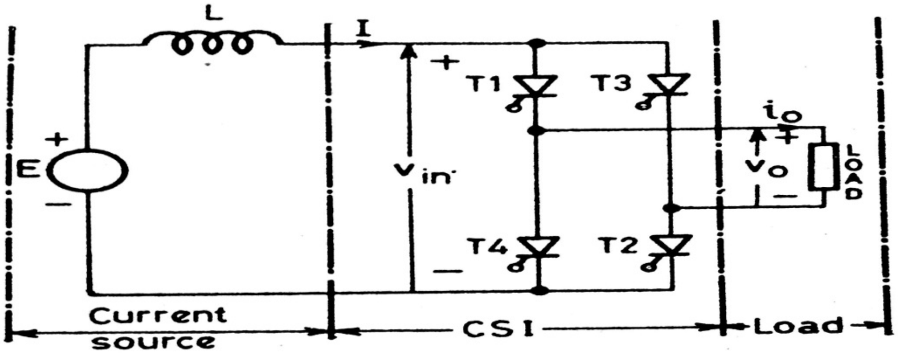
This method may be called as wave stepping, in which pulses of different widths and

<table>
<tr><td></td><td>heights are added to produce a resultant stepped wave reduced harmonics content. These inverters are connected to a common load through transformers having turns ratio of 1:3 and 1:1 respectively.</td></tr>
<tr><td>3</td><td>

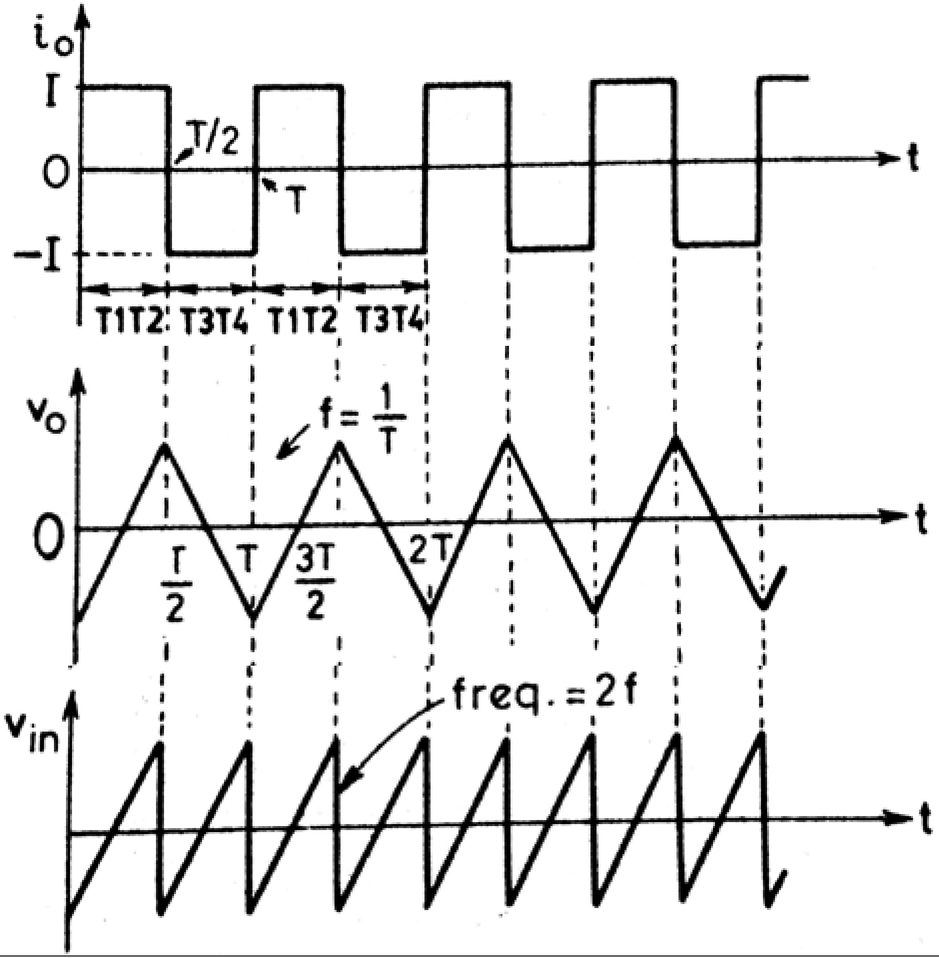
Explain the operation of CSI with relevant waveforms. (13M) (NOV/DEC-2008) BTL2

Answer : Page : 5. 50 - J.GNANAVADIVEL

- Draw the circuit diagram CSI & explain (5M)



- Draw the relevant waveform and explain (8M)



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<tr><td>4</td><td>

Explain Sinusoidal pulse-width modulation with neat waveform. (13 M) (NOV/DEC-2007) BTL1

Answer : Page : 5. 35 - J.GNANAVADIVEL

- Draw the sinusoidal pulse width modulation waveform and explain its operation (13M)

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	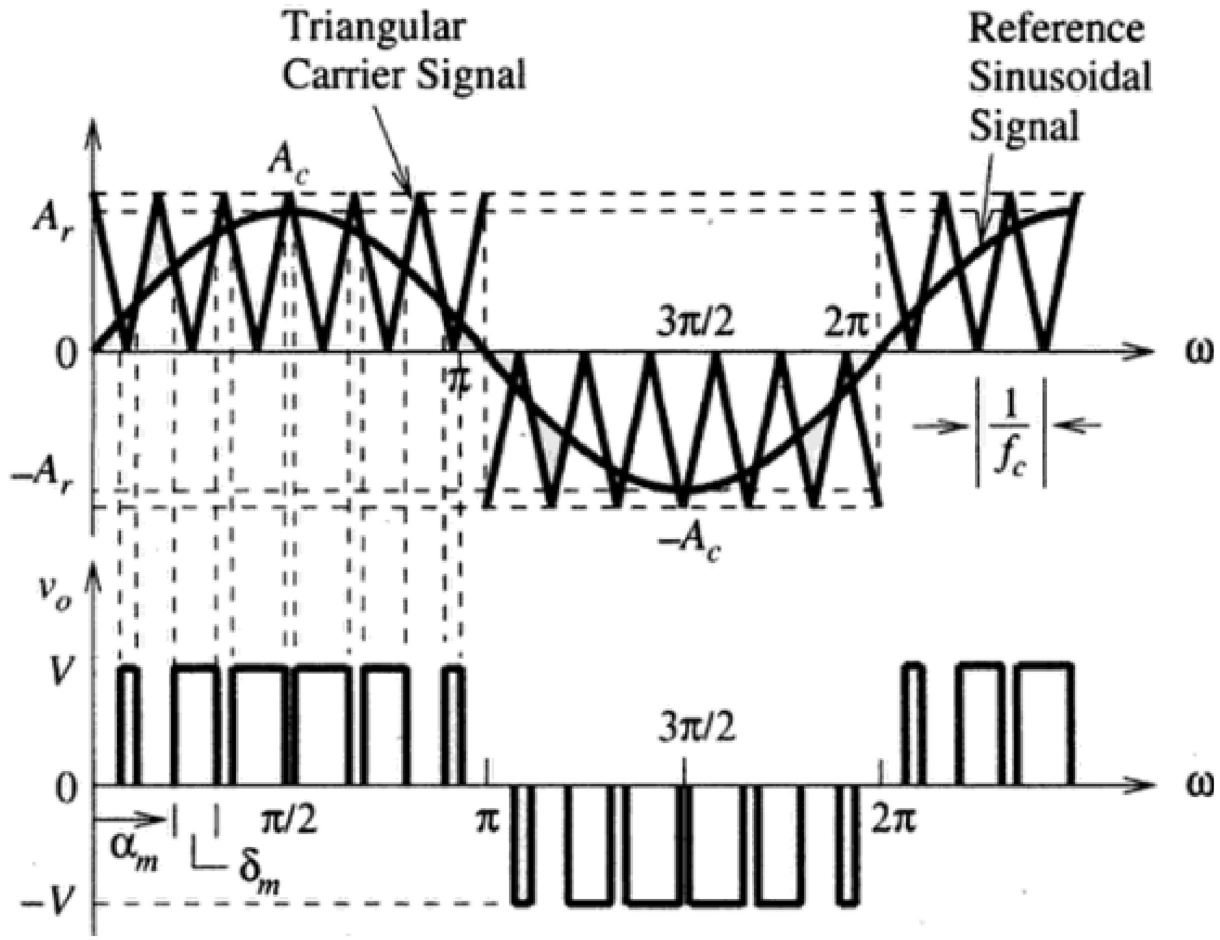 ➢ The most common PWM approach is sinusoidal PWM. ➢ In this method a triangular wave compared to sinusoidal wave of desired frequency. ➢ Relative levels of two waves is used to control the switching of devices in each phase leg of the inverter.
5	**Explain Space vector pulse-width modulation with neat waveform. (13 M)** BTL2 **Answer :Page :5.39- J.GNANAVADIVEL** ➢ Explain space vector concept (5M)

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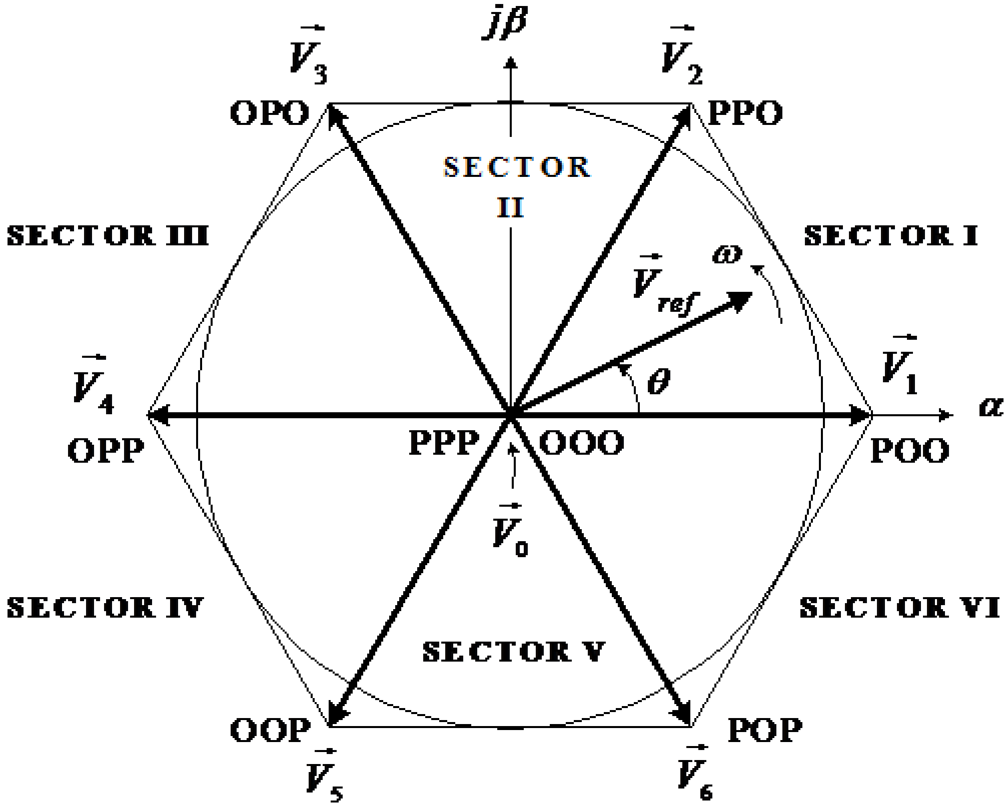
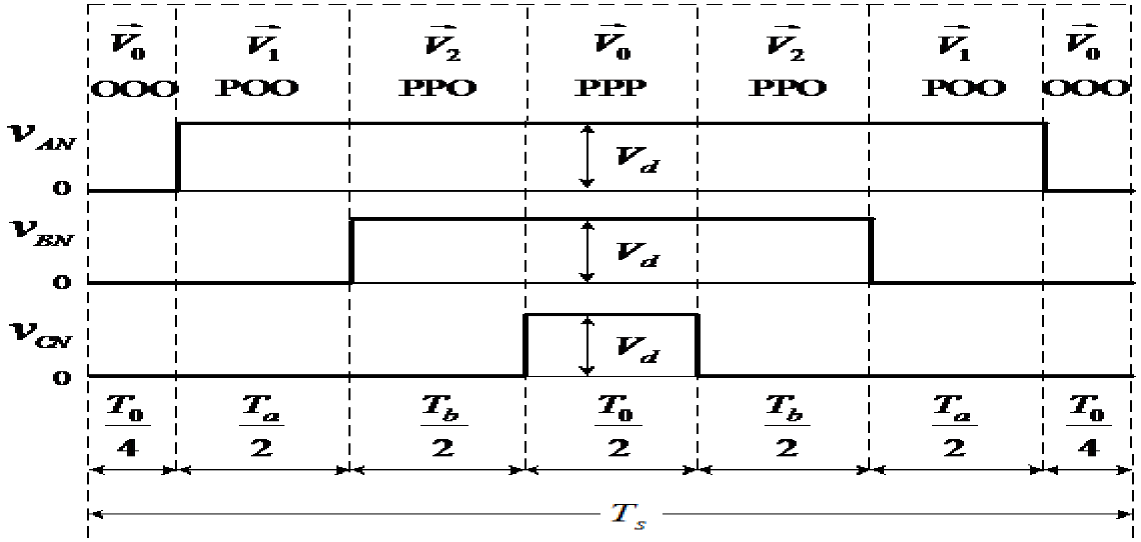


- Draw the space vector truth table (8M)



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Comparison of Sinusoidal pulse-width modulation and Space vector pulse-Modulation. (13M) BTL4

Answer: Page :5.39- J.GNANAVADIVEL

- Explain the comparison between sinusoidal pwm and space vector pwm (13M)

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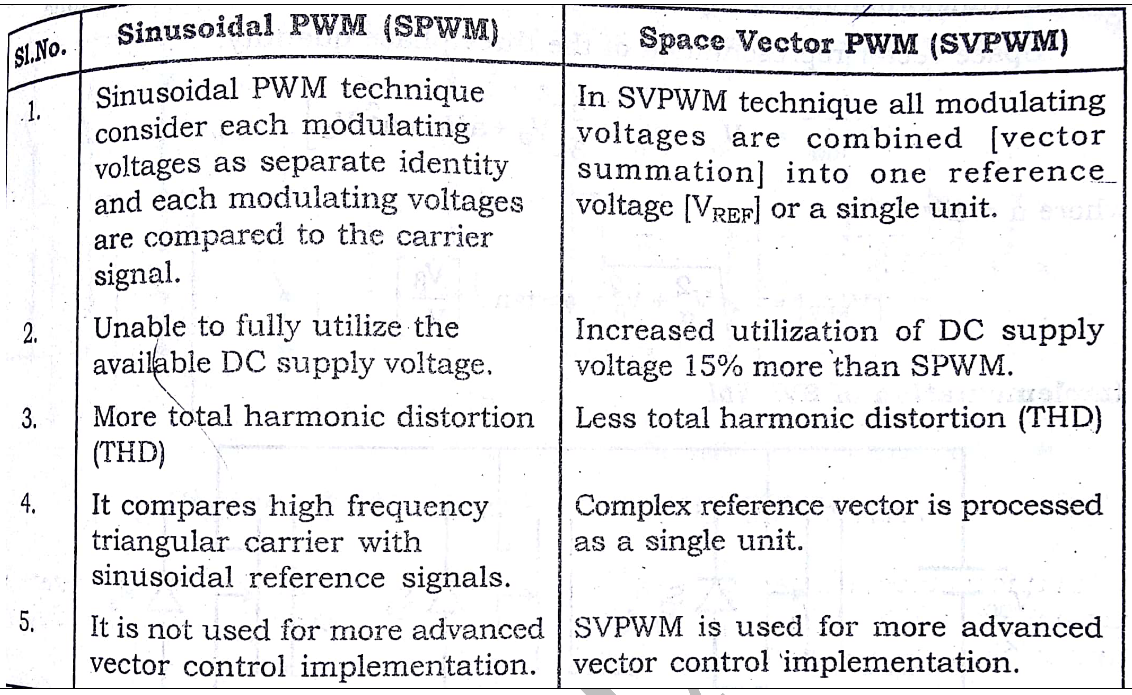


Sl.No.	Sinusoidal PWM (SPWM)	Space Vector PWM (SVPWM)
1.	Sinusoidal PWM technique consider each modulating voltages as separate identity and each modulating voltages are compared to the carrier signal.	In SVPWM technique all modulating voltages are combined [vector summation] into one reference voltage [V_{REF}] or a single unit.
2.	Unable to fully utilize the available DC supply voltage.	Increased utilization of DC supply voltage 15% more than SPWM.
3.	More total harmonic distortion (THD)	Less total harmonic distortion (THD)
4.	It compares high frequency triangular carrier with sinusoidal reference signals.	Complex reference vector is processed as a single unit.
5.	It is not used for more advanced vector control implementation.	SVPWM is used for more advanced vector control implementation.

Part*C

1

With the neat sketch and output waveforms, Discuss the operation of three phase inverter operating in 180° mode. (15M) (NOV/DEC-2016) (NOV/DEC-2012) (NOV/DEC-2008).

BTL2

Answer :Page :5.22 - J.GNANAVADIVEL

- Draw the circuit diagram (3M)

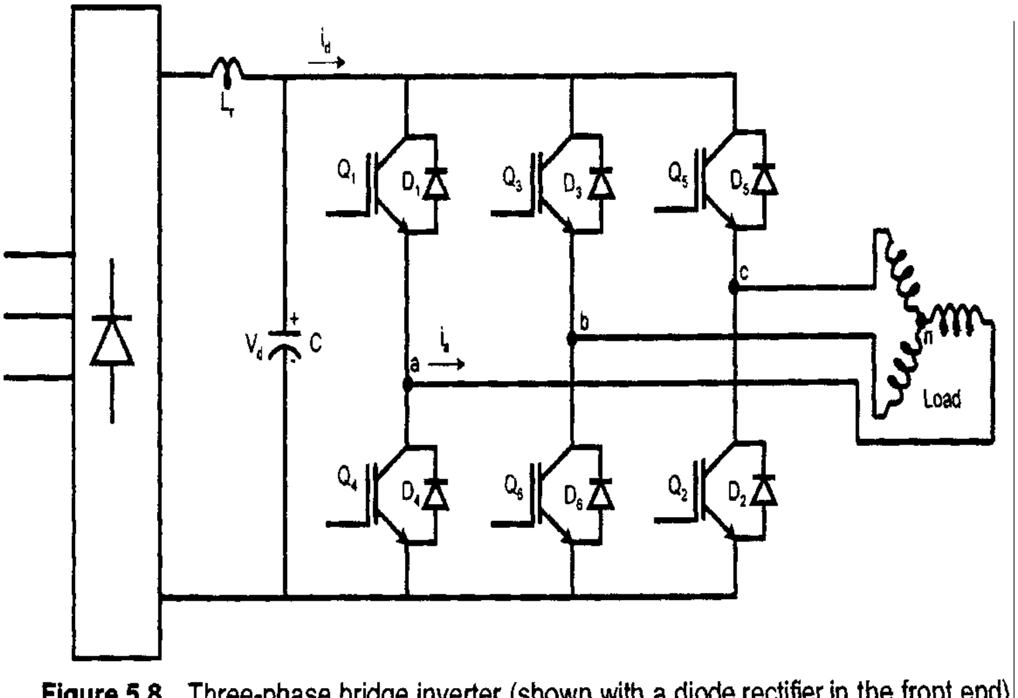


Figure 5.8 Three-phase bridge inverter (shown with a diode rectifier in the front end)

- Equivalent circuit (4M)

- Voltage waveforms for 180 conduction (8M)

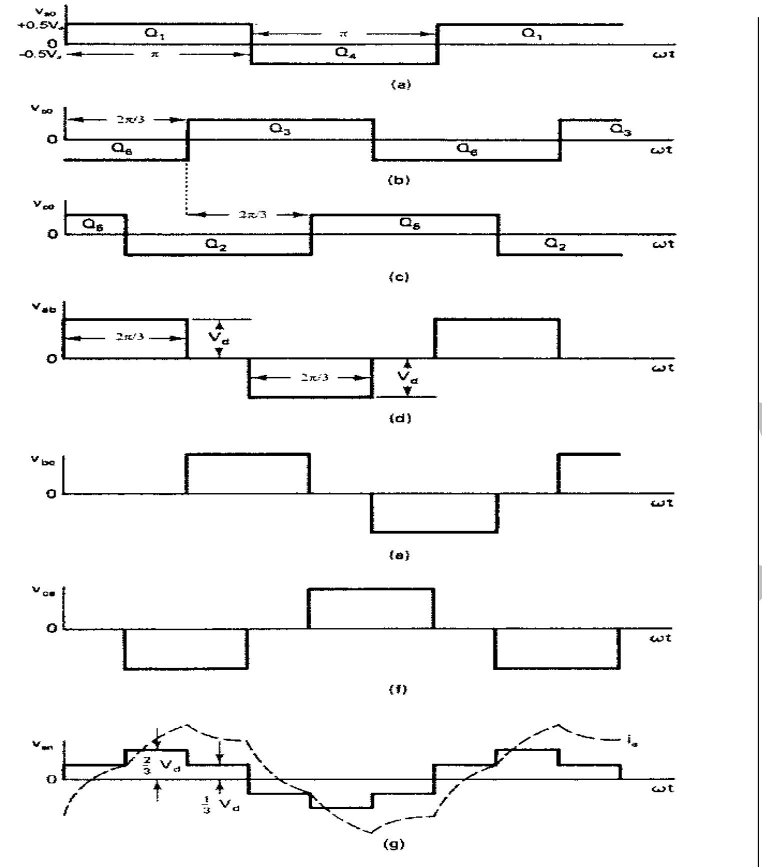
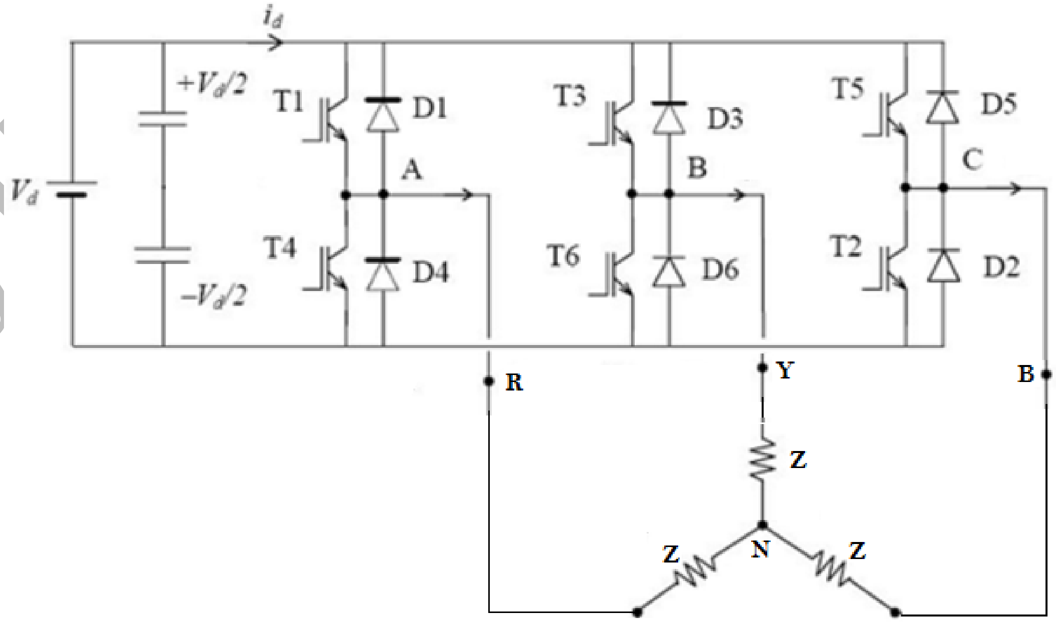


Figure 0.1 Synthesis of output voltage waves in square-wave mode

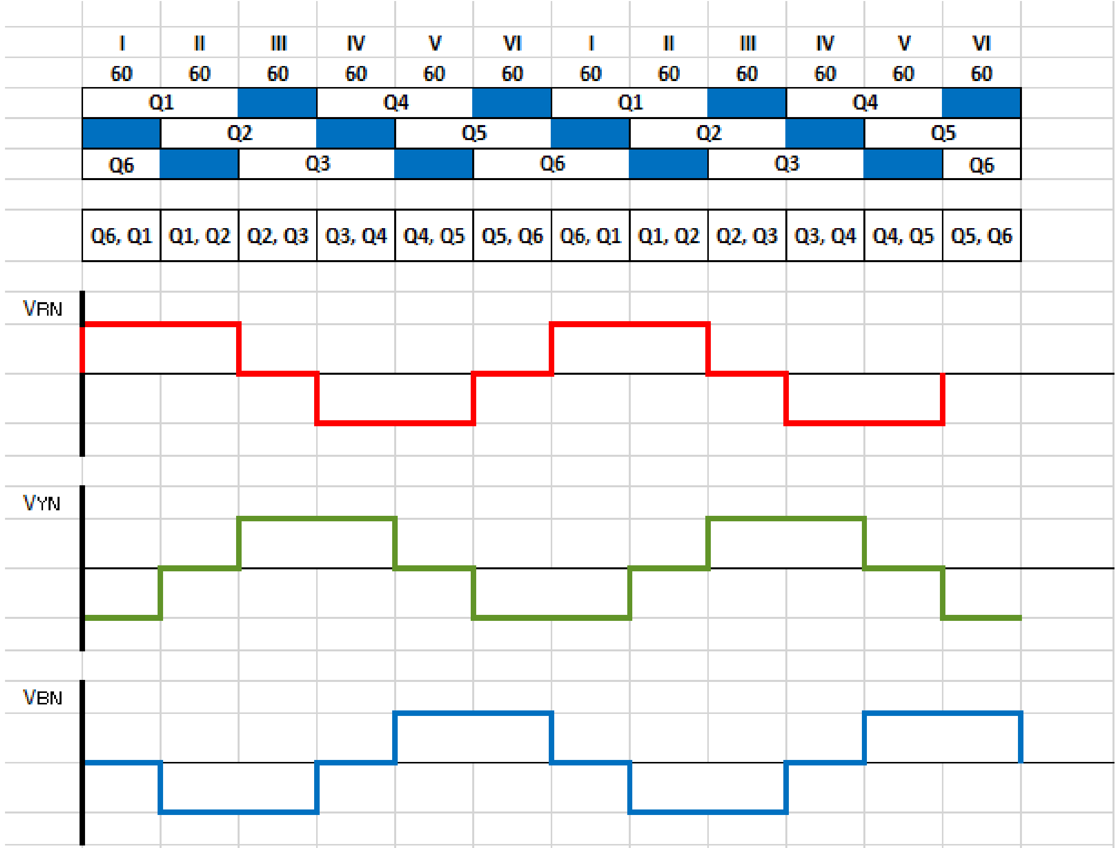
2 **Explain the operation of 3 phase bridge inverter for 120° mode of operation with aid of relevant phase and line voltage waveforms. (15M) (APRIL/MAY-2017)(MAY/JUNE-2009)** BTL2

Answer :Page :5.26 - J.GNANAVADIVEL

- Draw the circuit diagram (3M)



- Voltage waveforms for 120 conduction (12M)



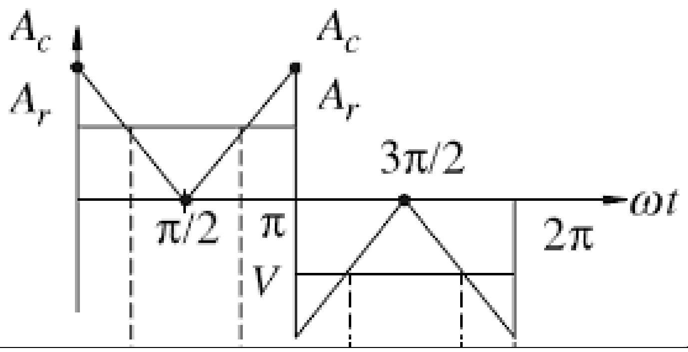
3

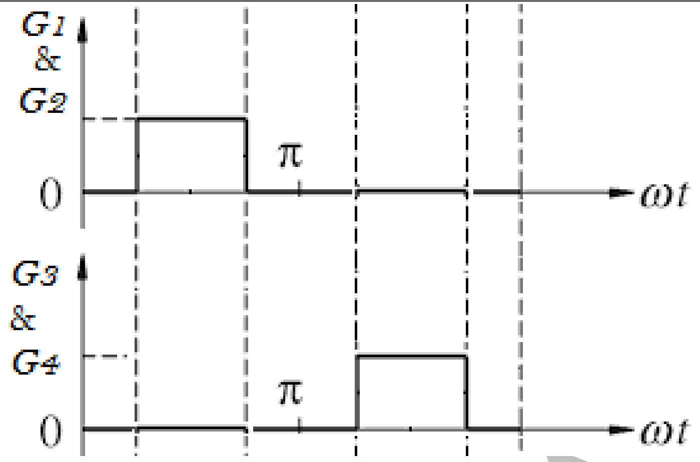
Explain PWM techniques in Inverter with neat waveform. (15M)
(NOV/DEC-2010) (NOV/DEC-2008) BTL 2

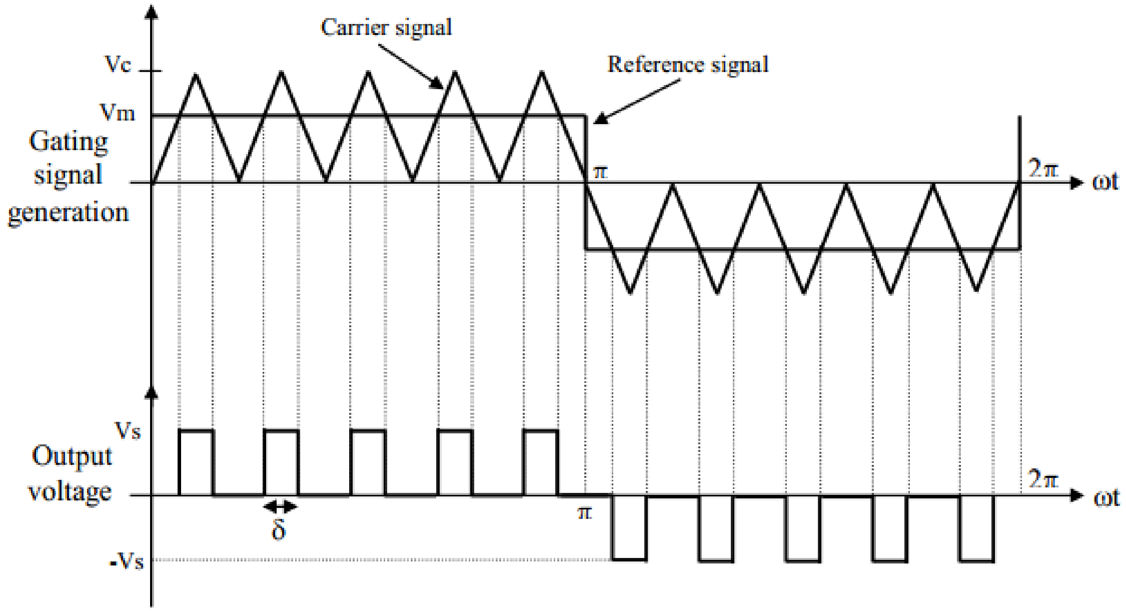
Answer :Page :5.33- J.GNANAVADIVEL

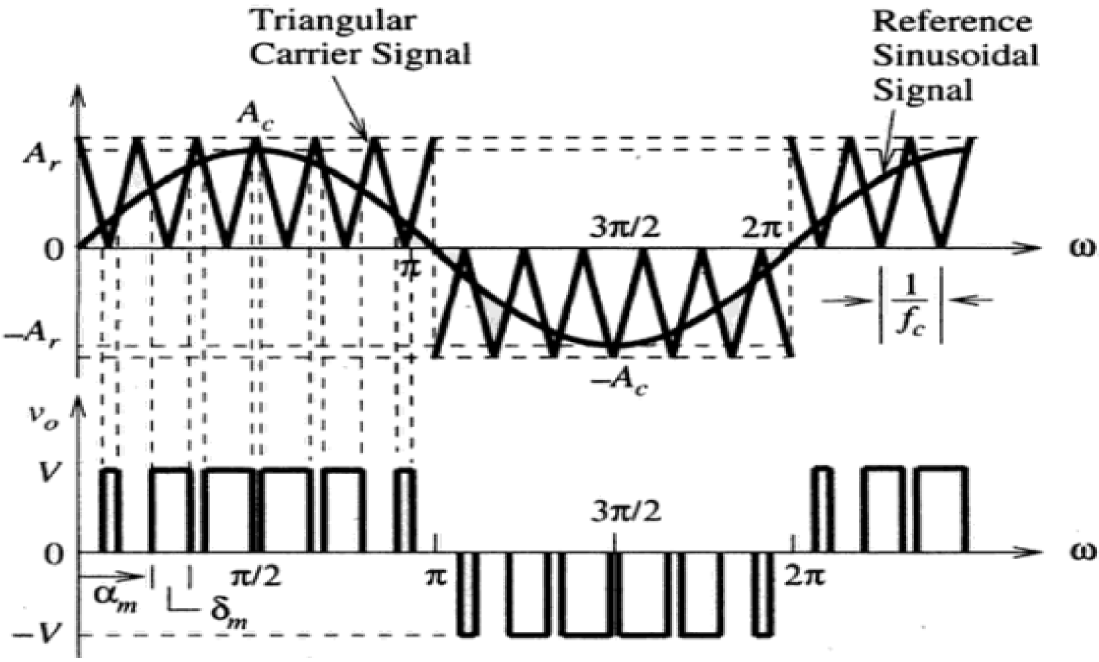
- Types of PWM control techniques (6M)
  1. single pulse width modulation
  2. Multiple pulse width modulation
  3. Sinusoidal pulse width modulation

- Explain each type in control technique (9M)




G1
&
G2
π
0
ωt
G3
&
G4
π
0
ωt


Carrier signal
Reference signal
Vc
Vm
Gating signal generation
π
2π
ωt
Vs
Output voltage
δ
π
-Vs
2π
ωt

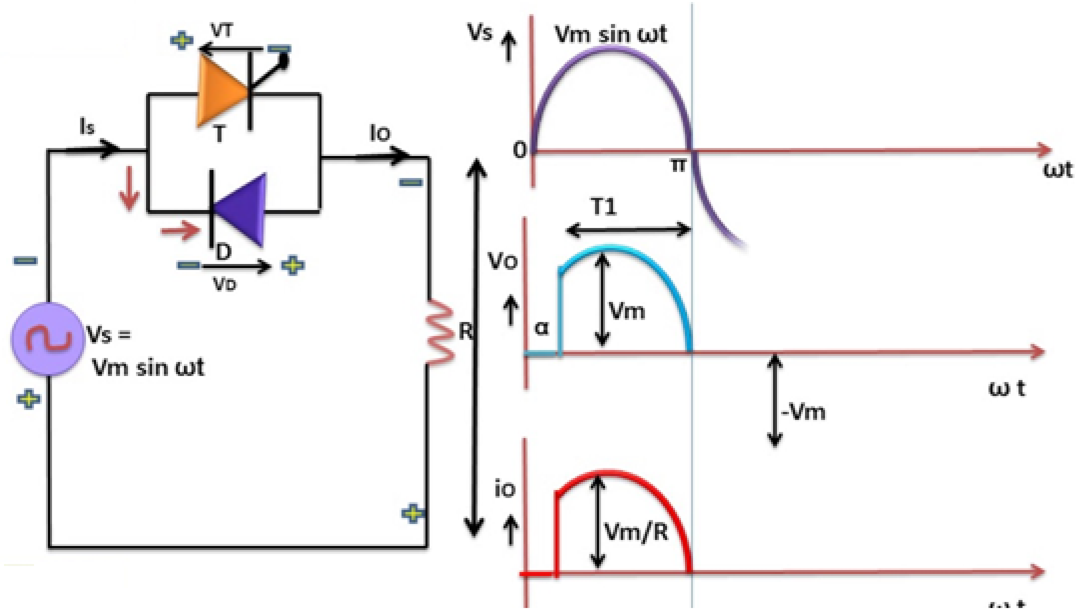
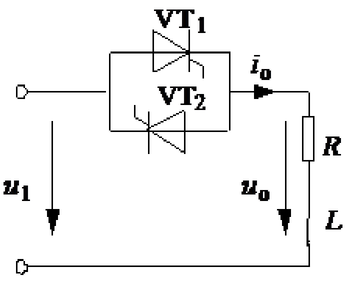
UNIT V - AC TO AC CONVERTERS

Single and three phase ac voltage controller- control strategy- power factor control-Multistage sequence control- single and three phase cyclo converters-Introduction to matrix converters.

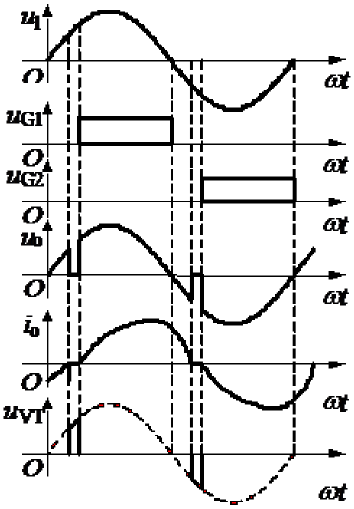
Part*A

Q.No.	Questions
1.	**What does ac voltage controller mean?(DEC-2003)** BTL1 It is device which converts fixed alternating voltage into a variable voltage without change in frequency.
2	**What are the applications of ac voltage controllers?** BTL1 • Domestic and industrial heating • Lighting control • Speed control of single phase and three phase ac motors • Transformer tap changing
3	**What are the advantages of ac voltage controllers? (DEC-2003)** BTL4 • High efficiency • Flexibility in control • Less maintenance
4	**What are the disadvantages of ac voltage controllers? (DEC-2003)** BTL4 The main drawback is the introduction of harmonics in the supply current and the load voltage waveforms particularly at low output voltages
5	**What is the difference between ON-OFF control and phase control?(MAY-2005)** BTL1 In the ON-OFF control method, the thyristors are employed as switches to connect the load circuit to the source for a few cycles of the load voltage and disconnect it for another few cycles. Phase control In this method thyristor switches connect the load to the ac source for a portion of each half cycle of input voltage.

6	**What is meant by bidirectional or full-wave ac voltage controller?(JAN-2008,MAY-2003)** BTL1 In bidirectional ac voltage controller the power flow is controlled during both cycles of the input voltage.
7	**Which type of gating signal is used in single phase ac voltage controller with RL load?** BTL1 High frequency carrier a train signal is used for single phase ac voltage controller with RL load.
8	**What are the disadvantages of continuous gating signal?** BTL2 • More heating of the SCR gate. • Increases the size of pulse transformer.
9	**What is meant by high frequency carrier gating?** BTL1 Thyristor is turned on by using a train of pulses from low to high. This type of signal is called as high frequency carrier gating.
10	**What is meant by sequence control of ac voltage regulators?** BTL1 It means that the stages of voltage controllers in parallel triggered in a proper sequence one after the other so as to obtain available output with low harmonic content.
11	**Explain the advantages of sequence control of ac voltage regulators.** BTL1 • System power factor is improved. • Harmonics are reduced in the source current and the load voltage.
12	**What is meant by cyclo-converter?** BTL1 It converts input power at one frequency to output power at another frequency with one-stage conversion. Cyclo-converter is also known as frequency changer.
13	**What are the two types of cyclo-converters?** BTL1 • Step-upcyclo-converters • Step-downcyclo-converters
14	**What is meant by step-up cyclo-converters?** BTL1 In these converters, the output frequency is less than the supply freque(BTL1)ncy
15	**What are the applications of cyclo-converter?** BTL5 • Induction heating • Speed control of high power ac drives • Static VAR generation • Power supply in air craftorship boards
16	**What is meant by positive converter group in a cyclo-converter?** BTL1 The part of the cyclo-converter circuit that permits the flow of current during positive half cycle of output current is called positive converter group.
17	**What is meant by negative converter group in a cyclo-converter?** BTL4 The part of the cyclo-converter circuit that permits the flow of current during negative half cycle of output current is called negative converter group.
18	**What are the two methods of control in ac voltage controllers?** BTL1 • ON-OFF control • Phase control
19	**What is a matrix converter?** BTL1 Matrix converter is capable of direct conversion from AC to AC by using bidirectional fully controlled switches

20	**What is meant by bidirectional or full-wave ac voltage controller? (JAN-2008,MAY-2003)** BTL1 In bidirectional ac voltage controller power flow is controlled during both cycles of the input voltage.
	Part * B
1	**Explain 1 phase half wave AC Voltage controller with R-Load. Derive the Average output voltage & RMS output voltage with output waveforms. (13M)(NOV/DEC-2010)** BTL2 **Answer: Page: 6.8 - J.GNANAVADIVEL** • Draw the circuit diagram & operation (5M) • Waveform for single phase half wave ac voltage controller (5M)  • Derive its average and rms voltage. (3M) $V_o = V_m/2\pi(\cos \alpha-1)$
2	**Explain 1 phase full wave AC Voltage controller with R-Load, Derive the Average output voltage & rms output voltage with output waveforms. (13M)** BTL2 **Answer : Page :6.14 - J.GNANAVADIVEL** • Draw the circuit diagram ,operation (4M)  **The phase shift range:** $\varphi < \alpha < \pi$

Waveform for single phase half wave ac voltage controller (5M)



- Derive its average and rms voltage. (4M)

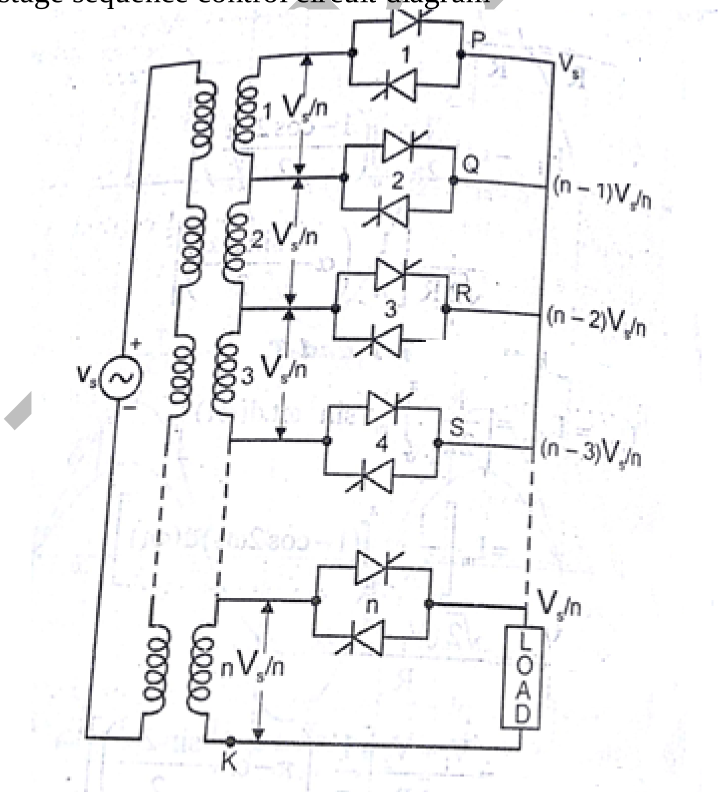
  $V_o = V_m/\prod(\cos\alpha+1)$

3

Explain Multistage Sequential control. (13M)(NOV/DEC-2012) BTL2

Answer: Page:6.36 - J.GNANAVADIVEL

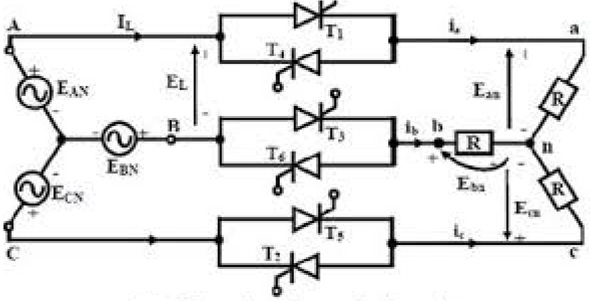
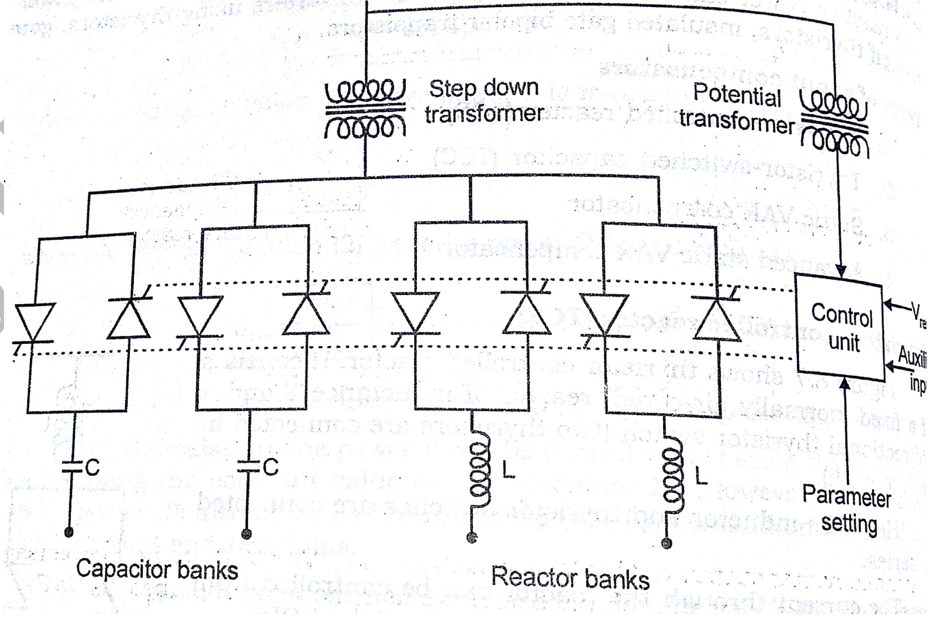
- Draw the multistage sequence control circuit diagram (5M)



Multistage sequence control of AC voltage controllers

- **Explain its operation** (8M)

  1. The reduction of harmonics and improvement of power factor can be increased by using more than two stage control.

	2. Here, the transformer has n secondary windings. 3. Each secondary is rated for Vs/n, where Vs, is source voltage. 4. The presence of harmonics in output voltage depends upon voltage variation.
4	**Explain about 3 ϕ voltage controllers with star connected load. (13M)** BTL2 **Answer : Page: 6.37 – J. Gnanavadivel** - Draw circuit diagram of 3 ϕ voltage controllers (5M)  Three-phase, three-wire Ac regulator - **Explain its operation** (8M) 1. The unidirectional controllers, which contain dc input current and higher harmonic content due to the asymmetrical nature of the output voltage waveform, not normally used in ac motor drives. 2. A three-phase bidirectional control is commonly used. 3. For 0 < α < 60^o: $$V_o = \sqrt{6}V_s\left[\frac{1}{\pi}(\frac{\pi}{6}-\frac{\alpha}{4}+\frac{\sin 2\alpha}{8})\right]^{1/2}$$
5	**Explain about power factor control and Static Var Compensator. (13M) (NOV/DEC-2008)** BTL2 **Answer : Page: 8.8 – J. Gnanavadivel** - Draw the static Var compensator diagram (5M) 

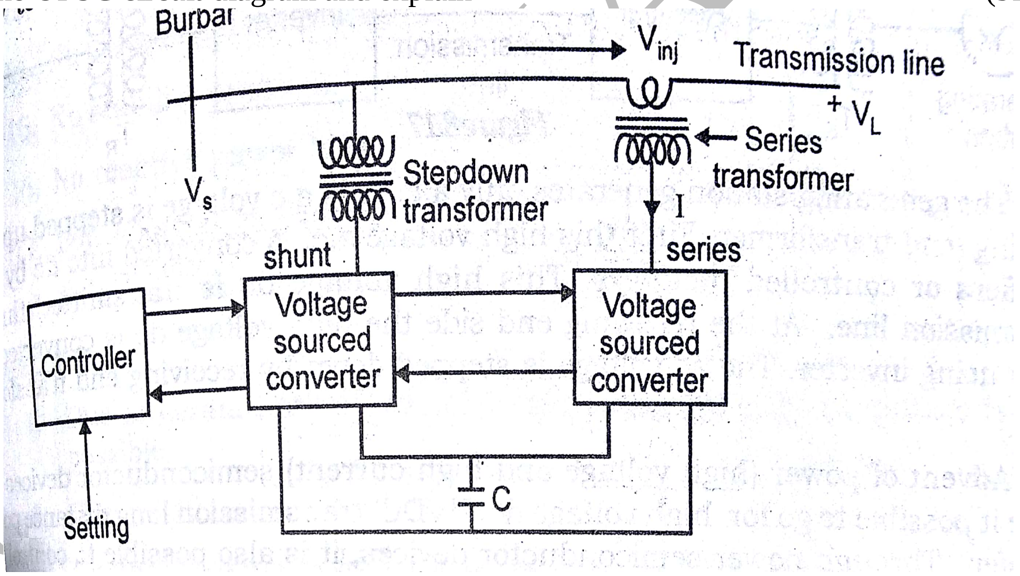
- SVC and its operation (8M)

1. A static VAR compensator is a set of electrical devices for providing fast-acting reactive power on high-voltage electricity transmission networks.
2. SVCs are part of the Flexible AC transmission system device family, regulating voltage, power factor, harmonics and stabilizing the system.
3. A static VAR compensator has no significant moving parts (other than internal switchgear).
4. Prior to the invention of the SVC, power factor compensation was the preserve of large rotating machines such as synchronous condensers or switched capacitor banks.
5. The SVC is an automated impedance matching device, designed to bring the system closer to unity power factor.

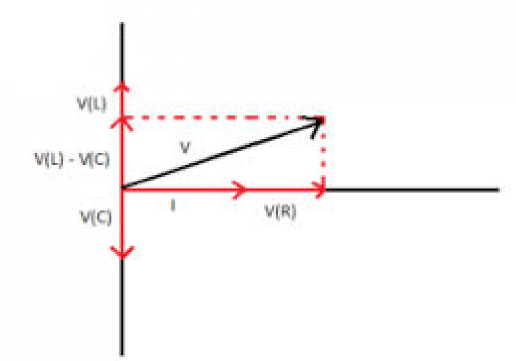
6 **Explain about power factor control and UPF.** **(13M) (NOV/DEC-2008, NOV/DEC-2007)** BTL2

Answer : Page: 8.12 – J. Gnanavadivel

- Draw the UPSC circuit diagram and explain (9M)



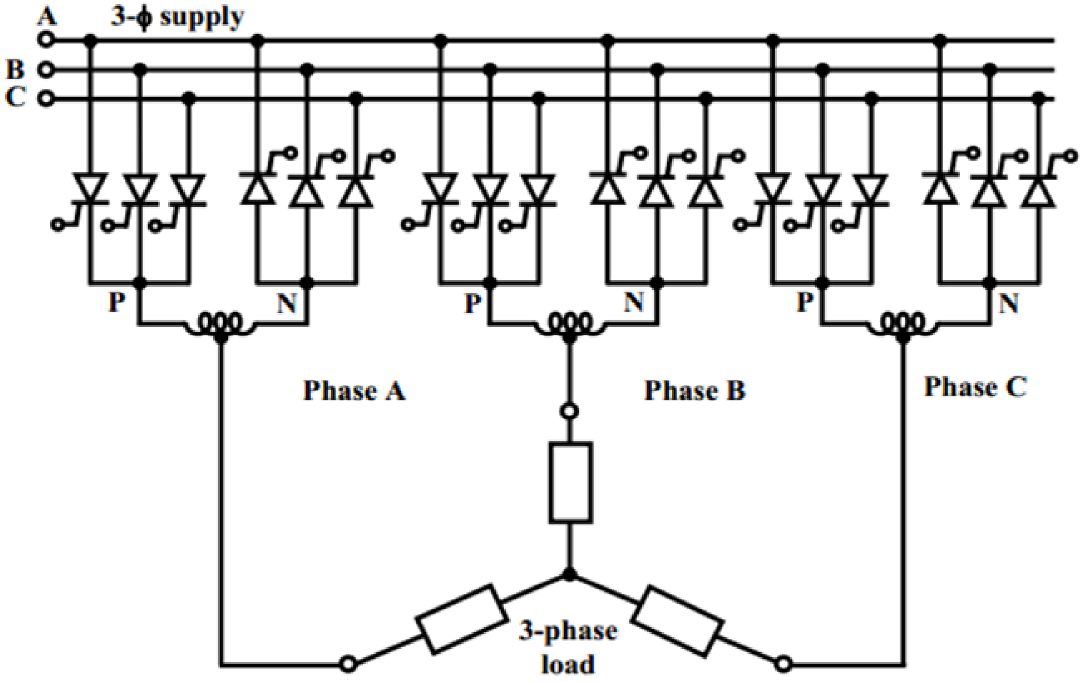
- Draw phasor diagram (4M)



7 **Explain the working of three phase to three phase cyclo converter with neat diagrams and necessary waveforms. (13 M) (NOV/DEC-2010)** BTL 1

Answer : Page: 6.56 – J. Gnanavadivel

- Draw and explain circuit diagram of cyclo converter (5M)



- Working principle (8M)

  1. In industrial applications, the cyclo-converter is commonly required to deliver a three phase output from a three phase input.

  2. One group is responsible for producing the positive alternations and it is known as positive group P.

  3. The other produces the negative group N.

  4. Each group consists of 3 thyristors, thus in total 6 thyristors are required.

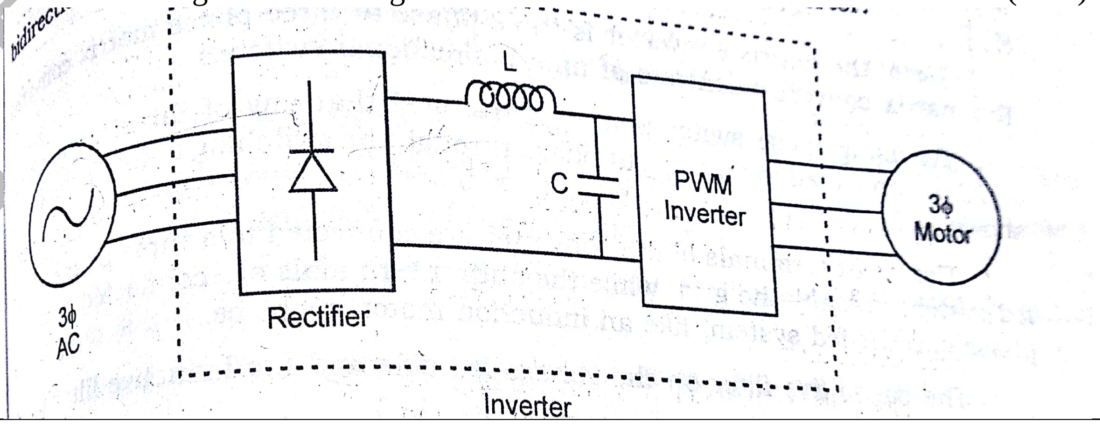
8 **Explain about Matrix converter.** (**13 M**) BTL1

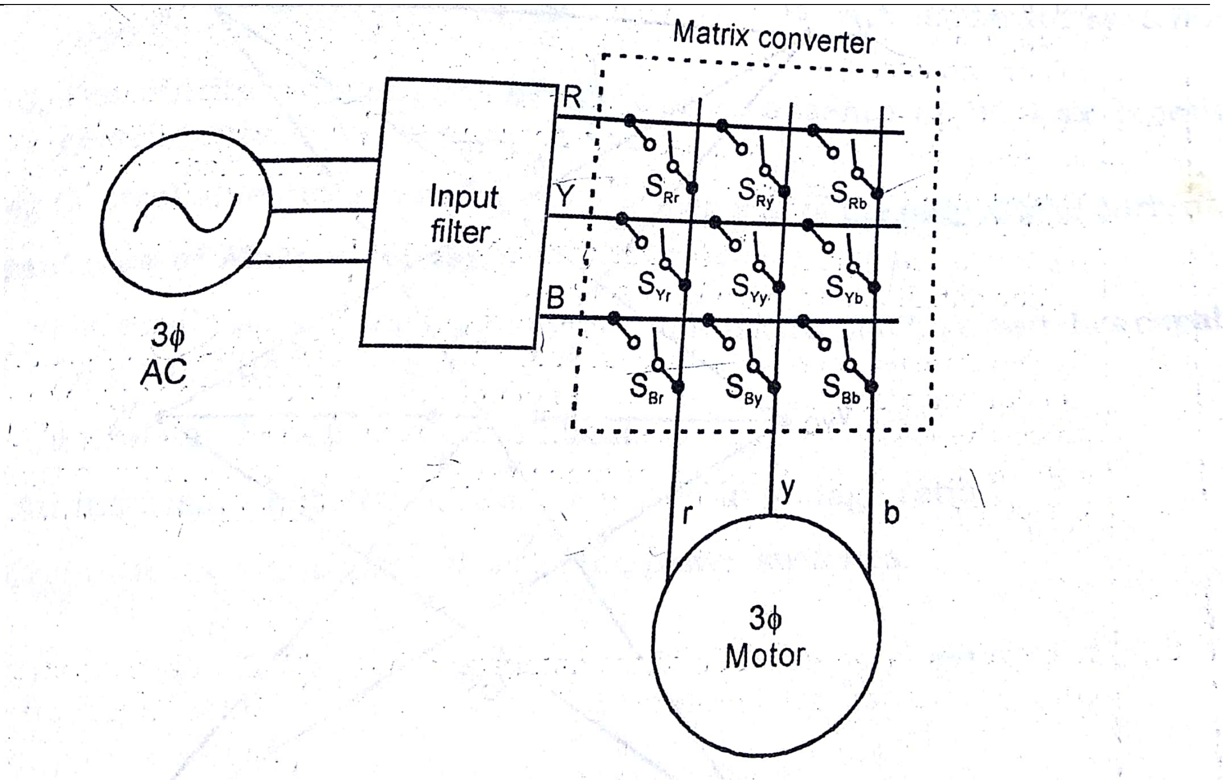
Answer : Page: 6.59 – J. Gnanavadivel

- Define **matrix converter** (3M)

  Matrix converter is capable of direct convertion from AC to AC by using bidirectional fully controlled switches. It is a single stage converter.

- Draw its circuit diagram & working (10M)



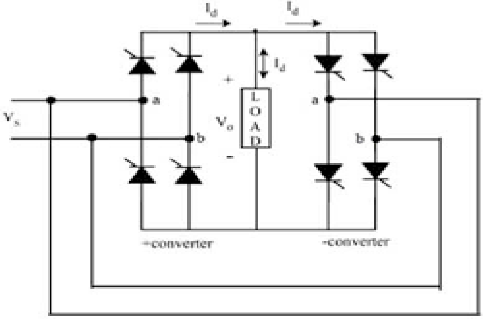


9

Explain about 1 ϕ cycloconverter. (13M) BTL1

Answer : Page: 6.43, 6.51 – J. Gnanavadivel

- Circuit diagram (5M)



- **Working principle of cycloconverter** (8M)

1. During the positive half cycle (0 to π), SCR P1 & P2 forward biased and is triggered at wt= α.
2. Then P1, P2 are on state we can get positive output voltage and positive output current.
3. During negative half cycle (π to 2π), scr P3 & P4 are forward biased and is triggered at wt= π + α.
4. P3 & P4 are on state, again we can get positive output voltage and positive output current.

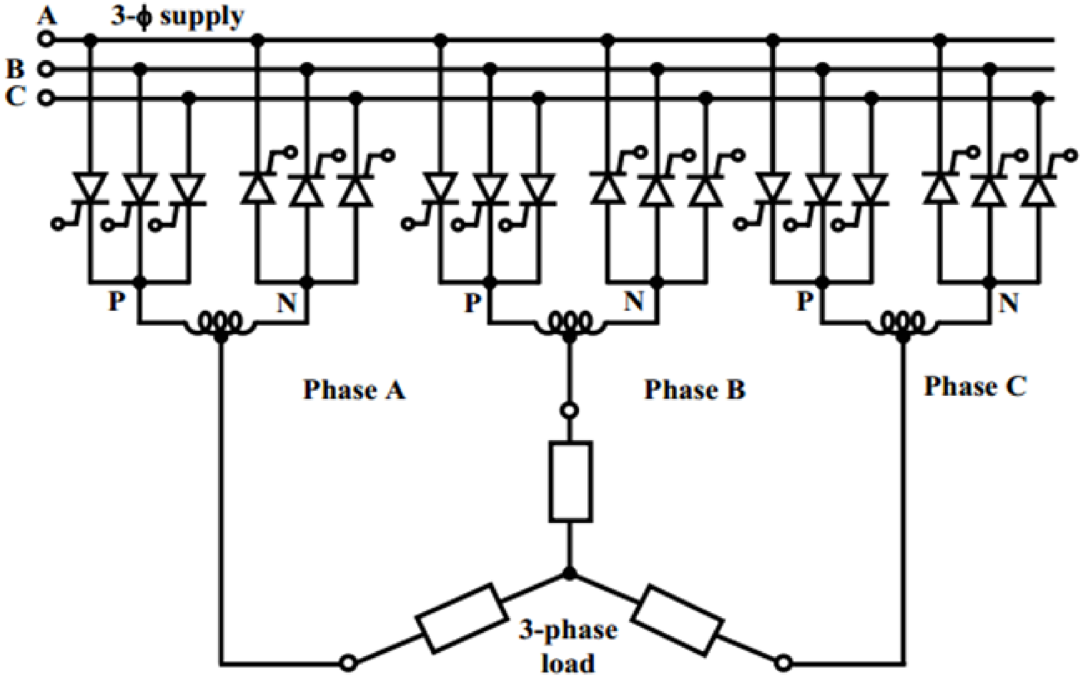
Part * C

1

Explain the working of three phase to three phase cyclo converter with neat diagrams and necessary waveforms. (15 M) (NOV/DEC-2010) BTL 1

Answer : Page: 6.56 – J. Gnanavadivel

- Draw and explain circuit diagram of cyclo converter (7M)



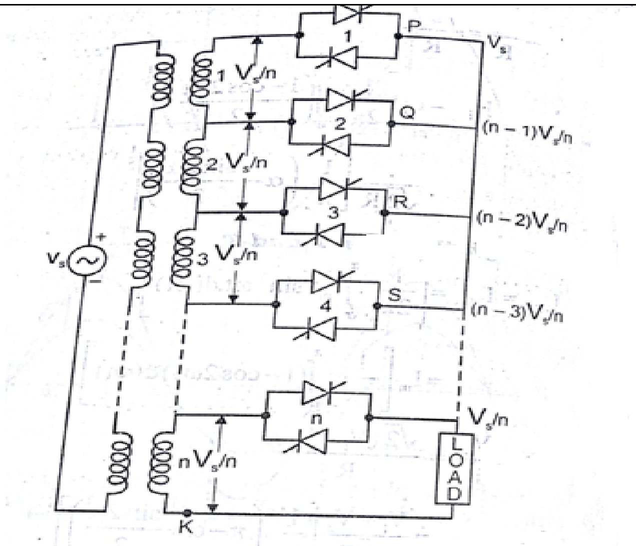
- **Working principle** (8M)

1. In industrial applications, the cycloconverter is commonly required to deliver a three phase output from a three phase input.
2. One group is responsible for producing the positive alternations and it is known as positive group P.
3. The other produces the negative group N.
4. Each group consists of 3 thyristors, thus in total 6 thyristors are required.

2 **Explain the working of multi Stage sequence control of AC Voltage controller. (15 M) (NOV/DEC-2016)** BTL2

Answer: Page:6.36 - J.GNANAVADIVEL

- Draw the multistage sequence control circuit diagram (7M)



Multistage sequence control of AC voltage controllers

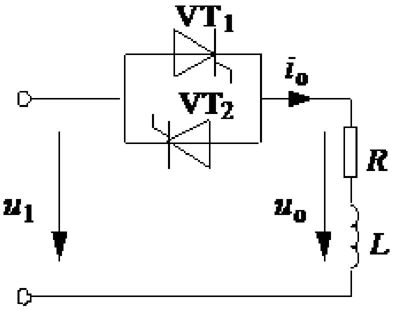
- Explain its operation (8M)

  1. The reduction of harmonics and improvement of power factor can be increased by using more than two stage control.
  2. Here, the transformer has n secondary windings.
  3. Each secondary is rated for Vs/n, where Vs, is source voltage.
  4. The presence of harmonics in output voltage depends upon voltage variation.

3

Explain 1 phase full wave AC Voltage controller with RL-Load, Derive the Average output voltage & rms output voltage with output waveforms. (15M)
(NOV/DEC-2012,NOV/DEC-2010) BTL1
Answer : Page: 6.22 – J. Gnanavadivel

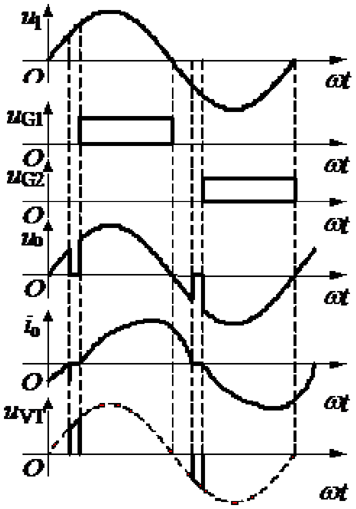
- Draw the circuit diagram of AC voltage controller (5M)



The phase shift range:

$\varphi \leqslant \alpha < \pi$

- Draw its waveform with output voltage derivation (10M)



- **Derive its average and rms voltage.** (2M)

$V_o = V_m/\pi(\cos \alpha+1)$

EE6504 ELECTRICAL MACHINES – II L T P C 3 1 0 4

OBJECTIVES:

- To impart knowledge on Construction and performance of salient and non – salient type synchronous generators.
- To impart knowledge on Principle of operation and performance of synchronous motor.
- To impart knowledge on Construction, principle of operation and performance of induction machines.
- To impart knowledge on Starting and speed control of three-phase induction motors.
- To impart knowledge on Construction, principle of operation and performance of single phase induction motors and special machines.

UNIT I SYNCHRONOUS GENERATOR 9

Constructional details – Types of rotors –winding factors- emf equation – Synchronous reactance – Armature reaction – Phasor diagrams of non salient pole synchronous generator connected to infinite bus--Synchronizing and parallel operation – Synchronizing torque -Change of excitation and mechanical input- Voltage regulation – EMF, MMF, ZPF and A.S.A methods – steady state power angle characteristics– Two reaction theory –slip test -short circuit transients - Capability Curves

UNIT II SYNCHRONOUS MOTOR 9

Principle of operation – Torque equation – Operation on infinite bus bars - V and Inverted V curves – Power input and power developed equations – Starting methods – Current loci for constant power input, constant excitation and constant power developed-Hunting – natural frequency of oscillations – damper windings- synchronous condenser.

UNIT III THREE PHASE INDUCTION MOTOR 9

Constructional details – Types of rotors –- Principle of operation – Slip –cogging and crawling- Equivalent circuit – Torque-Slip characteristics - Condition for maximum torque – Losses and efficiency – Load test - No load and blocked rotor tests - Circle diagram – Separation of losses – Double cage induction motors –Induction generators – Synchronous induction motor.

UNIT IV STARTING AND SPEED CONTROL OF THREE PHASE INDUCTION MOTOR 9

Need for starting – Types of starters – DOL, Rotor resistance, Autotransformer and Star-delta starters – Speed control – Voltage control, Frequency control and pole changing – Cascaded connection-V/f control – Slip power recovery scheme-Braking of three phase induction motor: Plugging, dynamic braking and regenerative braking.

UNIT V SINGLE PHASE INDUCTION MOTORS AND SPECIAL MACHINES 9

Constructional details of single phase induction motor – Double field revolving theory and operation – Equivalent circuit – No load and blocked rotor test – Performance analysis – Starting methods of single-phase induction motors – Capacitor-start capacitor run Induction motor- Shaded pole induction motor - Linear induction motor – Repulsion motor - Hysteresis motor - AC series motor- Servo motors- Stepper motors - introduction to magnetic levitation systems.

TOTAL (L:45+T:15): 60 PERIODS

OUTCOMES:

Ability to model and analyze electrical apparatus and their application to power system.

TEXT BOOKS:

1. A.E. Fitzgerald, Charles Kingsley, Stephen. D.Umans, ‘Electric Machinery’, Tata Mc Graw Hill publishing Company Ltd, 2003.
2. D.P. Kothari and I.J. Nagrath, ‘Electric Machines’, Tata McGraw Hill Publishing Company Ltd, 2002.
3. P.S. Bhimbhra, ‘Electrical Machinery’, Khanna Publishers, 2003.

REFERENCES:

1. M.N.Bandyopadhyay, Electrical Machines Theory and Practice, PHI Learning PVT LTD., New Delhi, 2009.
2. Charless A. Gross, “Electric /Machines, “CRC Press, 2010.
3. K. Murugesh Kumar, ‘Electric Machines’, Vikas Publishing House Pvt. Ltd, 2002.
4. Syed A. Nasar, Electric Machines and Power Systems: Volume I, Mcgraw -Hill College; International ed Edition, January 1995.
5. Alexander S. Langsdorf, Theory of Alternating-Current Machinery, Tata McGraw Hill Publications, 2001.

Subject Code: EE6504 **Year/Semester: III/05**
Subject Name: Electrical Machines – II **Subject Handler: Mr. K. Jayavelu**

UNIT I - SYNCHRONOUS GENERATOR

Constructional details – Types of rotors –winding factors- emf equation – Synchronous reactance – Armature reaction – Phasor diagrams of non-salient pole synchronous generator connected to infinite bus--Synchronizing and parallel operation – Synchronizing torque - Change of excitation and mechanical input- Voltage regulation – EMF, MMF, ZPF and A.S.A methods – steady state power angle characteristics– Two reaction theory –slip test - short circuit transients - Capability Curves

PART * A

Q. No	Questions
1	**List the essential parts for generating emf in alternators. (Nov/Dec 2014)** (BTL 1) ➢ Magnetic field ➢ Armature system ➢ Relative motion between the above two.
2	**Write the EMF equation of a three-phase alternator.** (BTL 1) The emf equation of alternator is $E = 4.44\, K_c\, K_d \Phi\, f\, T$ volts

	Where E = Induced emf per phase $K_c =$ Pitch factor K_d= Distribution factor T = No of turns connected in series in each phase.
3	**Two reaction theory is applied only to salient pole machines. State the reason. (Nov/Dec 2014)** (BTL 1) According to two reaction theory, the armature mmf Fa is resolved in to two components, one along the d-axis and another along q-axis. d-axis reactance can be obtained from occ and scc. $E_f = \overline{V}_t + \overline{I}_a R_a + jX_d \overline{I}_d + jX_q \overline{I}_q$ The current I_a lags terminal voltage V_t by Φ. Then add I_a R_a in phase with I_a to V_t. The drop I_d $X_d$leads I_d by 90^o as in case purely reactive circuit current lags voltage by 90^o i.e. voltage leads current by 90^o . Similarly the drop I_q X_q leadsX_q by 90^o . The total e.m.f. is E_f.
4	**List the advantages of salient pole type construction used for Synchronous machines.** (BTL 1) Advantages of salient-pole type construction are: ➢ The pole faces are so shaped that the radial air gap length increases from the pole center to the pole tips so that the flux distribution in the air-gap is sinusoidal in shape which will help the machine to generate sinusoidal emf. ➢ Due to the variable reluctance the machine develops additional reluctance power which is independent of excitation. ➢ They allow better ventilation.
5	**How does electrical degree differ from mechanical degree?** (BTL 1) Mechanical degree is the unit for accounting the angle between two points based on their mechanical or physical placement. Electrical degree is used to account the angle between two points in rotating electrical machines. Since all electrical machines operate with the help of magnetic fields, the electrical degree is accounted with reference to the magnetic field. 180 electrical degree is accounted as the angle between adjacent North and South poles. 1 degree electrical = (P/2) mechanical degree. where P = No. of poles
6	**Why short pitch winding is preferred over full-pitch winding?** (BTL 2) Advantages ➢ Waveform of the emf can be approximately made to a sine wave and distorting harmonics can be reduced or totally eliminated. ➢ Conductor material, copper is saved in the back and front-end connections due to less coil-span. ➢ Fractional slot winding with fractional number of slots/phase can be used which in turn reduces the tooth ripples. ➢ Mechanical strength of the coil is increased.
7	**Why Alternators rated in kVA and not in kW?** (BTL 2) The continuous power rating of any machine is generally defined as the power of the machine or apparatus can deliver for a continuous period so that the losses incurred in the machine gives rise to a steady temperature rise not exceeding the limit prescribed by the insulation class. Apart from the constant loss incurred in Alternators is the copper loss, occurring in the 3 –phase winding which depends on I^2 R, the square of the current delivered

	by the generator. As the current is directly related to apparent – power delivered by the generator, the Alternators have only their apparent power ratings in VA/kVA/MVA.
8	**Write short note on "single layer" and "double layer" winding. (Nov/Dec 2011)** (BTL 2) In single layer winding, there- is only one coil side per slot- But in double layer winding, in each slot there are two coil sides namely upper coil side and lower coil side. Hence, in single layer winding, the number of coils is half the number of slots, but in double layer winding, the number of coils is equal to the number of slots.
9	**Where the damper windings are located? What are their functions? (Nov/Dec 2011)** (BTL 3) Damper windings are provided in the pole shoes of the salient pole rotor. Slots or holes are provided in the pole shoes. Copper bars are inserted in the slots and the ends of all the bars in both the sides are short circuited by copper end rings to have a closed circuit. These windings are useful in preventing the hunting in alternators; they are also needed, in synchronous motor to provide the starting torque.
10	**List the causes of changes in terminal voltage of Alternators when loaded. (Nov/Dec 2012)** (BTL 1) Variations in terminal voltage in Alternators on load condition are due to the following three causes: ➢ Voltage drop due to the resistance of the winding, IR. ➢ Voltage drop due to the leakage reactance of the winding, IX_l. ➢ Voltage variation due to the armature reaction effect, IX_a.
11	**What is meant by armature reaction in Alternators? (Nov/Dec 2013)** (BTL 2) The effect of armature flux on the flux produced by the field ampere turns is called as armature reaction.
12	**Define synchronous reactance.** (BTL2) Synchronous reactance $X_s= (X_l + Xa)$ The value of leakage reactance X_l is constant for a machine based on its construction. X_l depends on saturating condition of the machine. Xa, which represent the armature reaction effect between two synchronously acting magnetic fields. The sum of leakage flux and armature reaction reactance makes the total reactance X_S to be called synchronous reactance.
13	**Explain the synchronous impedance of an Alternator.** (BTL 2) The complex addition of resistance, R and synchronous reactance, jXs can be represented together by a single complex impedance Zs called synchronous impedance. In complex form $Zs = (R + jXs)$ In polar form $Zs = \| Zs \| \angle\Theta$ Where $\Theta= \tan^{-1} (Xs /R)$.
14	**Define load angle of an Alternator. (**BTL 1) The phase angle introduced between the induced emf phasor, E and terminal voltage phasor (V), during the load condition of an Alternator is called load angle.
15	**Define the term voltage regulation of Alternator. (Nov/Dec 2013)** (BTL 1) The voltage regulation of an Alternator is defined as the change in terminal voltage from no-load to load condition expressed as a fraction or percentage of terminal voltage at load condition; the speed and excitation conditions remaining same.

16	**Why the synchronous impedance is called as pessimistic method?** (BTL 2) Compared to other methods, the value of voltage regulation obtained by the synchronous impedance method is always higher than the actual value and therefore this method is called the pessimistic method.
17	**Why the MMF method is called as the optimistic method?** (BTL 2) Compared to the EMF method, MMF method, involves more number of complex calculation steps. Further the OCC is referred twice, SCC is referred once while predetermining the voltage regulation for each load condition. Reference of OCC takes care of saturation effect. As this method require more effort, the final result is very close to the actual value. Hence this method is called optimistic method.
18	**State the condition for connecting two alternators in parallel.** (BTL 1) The following are the three conditions that is to be satisfied by synchronizing the additional alternator with the existing one or the common bus-bars. ➢ The terminal voltage magnitude of the incoming Alternator must be made equal to the existing Alternator or the bus-bar voltage magnitude. ➢ The phase sequence of the incoming Alternator voltage must be similar to the bus-bar voltage. ➢ The frequency of the incoming Alternator voltage must be the same as the bus-bar voltage.
19	**List the factors that affect the load sharing in parallel operating generators.** (BTL 1) The total active and reactive power delivered to the load, connected across the common bus-bars, are shared among Synchronous generators, operating in parallel, based on the following three factors ➢ Prime-mover characteristic/input ➢ Excitation level and ➢ Percentage synchronous impedance and its R/X ratio
20	**State briefly about infinite bus-bars. (May/June 2014)** (BTL 2) The source or supply lines with non-variable voltage and frequency are called infinite bus-bars. The source lines are said to have zero source impedance and infinite rotational inertia.
21	**What is meant by armature reaction? (Nov/Dec 2013)** (BTL 2) The load currents flowing in the stator winding usually generate a magnetic field which opposes the magnetic field generated by the excitation (field) winding, reducing the total airgap field and the terminal voltage. In order to **counter act** this reaction effect from the stator currents, the field current has to be adjusted (usually increased).
22	**Why the field system of an alternator made as a rotor? (April/May 2012)** (BTL 2) Number of brush, voltage drop across the brush, number of phases of windings in rotor and weight of rotor are reduced.
23	**What is synchronizing power of an alternator? (April/May 2012)** (BTL 2) When two alternators are operated parallel after synchronism, suppose due to change in input parameter of second alternator it act as motor, first alternator supplies power to second alternator. That power is called as synchronous power.
24	**How will you distinguish between the two types of large synchronous generator from their appearance? (May/June 2014)** (BTL 4) ➢ Salient pole type, the pole are projected out from the surface of the rotor and are

characterized by large diameters and short axial length
- Non-salient type, the poles are non-salient (i.e.) they do not project out from the surface of the rotor.

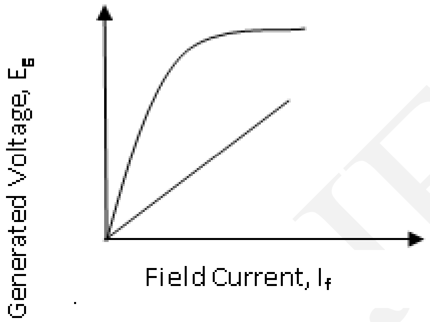
25

Distinguish the use of salient pole and round rotor synchronous machines. (May/June 2015) (BTL 4)

salient pole	**round rotor**
Rotor poles are projected	Smooth cylindrical type rotor
Mechanical strength is low	Mechanical strength is high
It has large diameter and small axial length	It has small diameter and large axial length
This type of rotor used for low speed applications	This type of rotor used for high speed applications
Operating noise is high	Operating noise is low
Non uniform airgap between stator and rotor	Uniform airgap between stator and rotor

26

Draw typical open circuit and short circuit characteristics of synchronous machine. (May/June 2015) (BTL 1)



PART * B

1

Explain the construction and working principle of synchronous generator with neat diagram. (13M) (BTL 1)

Answer: Page 1.3 to 1.5 - J. Gnanavadivel

Construction:

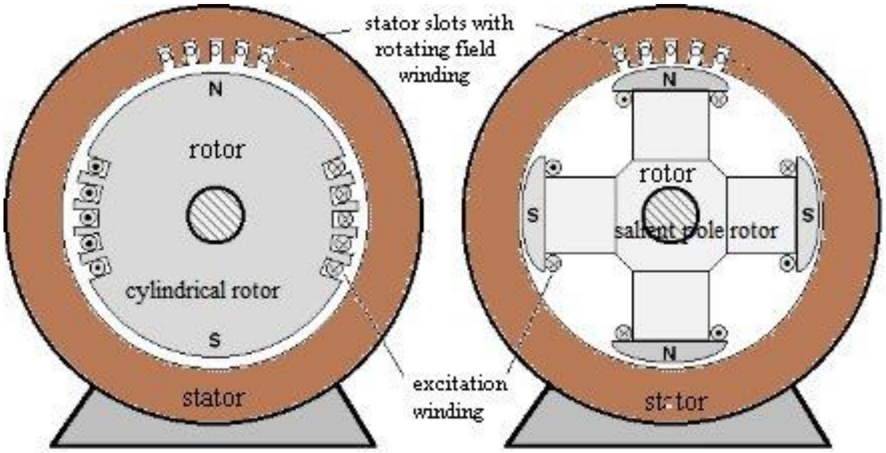
Principle:(2M)
- Conductor cuts magnetic flux.
- Dynamically induced emf is produced.
- Faraday’s laws of Electromagnetic Induction.
- Current flow in the conductor.

Construction: (5 M)

Stator
- Stator stationary member.
- Cylinder inside which rotor rotates.

- Air gap between the stator and the rotor.
- Armature windings are housed in the slots cut the stator

Diagram: (3M)



Rotor

- Two types of rotor.
- Cylindrical type rotor and salient pole.
- Cylindrical pole rotor has dc field winding.
- Cylindrical rotor provides greater mechanical strength
- Used in high speed turbo generators.
- Salient pole rotors have projecting poles.
- Projecting poles lessen its mechanical strength.
- Used for low speed applications.
- Larger in diameter and smaller in length.

Principle of operation: (3 M)

- DC excitation provided to the rotor
- Rotor produces a stationary flux in the air gap
- Which links stator winding.
- Generator converts mechanical energy into electrical energy.
- Rotor is rotated produces a sinusoidalflux in air gap.
- links the armature windings and induces sinusoidally alternating emf in it.
- The frequency of the induced emf.

$f = PN_s/120$

Where

P = number of stator poles.

N_s = Speed of the rotor in rpm.

2 **Derive the emf equation of alternator. (Nov/Dec 2011 & 2012 & 2013 &2014) (8M)**(BTL 1)

Answer: Page No. 1.11- J. Gnanavadivel

Let Φ = Flux per pole, in Wb
P = Number of poles
N_s = Synchronous speed in r.p.m.
f = Frequency of induced e.m.f. in Hz
Z = Total number of conductors
Z_{ph} = Conductors per phase connected in series
$\therefore$ $Z_{ph} = Z/3$ as number of phases = 3. (2M)

The average value of e.m.f. induced in a conductor
$= d\Phi/dt$
Total flux cut in one revolution is $\Phi \times P$
Time taken for one revolution is $60/N_s$ seconds.
e_{avg} per conductor = $2 f \Phi$ volts
$\therefore$ e.m.f. per turn = 2 x (e.m.f. per conductor)
$= 4 f \Phi$ volts
$\therefore$ Average $E_{ph} = T_{ph}$ x (Average e.m.f. per turn)
$\therefore$ Average Eph $= T_{ph} \times 4 f \Phi$

K_f = (R.M.S.)/Average = 1.11 .... for sinusoidal (3 M)
$E = 4.44 \times f \Phi T_{ph}$ volts .... (2)
$T_{ph} = Z_{ph}/2$
Actual available voltage/phase=$4.44 k_c k_d$ ø fT in Volts (3 M)

3. **Explain the condition for parallel operation of 3 phase alternator. (Nov/Dec 2012) (5M)** (BTL 2)

Answer: Page -1.73- J. Gnanavadivel

Condition :(5 M)

<u>Conditions for Paralleling Alternator with Infinite Busbars</u>

- An alternator connected to infinite busbars is synchronizing.
- Induced e.m.f. is zero at standstill and a short-circuit will result.

Condition:

- Terminal voltage must be same as busbars voltage.
- Frequency must be equal to the busbars frequency.
- Phase sequence of the voltage should be the same as that of the busbars.

4 **Explain the procedure for POTIER method to calculate voltage regulation of alternator. (April/May 2012) (13M)** (BTL 5)

Answer: Page -1.66 to 1.68 - J. Gnanavadivel

- Separation of armature leakage reactance and armature reaction.
- Armature leakage reactance X_L is called Potier reactance.
- To determine armature leakage reactance and armature reaction m.m.f. separately.
- Two tests are performed.
    - Open circuit test

- Zero power factor test (3 M)

Open Circuit Test

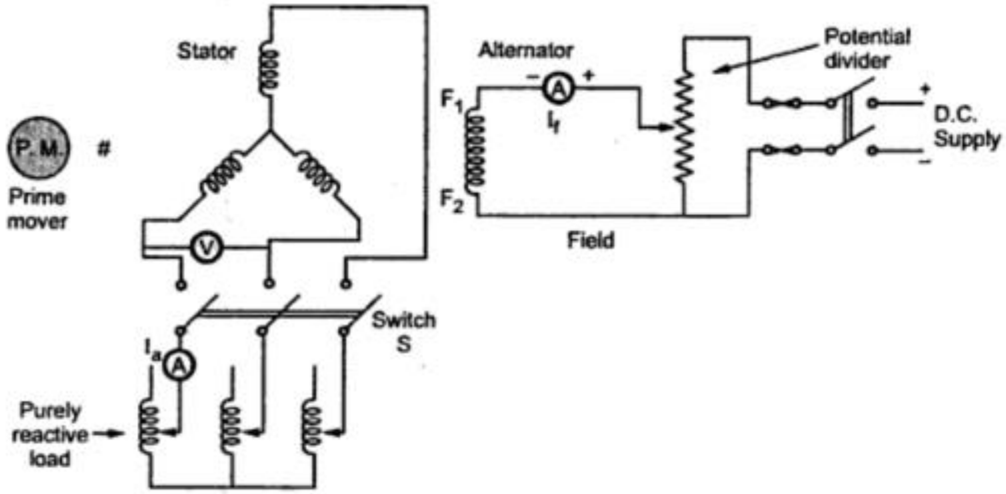


Fig. 1

The steps to perform open circuit test are,

- Switch S is kept open.
- Alternator is driven by its prime mover at its synchronous speed.
- Excitation is varied with the help of potential divide.
- Field current and open circuit voltage noted.
- Draw open circuit characteristics. (3 M)

Zero Power Factor Test

- Switch S is kept closed.
- Purely inductive load gets connected to an alternator through an ammeter.
- Speed is maintained constant at its synchronous value.
- An alternator will always operate at zero p.f. lagging.
- Plot open circuit characteristics on graph as shown in the Fig. 2. (3 M)

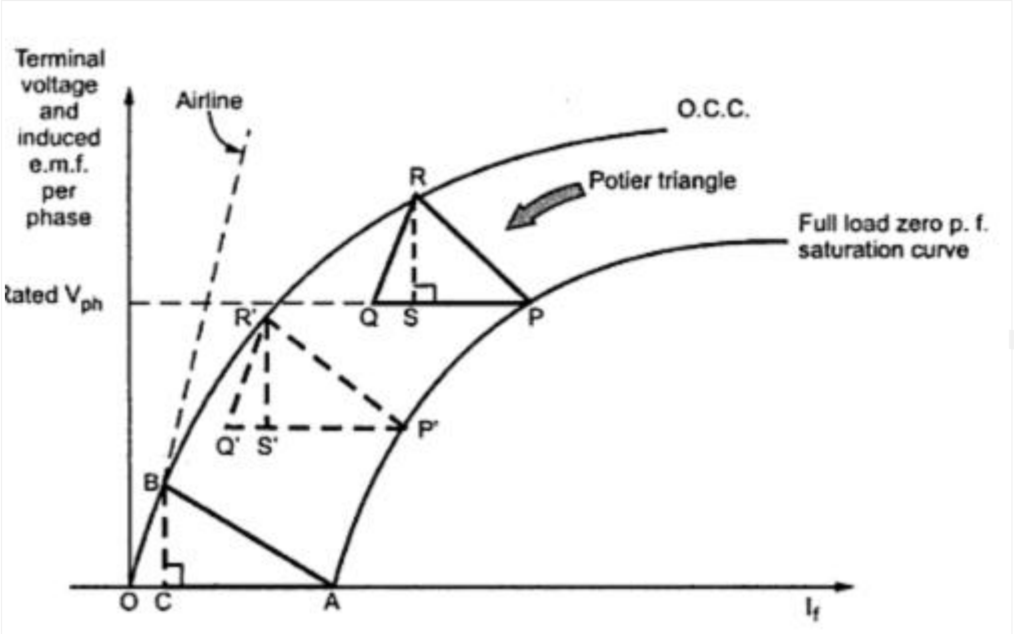


Fig. 2

- Draw tangent to O.C.C. through origin which is line OB
- Draw the horizontal line PQ parallel and equal to OA.
- Triangle PQR is called potier triangle.
- From point R, drop a perpendicular on PQ to meet at point S.
- Perpendicular RS gives the voltage drop due to the armature leakage reactance.
- Length PS gives field current to overcome de-magnetizing effect.

$$\therefore \quad \boxed{\bar{E}_{1ph} = \bar{V}_{ph} + \overline{I_{ph} R_{aph}} + \overline{I_{ph} X_{Lph}}}$$

Once E_{ph} is known, the regulation of an alternator can be predicted as,

$$\% R = \frac{E_{ph} - V_{ph}}{V_{ph}} \times 100$$

(4 M)

5

Explain about the various methods of Synchronization. (April/May 2012) (13M) (BTL 2)

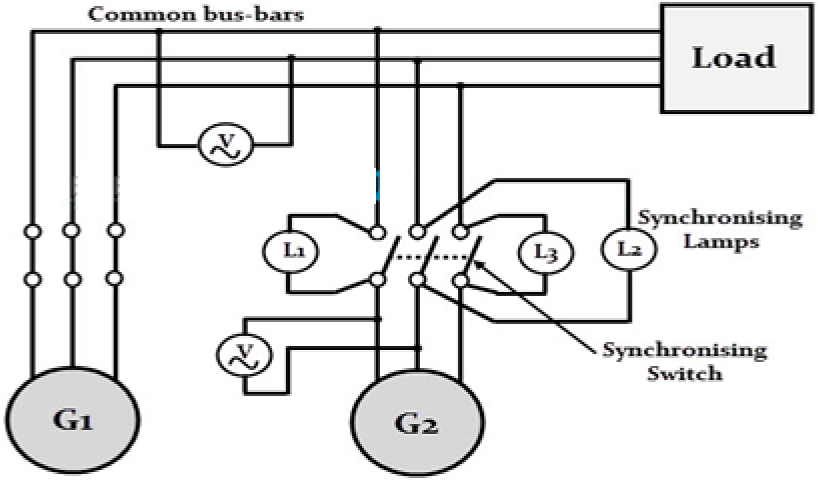
Answer: Page No. 1.73 to 1.76 - J. Gnanavadivel

- Connecting an alternator to busbars is synchronization.
- Methods of synchronization.
    - Three Lamp (one dark, two bright) method (5M)
    - Dark Lamp method (5 M)
    - By synchroscope (3M)

Three Dark Lamps Method

- Alternator connected to rated voltage and frequency.
- Three lamps are connected across the switches.
- Speed close to the synchronous speed.

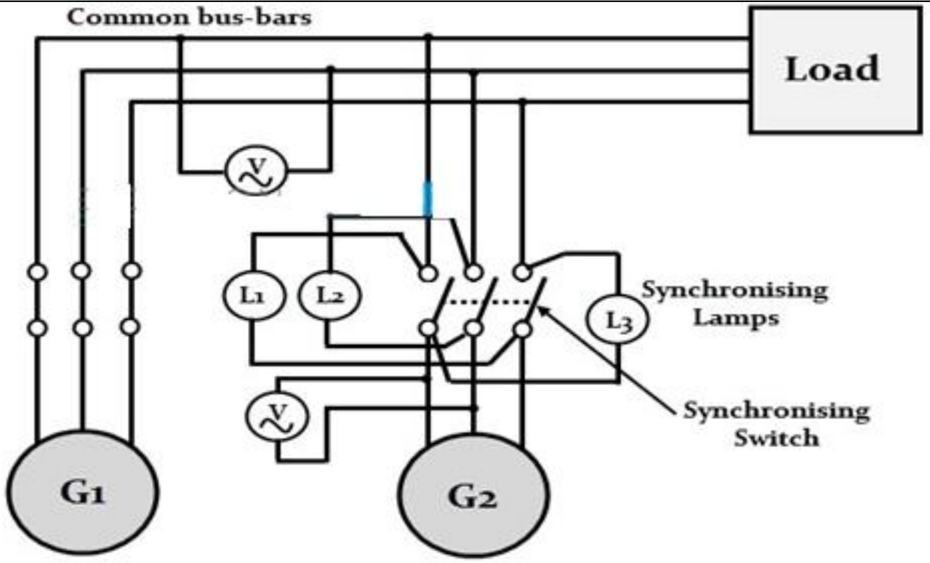
- Decided by the bus bar frequency and number of poles of the alternator.
- Field current of the generator-2 is increased.
- Machine terminals is equal to the bus bar voltage.
- If lamps go ON and OFF concurrently.
- Indicating that the phase sequence of alternator-2.
- If they ON and OFF one after another, incorrect phase sequence.
- By changing the connections of any two leads, phase sequence can be changed.



- Rate of flickering has to be reduce.
- Adjusting the speed of alternator by its prime mover control.
- Lamps become dark and synchronizing switch can be closed.
- Synchronize alternator-2 with alternator-1.

Two Bright and One Dark Lamp Method

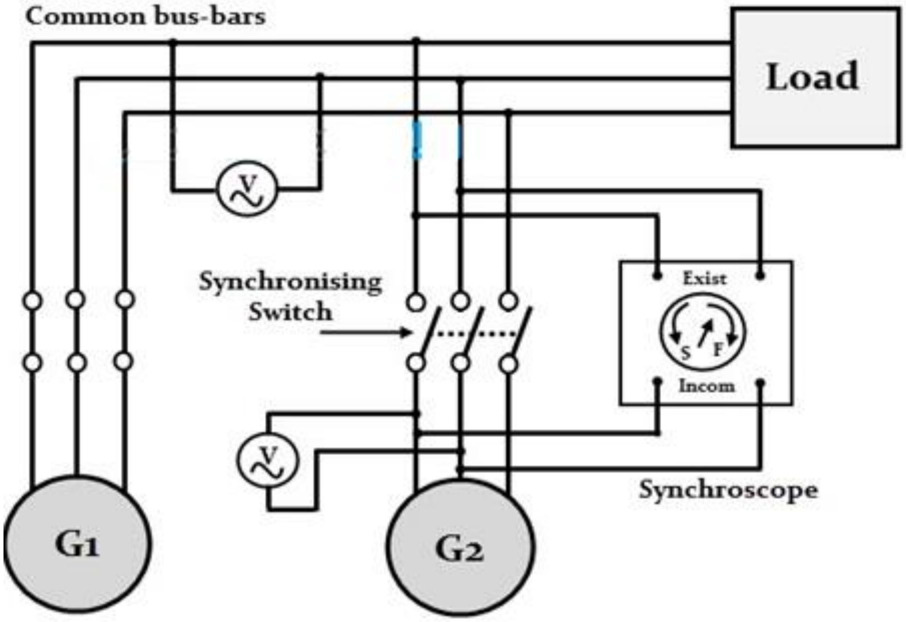
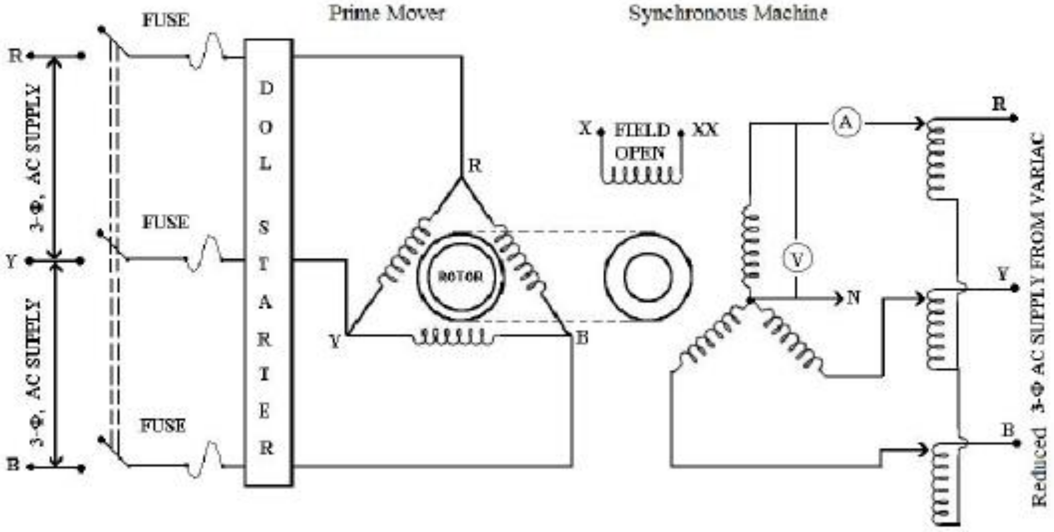
- Lamp L2 is connected across the pole in the middle line.
- Lamps L1 and L3 are connected in a transposed manner.
- Voltage condition checking is similar to the previous method.
- Lamps glow bright and dark one after another.
- Frequency is determined by the sequence in which the lamps become dark and bright.



- Bright and dark L1- L2 – L3 indicates frequency is higher than bus bar frequency.
- Alternator speed has to be reduced till flickering rate is small.
- Flickering L1- L3 – L2 indicates frequency is less than that of bus bar.
- Speed of the alternator is increased till flickering is small as possible.
- The synchronizing switch is then closed.
- Lamps L1 and L3 are equally bright and lamp L2 is dark.

Synchroscope Method

- Better accuracy of synchronization.
- It consists of two pairs of terminals.
- One pair of terminals connected across the bus bar terminals.
- Other pair of terminals connected across incoming alternator.
- It has circular dial.
- Rotating in clockwise and anticlockwise directions.

	 ➢ Pointer rotates indicates difference of frequency ➢ Frequency is higher or lower than bus bar frequency. Pointer moves either fast or slow. ➢ Correction to be made to control the speed of alternator.
6	**Explain how you will determine the d and q axis reactance of a synchronous machine in your laboratory. (Nov/Dec 2011)(May/June 2014) (13 M)** (BTL 2) **Answer: Page -1.98 to 1.100- J. Gnanavadivel** ➢ From this test Xd and Xq are determined. ➢ Field winding remains unexcited. ➢ Machine is run less than the synchronous speed. **Diagram –** (3 M) 

	Explanation (10 M) ➢ Voltage V applied to stator terminal. ➢ Current I flow causing a stator mmf. ➢ Stator mmf induced an emf in the field circuit. ➢ Stator mmf moves slowly relative to poles. ➢ Axis of the pole and axis of the armature reaction mmf wave coincide. ➢ Armature mmf acts field magnetic circuit. ➢ Voltage is constant, air-gap flux would be constant. ➢ Minimum air-gap offers minimum reluctance. ➢ Current required in armature for constant air-gap flux must be minimum. ➢ d-axis synchronous reactance is given by • Xd= Maximum armature terminal voltage per phase / Minimum armature current per phase. • Xq = Minimum armature terminal voltage per phase / Maximum armature current per phase.
7	**A four pole alternator has an armature with 25 slots and 8 conductors per slot and rotates at 1500 rpm and the flux per pole is 0.05Wb. Calculate the emf generated, if winding factor is 0.96 and all the conductors are in series. (Nov/Dec 2012). (5M)** (BTL 4) **Answer: Page1.12- J. Gnanavadivel** Frequency, f=(PN)/120=(4*1500)/120=50Hz (2 M) Generated emf/phase, $E=4.44f\Phi K_wT=4.44*50*0.05*0.96*100=1065.6$ V (3 M)
8	**Explain the EMF method of determining the regulation of an alternator. (Nov/Dec 2012 & 2014) (13 M)** (BTL 5) **Answer: Page -1.38 to 1.41- J. Gnanavadivel** ➢ Also known as synchronous impedance method. ➢ Magnetic circuit is assumed to be unsaturated. ➢ MMFs (fluxes) produced by rotor and stator. ➢ Replaced by equivalent emf. ➢ Determine armature resistance /phase of the alternator, open circuit and short circuit characteristics. **Determination of synchronous impedance Zs:** Diagram – (3 M)

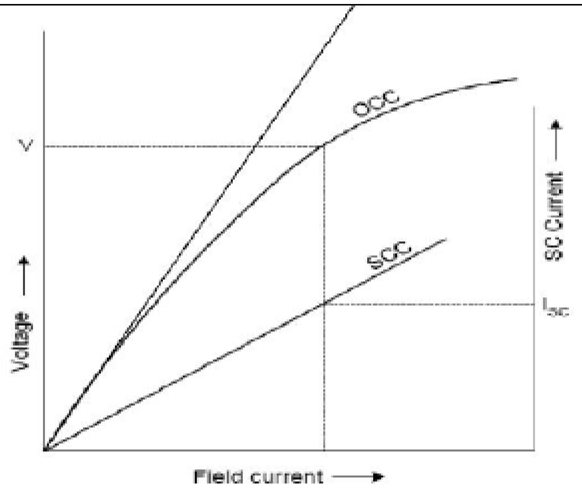


Fig: 1.16 OCC and SCC of alternator

Explanation (7M)

- Terminals of stator are short circuited in SC test.
- Impedance can be estimated form OC and SC characteristics.
- Synchronous impedance Zs = (open circuit voltage per phase)/(short circuit current per phase) for same If Hence Zs = (Voc) / (Isc).
- synchronous impedance Zs = V/Isc

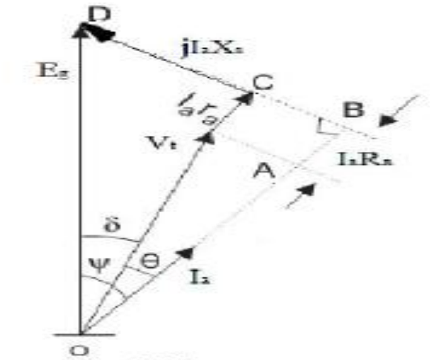


Fig: 1.17

- $Z_s = \sqrt{[(R_a)^2 + (X_S)^2]}$ and Synchronous reactance $X_s = \sqrt{[(Z_s)^2 - (R_a)^2]}$
- Induced emf per phase $E_g = \sqrt{[(V_t \cos + I_aR_a)^2 + (V_t \sin \pm I_aX_S)^2]}$
  where Vt = phase voltage per phase = Vph,
  Ia = load current per phase
  + sign is for lagging power factor
  - sign is for leading power
- *V* % Regulation = (Eg – Vt) / Vt
  - where Eg = no-load induced emf /phase,
  - Vt = rated terminal voltage/phase
- It gives approximate results.
- This method is called pessimistic method.

Phaser Diagram (3M)

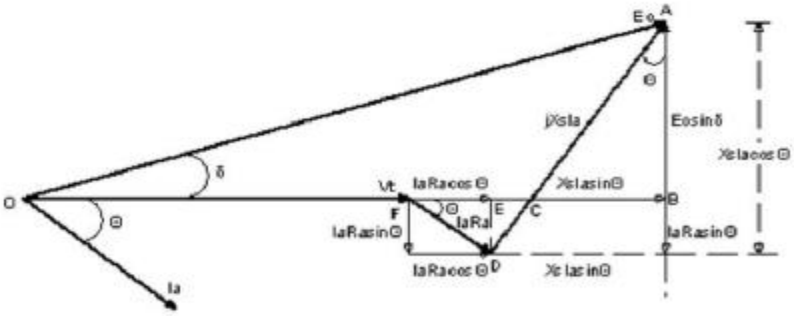


Fig: 1.18

9 **Explain the phenomenon of armature reaction in alternator for different load power factors. (April/May2012) (Nov/Dec2015) (13 M)** (BTL 2)

Answer: Page No. 1.31 to 1.33 - J. Gnanavadivel

- Alternator is running at no-load.
- No current flowing through the armature winding.
- Flux produced in air-gap.
- Alternator is loaded, three-phase currents produce a magnetic field in air-gap.
- Air-gap flux is changed from no-load condition.
- Effect of armature flux is called armature reaction.
- First, armature flux and flux produced by rotor ampere-turns.
- Rotate at the same speed and same direction.
- Two fluxes are fixed in space relative to each other.
- Power factor which determines whether armature flux distorts, opposes or helps the flux.
- To illustrate this important point:
  - When load p.f. is unity
  - When load p.f. is zero lagging
  - When load p.f. is zero leading (3 M)

When load p.f. is unity(3 M)

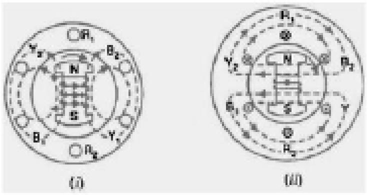


Fig: 1 (c)

- Armature is on open-circuit, there is no stator current.
- Flux due to rotor current is distributed in air-gap as shown in Fig: 1 (d).
- Direction of the rotor is assumed clockwise, the generated e.m.f. in phase.
- No armature flux is produced since no current flows in the armature winding.
- When a resistive load (unity p.f.) is connected across the terminals.
- Armature flux is clockwise due to currents in the top conductors.

- Anti-clockwise due to currents in the bottom conductors.
- Armature flux is at 90° to the main flux and is behind the main flux.
- In this case, the flux in the air-gap is distorted but not weakened.
- Unity p.f., the effect of armature reaction is merely to distort the main field.
- No weakening of the main field and the average flux practically remains the same.
- Since the magnetic flux due to stator currents.

When load Power Factor is Zero lagging :(3 M)

- Pure inductive load is connected across the terminals.
- Current in phase R1R2 will not reach its maximum.
- Armature flux is from right to left and field flux is from left to right.
- All the flux produced by armature current opposes be field flux.
- Therefore, weakens it.
- Armature reaction is directly demagnetizing.
- Hence at zero p.f. lagging, armature reaction weakens the main flux.
- Causes a reduction in the generated e.m.f.

When load Power Factor is Zero leading (4 M)

- Capacitive load (zero p.f. leading) is connected across the terminals.

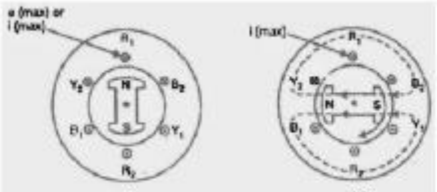


Fig. 1 (d)

- Effect of armature reaction will be reverse that for pure inductive load.
- Armature flux now aids the main flux and the generated e.m.f. is increased.
- Note that e.m.f. as well as current in phase R1R2 is maximum.
- Maximum current in R1R2 will occur 90° electrical.
- Armature flux is now in same direction as field flux.
- Therefore, strengthens it.
- Causes an increase in generated voltage.
- Hence at zero p.f. leading, armature reaction strengthens the main flux.

PART * C

1 **A 11 kV, 1000 kVA, 3-phase, star connected alternator has a resistance of 2 Ω per phase. The open-circuit and full load zero power factor characteristics are given below. Find the voltage regulation of the alternator for full load current at 0.8 pf lagging by potier method. (15 M)**(BTL 4)

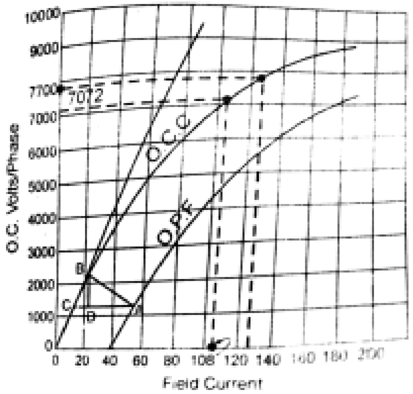
Field current (A)	**40**	**50**	**110**	**140**	**180**
OCC line voltage	**5800**	**7000**	**12500**	**13750**	**15000**
Line volt zero p.f	**0**	**1500**	**8500**	**10500**	**12500**

Answer: Page –1.68 - J. Gnanavadivel

The OCC and full load zero power factor curve for phase voltage are drawn figure. The corresponding phase voltages are

Field current (A)	40	50	110	140	180
OCC phase voltage	3350	4040	7220	7940	8660
Phase volt zero p.f	0	866	4900	6060	7220

- Full load current = (1000 * 10^3) / (√3 * 11000) = 52.5 A
- Phase voltage = 11000 / √3 = 6350 V
- In potier triangle ABC, AC = 40 A, CB is parallel to the tangent to the initial portion of the OCC and BD is perpendicular to AC.
- BD = Leakage reactance drop IX_L = 1000 V by measurement
- AD = 30 A – field current required to overcome demagnetizing effect armature reaction on full load.
- From the figure,
  OA = 6350, AB = IRa = 52.5 * 2 = 105 V
- IX_L = BC = 1000 V
- OC = $\sqrt{[(V \cos \varphi + I\,Ra)^2 + (V \sin \varphi + IX_L)^2]}$ (5 M)



(3 M)

- E = $\sqrt{[(6350*0.8 + 105)^2 + (6350 * 0.6 + 1000)^2]}$
  = 7072 V (5 M)
- As seen from OCC field current required for 7072 V is 108 A. Vector OD represents 108 A and is drawn perpendicular to OC. DF represents 30 A and is draw parallel to OI or at (90 + 36.86 = 126.86) with OD. The total field current is OF.
- OF = $\sqrt{[108^2 + 30^2 + 2*108*30*\cos 53.14]}$ = 128 A
- From OCC it is found that the emf corresponding to this field current is 7700 V.

- Eg = 7700 V
- % Regulation = (7700 – 6350) * 100 / 6350

  = 21.3 % (5 M)

2

A 3-Phase, star-connected,1000KVA, 11,000V alternator has rated current of 52.5A. The ac resistance of the winding per phase is 0.45Ω.The test results are given below:

OC Test: field current = 12.5A, voltage between lines = 422V.

SC Test: field current = 12.5A, line current = 52.5A

Determine the full load voltage regulation of the alternator

(i) 0.8 pf lagging and (ii) 0.8 pf leading. (May/June 2014) (15 M) (BTL 4)

Answer: Page - J. Gnanavadivel

(i) Answer: For 0.8 lagging $E_o = \sqrt{(V\cos\Phi + IR_a)^2 + (V\sin\Phi + IX_s)^2}$ (2 M)

(ii) Voltage regulation = 19.96 % (6 M)

(iii) For 0.8 leading $E_o = \sqrt{(V\cos\Phi + IR_a)^2 + (V\sin\Phi - IX_s)^2}$ (2 M)

(iv) Voltage regulation = - 11. 276 % (5 M)

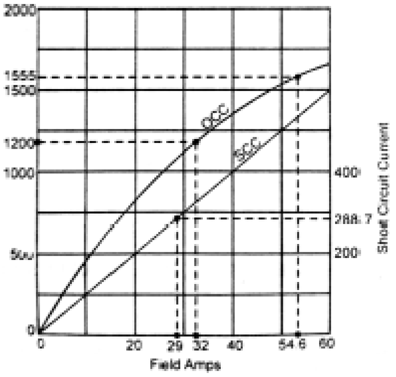
3

A three phase, star connected,1000 kVA, 2000V, 50Hzalternator gave the following open circuit and short circuit test readings:

Field current(A):	**10**	**20**	**25**	**30**	**40**	**50**
O.C. voltage(V):	**800**	**1500**	**1760**	**2000**	**2350**	**2600**
S.C.armature current(A):	**-**	**200**	**250**	**300**	**-**	**-**

The armature effective resistance per phase is 0.2Ω. Draw the characteristic curves and determine the full load percentage regulation at i.0.8 p.f lagging, ii. 0.8 p.f leading by MMF method.(15 M)(BTL 4)

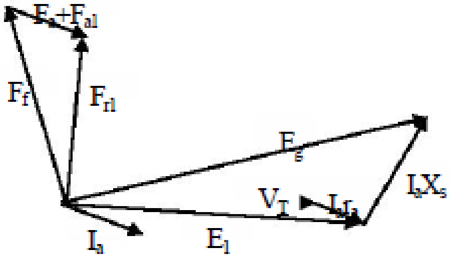
Answer: Page - 1.61 to 1.62- Dr. Gananvadivel



(a)

Graph (5 M)

- The phase voltages are: 462, 866, 1016, 1357, 1502
- Full load phase voltage = 2000/√3 = 1155 V
- Full load current = 1000000/(2000*√3) = 288.7 A

	➢ Voltage/phase at full load at 0.8 pf =V + IRa cos φ = 1155 + (288.7 * .02 * 0.8) = 1200 V ➢ From open circuit curve, it is found that field current necessary to produce this voltage = 32 A. • From short circuit characteristics it is found that field current necessary to produce full load current 288.7 A s 29 A From figure AB = 32 A, BC = 29 A and is at an angel of (90 + 36.86) = 126.86 with AB • The total field current at full load 0.8 pf lagging is AC = 54.6 A • Open circuit volt corresponding to a field current of 54.6 A is = 1554 V • % Regulation = (1555 -1155)*100 / 1155 ➢ Cos φ = 0.8, φ = 36.86 % Voltage regulation = 34.6 % (5 M) ➢ As power factor is leading, BC is drawn with AB at an angle of 90 – 36.86 = 53.14 A ➢ AC = 27.4 A ➢ Open circuit voltage corresponding to 27.4 A of field excitation is 1080 V ➢ % Regulation = (1080 – 1155) * 100 / 1155 ➢ % Voltage regulation = - 6.4 % (5 M)
4	**Explain the MMF method of evaluating the voltage regulation of alternator. (May/June 2015) (15 M)** (BTL 6) **Answer: page - 1.38 to 1.4 - J. Gnanavadivel** **Explanation** – (10M) ➢ This method is also known as amp - turns method. ➢ Emfs produced by rotor and stator are replaced by their equivalent. ➢ Assumed that magnetic circuit is unsaturated. ➢ Reactance drops are replaced by their equivalent mmfs. ➢ Emf method OC and SC characteristics are used for determination of regulation by mmf method. **Phasor Diagram** (3 M)  Fig: 1.19 ➢ From phasor diagram mmf required to produce emf E1= (V + IRa) is FR1. ➢ Large machines resistance drop may neglected. ➢ Mmf required to overcome reactance drops is (Fa+Fal).

	➢ Mmf (Fa+Fal) can be found from SC characteristic Following procedure can be used for determination of regulation by mmf method. ➢ By conducting OC and SC test plot OCC and SCC. ➢ From OCC find field current *If1* required to produce voltage, E1= (V + IRa). ➢ From SCC find magnitude of field current *If2* (Fa+Fal) to produce armature current. ➢ Fa+Fal can also found from ZPF characteristics. ➢ Draw *If2* at angle (90+) from *If1*. ➢ If current is leading, take the angle of *If2* as (90-). ➢ Determine resultant field current, *If* and mark its magnitude on the field current axis. ➢ From OCC. find voltage corresponding to *If*, which will be *E0*. ➢ Find regulation.

	UNIT II SYNCHRONOUS MOTOR
	Principle of operation – Torque equation – Operation on infinite bus bars - V and Inverted V curves – Power input and power developed equations – Starting methods – Current loci for constant power input, constant excitation and constant power developed-Hunting – natural frequency of oscillations – damper windings- synchronous condenser.
	PART * A
Q.No.	**Questions**
1	**Name the methods of starting a synchronous motor. (May/June 2014)** (BTL 1) ➢ By an extra 3 phase induction motor ➢ By providing damper winding in pole shoes ➢ By operating the pilot exciter as a dc motor
2	**Why a synchronous motor is called as constant speed motor? (April/May 2012)** (BTL 1) Synchronous motor work on the principle of force developed due to the magnetic attraction established between the rotating magnetic field and the main pole feed. Since the speed of rotating magnetic field is directly proportional to frequency the motor operates at constant speed.
3	**State V and inverted V curves of synchronous motor. (Nov/Dec 2011)** (BTL 1) The variation of magnitude of line current with respect to the field current is called V curve. The variation of power factor with respect to the field current is called inverted V curve.
4	**What happens when the field current of a synchronous motor is increased beyond the normal value at constant input?** (BTL 2) Increase in emf causes the motor to have reactive current in the leading direction. The additional leading reactive current causes the magnitude of line current, accompanied by the decrease in power factor.
5	**Distinguish between synchronous phase modifier and synchronous condenser.** (BTL 4) A synchronous motor used to change the power factor or power factor in the supply lines is called synchronous phase modifier. A synchronous motor operated at no load with over excitation condition to draw large leading reactive current and power is called a synchronous condenser.
6	**How does the synchronous motor can be used as synchronous condenser? (Nov/Dec 2011& 2012 & 2014)** (BTL 2) Synchronous motor is operated on over excitation so as to draw leading reactive current and power from the supply lines. This compensates the lagging current and power requirement of the load making the system power factor to become unity. The motor does the job of capacitors and hence called as synchronous condenser.

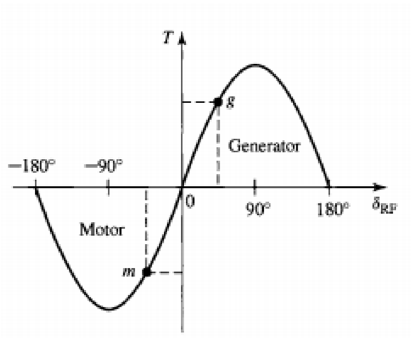
7	**Mention the methods of starting of 3-phase synchronous motor. (May/June 2014)** (BTL 2) ➢ A D.C motor coupled to the synchronous motor shaft. ➢ A small induction motor coupled to its shaft ➢ Using damper windings as a squirrel cage induction motor.
8	**What is meant by hunting of synchronous motor? (April/May 2012) & (Nov/Dec 2013)** (BTL 1) When the load applied to the synchronous motor is suddenly increased or decreased, the rotor oscillates about its synchronous position with respect to the stator field. This action is called hunting.
9	**Write important differences between a 3-phase synchronous motor and a 3-phase induction motor. (May/June 2014)** (BTL 1) ➢ Synchronous motor is a constant speed motor whereas induction motor speed will decrease on load. ➢ Synchronous motor requires A.C and D.C supplies whereas induction motor requires only A.C supply. ➢ Synchronous motor can be worked under various power factors such as lagging, leading and unity. But induction motor can be run with lagging power factor only.
10	**What could be the reasons if a 3-phase synchronous motor fails to start? (Nov/Dec 2014& May/June2015)** (BTL 4) It is usually due to the following reasons ➢ Voltage may be too low. ➢ Too much starting toad. ➢ Open circuit in one phase or short circuit. ➢ iv. Field excitation may be excessive.
11	**How does a change of excitation affect its power factor?** (BTL 4) When the excitation is reduced, the motor draws a lagging current and when the excitation is increased, the armature current is leading the applied voltage. It may also happen for some value of excitation, that current may be in phase with the voltage i.e. power factor is unity.
12	**Define phase swinging.** (BTL 1) Phase swinging is otherwise called as hunting. When the load on the synchronous motor is varying or the supply frequency is pulsating the speed of the machine will fluctuate causing vibration on the rotor, which is called hunting or phase swinging.
13	**Which condition a synchronous motor will fail to pull in to step?** (BTL 2) ➢ No field excitation. ➢ Excessive load. ➢ Excessive load inertia.
14	**Write the applications of synchronous motor.** (BTL 1) ➢ Used for power factor improvement in sub-stations and in Industries. ➢ Used in industries for power applications- ➢ Used for constant speed drives such as motor -generator set, pumps and compressors.
15	**Why a synchronous motor is a constant speed motor?** (BTL 4) It runs always with a constant speed called synchronous speed N =120 f/P. where f is the supply frequency and P is the no- of poles.

16	**How the synchronous motor is made self-starting?** (BTL 2) By providing damper windings in the pole face's, it will start and run like a squirrel cage induction motor.
17	**State the characteristic features of synchronous motor.** (BTL 1) ➢ The motor is not inherently self-starting ➢ The speed of operation is always in synchronous with the supply frequency irrespective of load conditions. ➢ The motor is capable of operating at any power factor.
18	**How the synchronous motor is differed from other motors?** (BTL 4) All dc and ac motors work on the same principle. Synchronous motor operates due to magnetic locking taking place between stator and rotor magnetic fields.
19	**Why a 3-phase synchronous motor always runs at synchronous speed?** (BTL 2) Because of the magnetic coupling between the stator poles and rotor poles the motor runs exactly at synchronous speed.
20	**What are the uses of damper winding in synchronous motor? (Nov/Dec 2013)** (BTL 1) ➢ Starting of synchronous motor ➢ Reduce the Oscillations
21	**What is the effect on speed if the load is increased on a 3-phase synchronous motor?** (BTL 1) The speed of operation remains constant from no load to maximum load if the motor operated constant frequency supply.
22	**What is the phasor relation between induced emf and terminal voltage of a 3 phase synchronous motor?** (BTL 1) The rotating magnetic field is initially established by the prime source of supply V. The main field then causes an emf (e) to get induced in the 3- phase winding. Hence when the machine operates as a synchronous motor the emf phasor always lags the terminal voltage phasor by the load/torque angle δ .
23	**What is meant by pull out torque?** (BTL 2) When the load on the motor is increased, the load angle is also increased, i.e. the rotor goes on progressively falling back in phase and draws more current. If we increase the load further, then the motor pulls out of synchronism and stops. The torque developed at pull out point is called pull out torque.
24	**How will you reverse the direction of rotation of a 3-phase synchronous motor?** (BTL 2) By Inter changing two phases of the 3-phase supply connections the direction of rotation can be reversed.
25	**Give some merits and demerits of synchronous motor.** (BTL 1) Merits ➢ This motor runs at constant speed (synchronous speed) even at full load. ➢ Can be operated with leading power factor, for power factor improvement. Demerits ➢ Two sources of supply are necessary ➢ Since damper-winding resistance is low, it takes large currents, from supply mains.

26 **When synchronous motor receives 100% excitation? (Nov/Dec 2015)** (BTL 1)

The value of excitation for which back emfE_b is equal (in magnitude) to applied voltage V is known as 100% excitation.

27 **Draw the typical torque angle characteristics of synchronous machine. (May/June2015)** (BTL 1)

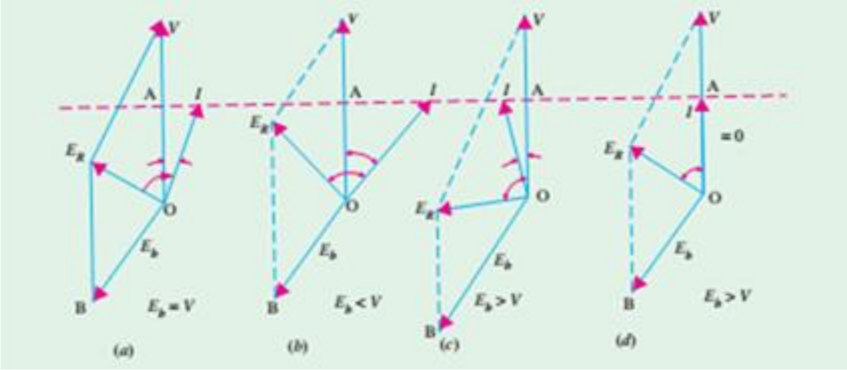


PART * B

1 **Explain the working of synchronous motor with different excitations. (May/June 2014) (13 M)** BTL 4

Answer: Page – 2.19 – J. Gnanavadivel

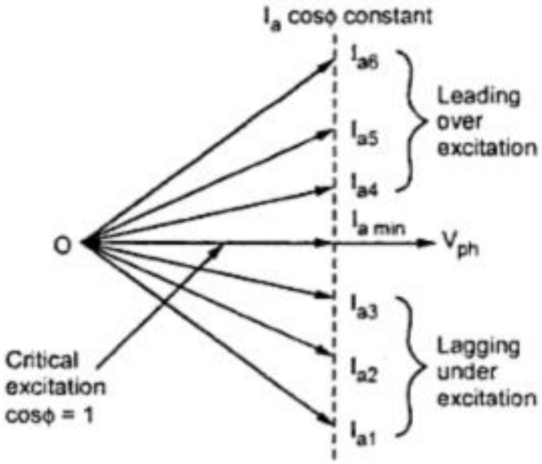
- Excitation for which back e.m.f. Eb is equal to oltage V is known as 100% excitation.
- Motor is either over-excited or under-excited.
- Consider a synchronous motor in which the mechanical load is constant.



(6 M)

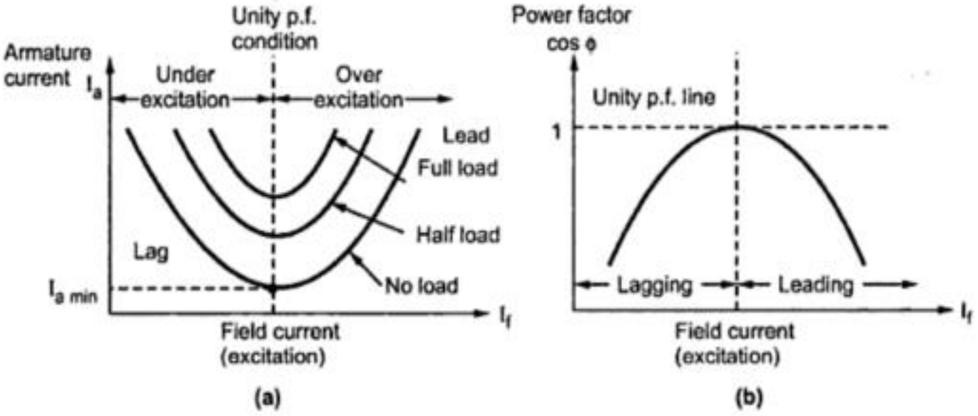
- Fig. 38.47 (a) shows for 100% excitation i.e., when Eb = V.
- Armature current I lags behind V by a small angle f.
- Angle q with ER is fixed by stator constants i.e. tan q = X S / Ra.
- In Fig. 38.47 (b)* excitation is less than 100% i.e., Eb < V.
- It lags behind ER by fixed angle q.
- Magnitude of I is increased but its power factor is decreased.
- Fig. 38.47 (c) represents for overexcited motor i.e. when Eb > V.
- Now motor is drawing a leading current.
- Current I may be in phase with V i.e., p.f. is unity.
- At that time, the current drawn by the motor would be minimum. (7 M)

2	**List out the main characteristic features of synchronous motor. (8 M)** BTL 4 **Answer: Page - 2.53- J. Gnanavadivel** Some salient features of a synchronous motor are: ➢ A synchronous motor runs at synchronous speed. ➢ Its speed is constant at all loads. ➢ To change its speed is to alter the supply frequency (Ns = 120 f/P). ➢ It can be made to operate over a wide range of power factors (lagging, unity or leading). ➢ By adjustment of its field excitation. (4 M) ➢ To carry the mechanical load at constant speed and at the same time improve the pf. ➢ Synchronous motors are generally salient pole type ➢ synchronous motor is not self-starting. ➢ An auxiliary means be used for starting it. (4 M)
3	**A 5kW,3 phase Y-connected 50 Hz,440 V, cylindrical rotor synchronous motor operates at rated condition with 0.8 pf leading. The motor efficiency excluding field and stator losses is 95% and X_s=2.5 Ω. Calculate** **1.Mechanical power developed** **2.armature current** **3.back emf** **4.power angle** **5.maximum or pull out torque of the motor. (13 M)** (BTL 3) **Answer: Page – 38 -Class Notes** Solution: ➢ Mechanical power developed =78950W (3 M) ➢ Armature current =129A (2 M) ➢ Back emf=516V (2 M) ➢ Power angle=-30^0(3 M) ➢ Maximum or pull out torque of the motor =1000Nm (3 M)
4	**Explain V-curves and inverted V-curves. (Nov/Dec 2011) & (Nov/Dec 2012)& (Nov/Dec 2013 & 2014) (13 M)** (BTL 4) **Answer: Page-2.18 - J. Gnanavadivel** ➢ If excitation is varied from very low to very high value, then current Ia decreases. ➢ minimum at unity p.f. and then again increases. ➢ initial lagging current becomes unity and then becomes leading.



(3 M)

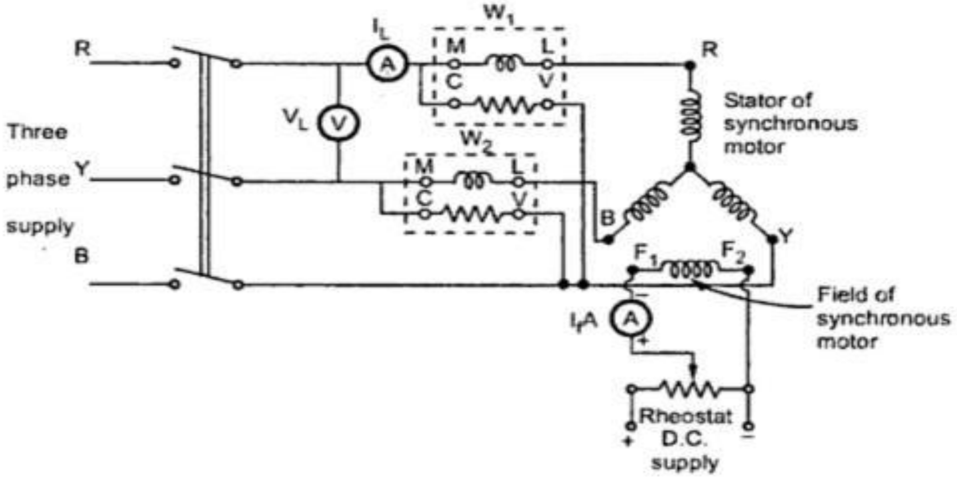
- ➢ Excitation can be increased by increasing the field current.
- ➢ graph of armature current drawn by Ia against field current (If) is plotted,
- ➢ then its shape looks like V curve.
- ➢ ower factor (cos Φ) is plotted against field current (If),
- ➢ then shape of graph looks an inverted V curve.



(3 M)

Experimental Setup to Obtain V-Curves

- ➢ Stator is connected top three phase supply through wattmeters and ammeter.
- ➢ two wattmeter method is used to measure input power of motor.
- ➢ ammeter is reading line current which is same as armature (stator) current.
- ➢ Voltmeter is reading line voltage.



- ➢ A rheostat in a potential divider arrangement is used in the field circuit.
- ➢ By controlling the voltage by rheostat, the field current can be changed.
- ➢ Hence motor can be subjected to variable excitation condition to note down the readings. (3 M)

Observation Table :

Sr. No.	V_L (V)	I_L (A)	W_1 (W)	W_2 (W)	I_f excitation (A)
1					
2					
:					

Now IL = Ia, per phase value can be determined, from the stator winding connections.

IL =Iaph for stator connection

IL/√3 = Iaph for delta connection

power factor can be obtained as

$$\cos\phi = \cos\left\{\tan^{-1}\left[\frac{\sqrt{3}\,(W_1 - W_2)}{(W_1 + W_2)}\right]\right\}$$

The result table can be prepared as :

Sr. No.	I_f (A)	I_a (A)	cos ϕ p.f.	Nature of p.f.
1				
2				
:				

The graph can be plotted from this result table.

- ➢ Ia Vs If → V-curve
- ➢ cosΦ Vs If → Inverted V-curve (4 M)

5.

Explain the various starting methods of a synchronous motor. (Nov/Dec 2012 & 2014) (13 M)(BTL 4)

Answer: Page – 2.14-2.15 - J. Gnanavadivel

Types: (2 M)

- Using pony motors
- Using damper winding
- As a slip ring induction motor
- Using small d.c. machine coupled to it.

Using pony motors(2 M)

- Rotor is brought to the synchronous speed.
- Some external device like small induction motor.
- Such an external device is called 'pony motor'.
- Rotor attains the synchronous speed, the d.c. excitation to the rotor is switched on.
- Synchronism is established pony motor is decoupled.
- Motor iscontinues to rotate as synchronous motor.

Using Damper Winding(3 M)

- Additional winding consisting of copper bars
- Placed in slots of pole faces.
- Bars are short circuited with help of end rings.
- Such an additional winding on the rotor is called damper winding.
- Winding as short circuited.

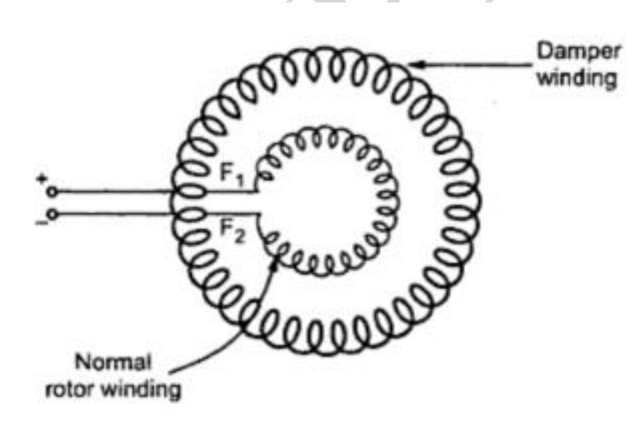


Fig . 1 Starting as a squirrel cage I.M.

- Rotor is excited by a three phase supply
- Motors starts rotating as an induction motor at sub synchronous speed.
- D.C supply is given to field winding.
- At a instant motor gets pulled into synchronism and starts rotating at a synchronous speed.
- As rotor rotates at synchronous speed,
- Relative motion between damper winding and rotating magnetic field is zero.
- Motor is running as synchronous motor, there can not be any induced e.m.f. indamper winding.
- Damper winding is active only at start

As a Slip Ring Induction Motor(3 M)

- Three ends of this winding are brought out through slip rings.
- An external rheostat then can be introduced in series with the rotor circuit.
- When stator is excited, motor starts as a slip ring induction motor
- Due to resistance added in the rotor provides high starting torque.
- Resistance is then gradually cut off, as motor gathers speed.

- Motor attains speed near synchronous. d.c. excitation is provided to rotor,
- then motors gets pulled into synchronism and starts rotating at synchronous speed.
- damper winding is shorted by shorting the slip rings.
- initial resistance added in rotor not only provides high starting torque
- but also limits high inrush of starting current.
- Hence it acts as a motor resistance starter.

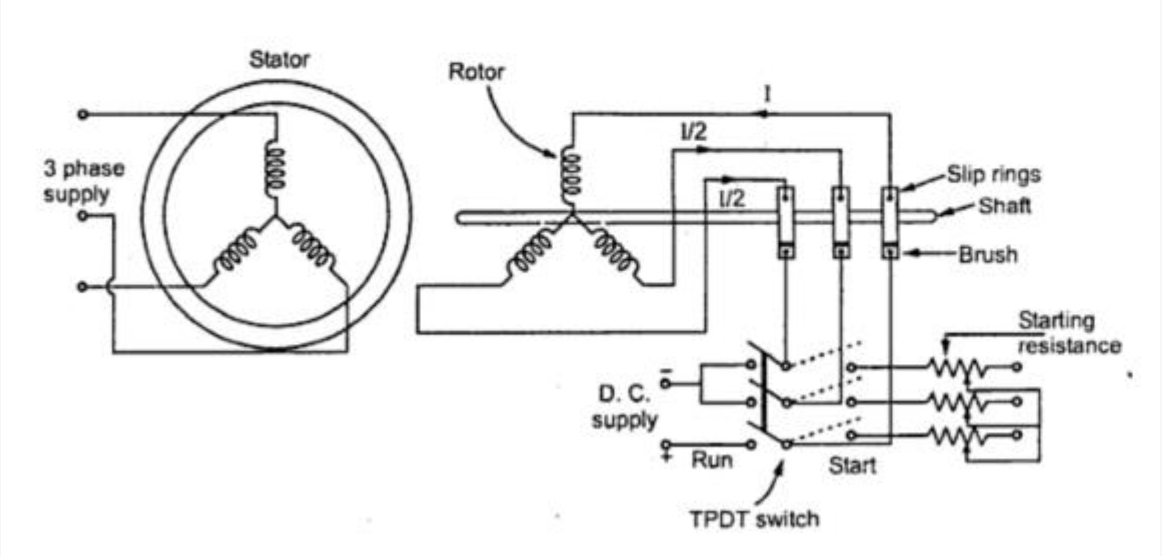


Fig. 2 Starting as a slip ring I.M.

Using Small D.C. Machine(3 M)

- synchronous motor is provided with a coupled d.c. machine.
- machine is used as a d.c. motor to rotate the synchronous motor at a synchronous speed.
- excitation to the rotor is provided.
- Once motor starts running as a synchronous motor,same d.c. machine acts as a d.c exciter.
- field ofsynchronous motor is then excited by this exciter itself.

6

Explain effect of changing field current excitation at constant load.
(i)Under excitation (ii) Normal excitation (iii) Over excitation (Nov/Dec 2011)& (April/May 2012) (13 M)(BTL 6)

Answer: Refer Page No. 2.18to 2.19 - J. Gnanavadivel

Under Excitation (3M)

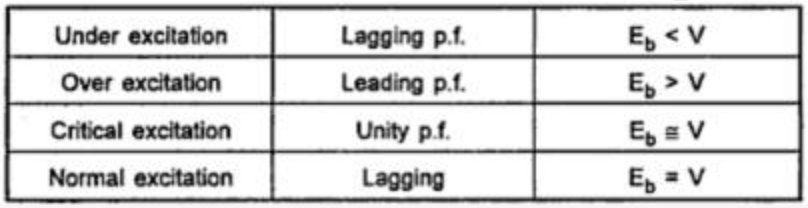
- magnitude of induced e.m.f. is less than the applied voltage ($E_b < V$)
- Due to this, E_R increases in magnitude.
- constant Z_s, current drawn by the motor increases.
- But E_R phase shifts in such a way that, phasor $I_a$also shifts (as $E_R \wedge I_a = \theta$) to keep $I_a \cos \Phi$ constant.
- under excited condition, current drawn by the motor increases.
- The p.f. cos Φ decreases and becomes more and more lagging in nature.

Normal Excitation (3M)

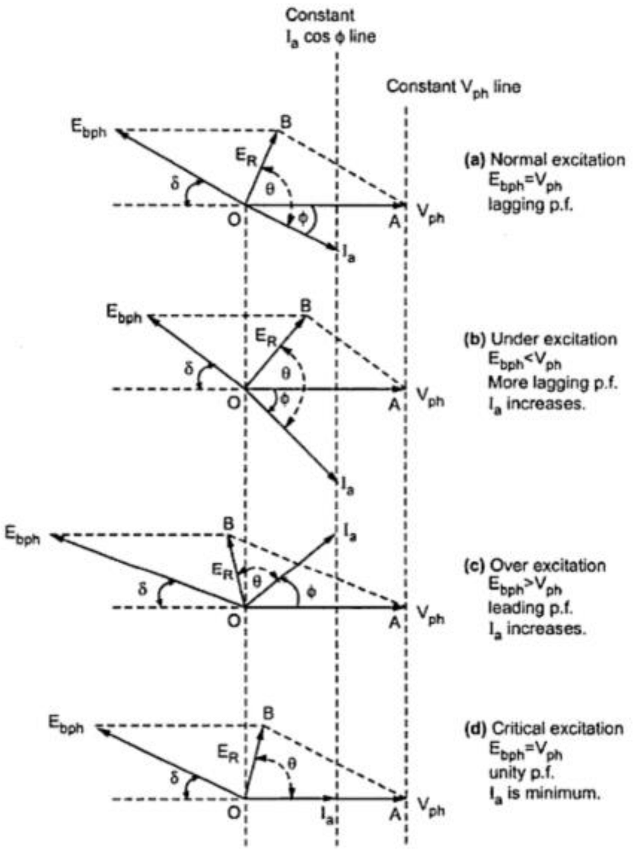
- where excitation is adjusted to get $E_b = V$ i.e. induced e.m.f. is equal to applied voltage.
- Such an excitation is called Normal Excitation of the motor.
- Motor is drawing certain current from the supply and power input to the motor is say P_{in}.
- The power factor of the motor is lagging in nature.

Over Excitation (3M)

- the induced e.m.f. becomes greater than applied voltage ($E_b < V$), is called over excitation.
- increased magnitude of E_b, E_R also increases in magnitude.
- But the phase of E_R also changes. Now = $E_R \wedge I_a = \theta$ is constant, hence I_a also changes its phase.
- Φ changes.
- I_a increases to keep $I_a \cos \Phi$ constant
- phase of E_R changes so that I_a becomes leading with respect to V_{ph} in over excited condition.
- So power factor of the motor becomes leading in nature.
- overexcited synchronous motor works on leading power factor.
- power factor decreases as over excitation increases but it becomes more and more leading in nature.



Under excitation	Lagging p.f.	$E_b < V$
Over excitation	Leading p.f.	$E_b > V$
Critical excitation	Unity p.f.	$E_b \cong V$
Normal excitation	Lagging	$E_b = V$



(4 M)

7

Illustrate the phenomenon of hunting and the use of damper winding with the help of dynamic equations. (May/June 2015) (13 M) (BTL 3)

Answer: Page No. 2.19 to 2.20- J. Gnanavadivel

Causes of Hunting in Synchronous Motor (6 M)

- Sudden change in load.
- Sudden change in field current.
- A load containing harmonic torque.
- Fault in supply system.

Effects of Hunting in Synchronous Motor (7 M)

- It may lead to loss of synchronism.
- Produces mechanical stresses.
- Increases machine losses and cause temperature rise.
- Cause greater surges in current and power flow.

8.

Explain how synchronous motor can be used as a synchronous condenser. Draw the phasor diagram. (April/May 2012) (13 M) (BTL 2)

Answer: Refer Page No. 2.27- J. Gnanavadivel

- When synchronous motor is over excited it takes leading p.f. current.
- If synchronous motor is on no load, where load angle δ is very small.
- It is over excited ($E_b > V$) then power factor angle increases almost upto 90^o.
- Motor runs with zero leading power factor condition.
- This characteristic is similar to a normal capacitor.
- Which takes leading power factor current.
- Over excited synchronous motor operating on no load condition is as synchronous condenser. (6 M)

Use of Synchronous Condenser in Power Factor Improvement

- Low power factor increases the cost of generation, distribution and transmission.
- Low power factor needs to be corrected.
- Such power factor correction is possible by connecting synchronous motor.
- V_{ph} is the voltage applied and I_{1ph} is the current lagging V_{ph} by angle Φ_1.
- This power factor Φ_1 is very low, lagging.
- Motor acting as a synchronous condenser.
- It draws a leading current of I_{2ph}.
- Total current drawn fromsupply is now phasor of I_{ph} and I_{2ph}.
- This total current I_T now lags V_{ph} by smaller angle Φ .
- Due to which effective power factor gets improved. (7 M)

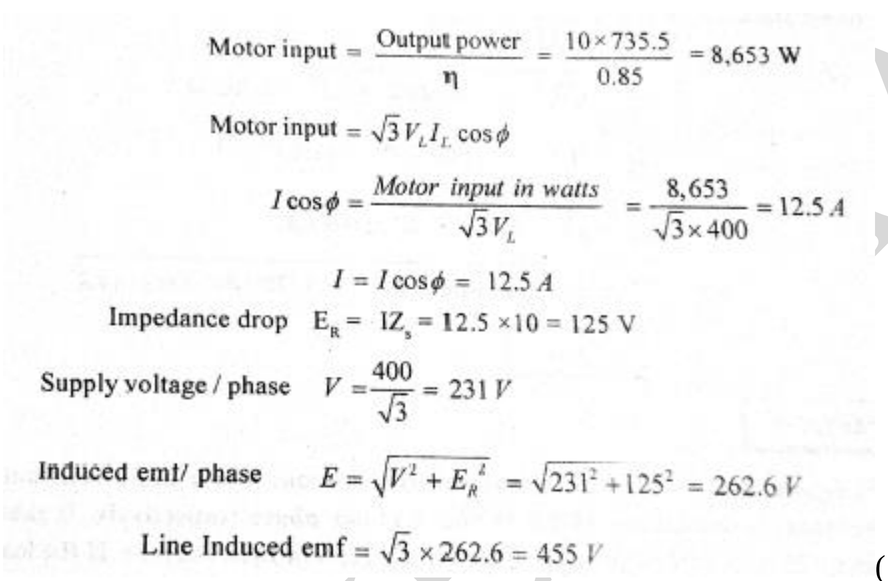
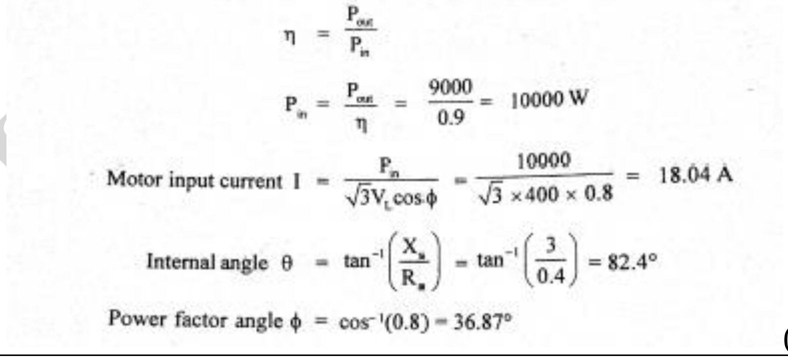
Part * C

1.

A 2.3 kV, 3 phase star connected synchronous motor has Zs = (0.2 + j 2.2) ohm per phase. The motor is operating at 0.5 PF leading with a line current of 200 A. Determine the generated emf per phase. (15 M) BTL 3

Answer: Page – 2.29-J. Gnanavadivel

- Input current I =200 A
- Supply voltage per phase = 2.3 * 1000 / √3 =1328 V (3 M)
- Internal angel $\theta = \tan^{-1} X_s/R_a = 84.8$ (3 M)

	➢ PF = $\cos^{-1}(0.5) = 60$ ➢ $Zs = \sqrt{(Ra^2 + Xs^2)} = 2.29$ (3 M) ➢ $E_R = I\ Zs = 200 * 2.209 = 441.8$ V (3 M) ➢ $E_b^2 = V^2 + E_R^2 - 2VE \cos(\varphi + \theta) = 1708$ V (3M)
2.	**A 400 V, 10 HP, 3 phase synchronous moto has negligible armature resistance and synchronous reactance of 10 ohm per phase. Determine the minimum current and the corresponding induced emf for full load condition. Assume an efficiency of 85 %. (15 M)** BTL 3 **Answer: Page – 2.31-J. Gnanavadivel**  Motor input $= \frac{\text{Output power}}{\eta} = \frac{10 \times 735.5}{0.85} = 8{,}653$ W Motor input $= \sqrt{3} V_L I_L \cos\phi$ $I \cos\phi = \frac{\textit{Motor input in watts}}{\sqrt{3} V_L} = \frac{8{,}653}{\sqrt{3} \times 400} = 12.5\ A$ $I = I\cos\phi = 12.5\ A$ Impedance drop $E_R = IZ_s = 12.5 \times 10 = 125$ V Supply voltage / phase $V = \frac{400}{\sqrt{3}} = 231\ V$ Induced emf/ phase $E = \sqrt{V^2 + E_R^2} = \sqrt{231^2 + 125^2} = 262.6\ V$ Line Induced emf $= \sqrt{3} \times 262.6 = 455\ V$ (15 M)
3.	**A 9 kW, 400 V, 3 phase star connected synchronous motor has synchronous impedance per phase of (0.4 + j3) ohm. Find the angle of retard and the voltage to which the motor must be excited to give a full load output at 0.8 leading pf. Assume in efficiency of 90%.** **(15 M)** BTL 3 **Answer: Page – 2.47 by Dr. J. Gnanavadivel**  $\eta = \frac{P_{out}}{P_{in}}$ $P_{in} = \frac{P_{out}}{\eta} = \frac{9000}{0.9} = 10000$ W Motor input current $I = \frac{P_{in}}{\sqrt{3} V_L \cos\phi} = \frac{10000}{\sqrt{3} \times 400 \times 0.8} = 18.04$ A Internal angle $\theta = \tan^{-1}\left(\frac{X_s}{R_s}\right) = \tan^{-1}\left(\frac{3}{0.4}\right) = 82.4°$ Power factor angle $\phi = \cos^{-1}(0.8) = 36.87°$ (5 M)

	Voltage per phase $V = \frac{400}{\sqrt{3}} = 231V$ Impedance drop per phase $E_R = IZ_s = 18.04 \times 3.026 = 54.58V$ $E_b = \sqrt{V^2 + E_R^2 - 2VE_R \cos(\theta + \phi)}$ $= \sqrt{231^2 + 54.58^2 - 2 \times 231 \times 54.58 \cos(82.4° + 36.87°)}$ $\boxed{E_b = 262.04 \text{ V}}$ (5 M) Line induced emf $= \sqrt{3} \times 262.04 = 453.86 \text{ V}$ Also $\frac{E_R}{\sin\delta} = \frac{E_b}{\sin(\theta + \phi)}$ $\sin\delta = \frac{E_R \sin(\theta + \phi)}{E_b} = \frac{54.58 \sin(82.4° + 36.87°)}{262.04} = 0.181$ $\delta = \sin^{-1}(0.181) = 10.46°$ $\boxed{\delta = 10.46°}$ (5 M)
4.	**A 1500 kW, 3 phase, star connected, 3.3 kV synchronous motor has reactance of Xd = 4.01 ohm and Xq = 2.88 ohm per phase. All losses may be neglected. Calculated the excitation emf when the motor is supplying rated load at unity PF. Also calculate the maximum mechanical power that the motor can supply with excitation held fixed at this value. (15 M)** BTL 3 **Answer: Page – 2.45 -J. Gnanavadivel.** $V = \frac{3300}{\sqrt{3}} = 1905 \text{ V}$ $\cos\phi = 1; \sin\phi = 0; \phi = 0°$ Armature current $I_a = \frac{kW}{\sqrt{3} V_L \cos\phi} = \frac{1500 \times 10^3}{\sqrt{3} \times 3300 \times 1} = 262.43 \text{ A}$ $\tan\psi = \frac{V\sin\phi - I_a X_q}{V\cos\phi} = \frac{1905 \times 0 - 262.43 \times 2.88}{1905 \times 1} = -0.3967$ $\psi = -21.63°$ $\delta = \phi - \psi = 0 - (-21.63°) = 21.63°$ $I_d = 262.43 \times \sin(-21.63°) = -96.76 \text{A}$ $I_q = 262.43 \times \cos(-21.63°) = 243.95 \text{A}$ $E_b = V\cos\delta - I_d X_d$ $= 1905(\cos(-21.63) - (-96.76 \times 4.01))$ $= 2158.86 \text{ V}$ (5 M)

$$P_m = \frac{E_b V}{X_d}\sin\delta + \frac{V^2\left(X_d - X_q\right)}{2X_dX_q}\sin 2\delta$$

$$= \frac{2158.86\times1905}{4.01}\sin\delta + \frac{1905^2\left(4.01-2.88\right)}{2\times4.01\times2.88}\sin 2\delta$$

$$= 1025.59\times10^3\sin\delta + 177.54\times10^3\sin 2\delta$$

(5 M)

If developed power has to achieve maximum value, then

$$\frac{dP_m}{d\delta} = 1025.59\times10^3\cos\delta + 2\times177.54\times10^3\cos 2\delta = 0$$

$$\therefore\ 1025.59\times10^3\cos\delta + 355.08\times10^3\left(2\cos^2\delta - 1\right) = 0$$

or $$710.16\times10^3\cos^2\delta + 1025.59\times10^3\cos\delta - 355.08\times10^3 = 0$$

$$\cos\delta = \frac{-1025.59\times10^3 \pm \sqrt{\left(1025.59\times10^3\right)^2 + 4\times710.16\times10^3\times355.08\times10^3}}{2\times710.16\times10^3}$$

$$= \frac{-1025.59\times10^3 \pm 1435.44\times10^3}{1420.32\times10^3} = 0.288$$

$$\delta = 73.22^\circ$$

Maximum $P_m = 1025.59\times10^3\sin\left(73.22^\circ\right) + 177.54\times10^3\ \sin\left(2\times73.22^\circ\right)$

$P_m = 1080$ kW

Maximum Power developed for three phases $= 3 \times P_m$

$= 3 \times 1080 = 3240$ kW

(5 M)

	UNIT III - THREE PHASE INDUCTION MOTOR
	Constructional details – Types of rotors –- Principle of operation – Slip –cogging and crawling- Equivalent circuit – Torque-Slip characteristics - Condition for maximum torque – Losses and efficiency – Load test - No load and blocked rotor tests - Circle diagram – Separation of losses – Double cage induction motors –Induction generators – Synchronous induction motor.
	PART * A
Q.No.	**Questions**
1	**State the principle of 3 phase IM.**(BTL 1) While starting, rotor conductors are stationary, and they cut the revolving magnetic field and so an emf is induced in them by electromagnetic induction. This induced emf produces a current if the circuit is closed. This current opposes the cause by Lenz's law and hence the rotor starts revolving in the same direction as that of the magnetic field.
2	**Why an induction motor is called as 'rotating transformer'?**(BTL 2) The rotor receives electric power in exactly the same way as the secondary of a two-winding transformer receiving its power from the primary. That is why an induction motor can be called as a rotating transformer i.e. one in which primary winding is stationary but the secondary is tree to rotate.
3	**Why an induction motor will never run at its synchronous speed?**(BTL 2) If the rotor runs at synchronous speed, then there would be no relative speed between the two; hence no rotor EMF, no rotor current and so no rotor torque to maintain rotation. That is why the rotor runs at a speed, which is always less than syn. speed.
4	**State the advantages of skewing. (Nov/Dec 2011)**(BTL 2) ➢ It reduces humming and hence quite running of motor is achieved. ➢ It reduces magnetic locking of the stator and rotor.
5	**State the condition for maximum torque.** (BTL 1) $R_2=X_2$
6	**What are the effects of increasing rotor resistance on starting current and starting torque?**(BTL 1) ➢ The additional external resistance reduces the rotor current and hence the current drawn from the supply. ➢ It improves the starting torque developed by improving the power factor in high proportion to the decrease in rotor current.
7	**What is slip of an induction motor? (Nov/Dec 2011)& (Nov/Dec 2012) & (Nov/Dec 2013 & 2014)**(BTL 1) The slip speed is defined as the ratio of relative speed to synchronous speed is expressed as % slip S=(Ns-N)/Ns*100

8	**What are the advantages of slip-ring IM over cage IM?(**BTL 1) ➢ Rotor circuit is accessible for external connection. ➢ By adding external resistance to the rotor circuit, the starting current is reduced with the added advantage of improving starting torque. ➢ Additional speed control methods can be employed with the accessibility in the rotor circuit.
9	**Name the tests to be conducted for predetermining the performance of 3-phase induction machine.**(BTL 1) ➢ No load test. ➢ Blocked rotor test.
10	**What is the information obtained from no-load test in a 3-phase I M?**(BTL 1) ➢ No –load input current per phase, Io. ➢ No load power factor and hence no-load phase angle. ➢ Iron and mechanical losses together. ➢ Elements of equivalent circuit shunt branch.
11	**What is the information obtained from blocked rotor test in a 3-phase I M?**(BTL 1) ➢ Blocked rotor input current per phase at normal voltage. ➢ Blocked rotor power factor and hence phase angle. ➢ Total resistance and leakage reactance per phase of the motor as referred to the stator.
12	**What is circle diagram of an IM?**(BTL 2) When an I M operates on constant voltage and constant frequency source, the loci of stator current phasor is found to fall on a circle. This circle diagram is used to predict the performance of the machine at different loading conditions as well as mode of operation.
13	**What are the advantages and disadvantages of circle diagram method of predetermining the performance of 3 –phase IM?**(BTL 2) The prediction can be carried out when any of the following information is available. The input line current., the input power factor, The active power input, The reactive power input, The apparent power input, The output power, The slip of operation, The torque developed, The equivalent rotor current per phase, Maximum output power, Maximum torque developed. The only disadvantage is, being a geometrical solution; errors made during measurements will affect the accuracy of the result.
14	**What are the advantages and disadvantages of direct load test for 3 – phase IM?**(BTL 2) Advantages ➢ Direct measurement of input and output parameters yield accurate results. ➢ Aside from the usual performance other performances like mechanical vibration, noise etc can be studied. ➢ By operating the motor at full load for a continuous period, the final steady temperature can be measured. Disadvantages ➢ Testing involves large amount of power and the input energy and the entire energy delivered is wasted.

15	**What is an induction generator? (April/May 2012)**(BTL 1) An induction generator does not differ in its construction from an induction motor. Whether the induction, machine acts as generator or motor depends solely upon its slip. Below synchronous speed it can operate only as motor, above synchronous speed it operates as generator and is now called as induction generator.
16	**What do you mean by slip speed?**(BTL 1) The difference between the synchronous speed and the rotor speed N is called as slip speed. The rotor speed will be always less than synchronous speed.
17	**Why an induction motor at no-load operates at very low power factor?**(BTL 2) The current drawn by an induction motor running at no load is largely a magnetizing current. So, no-load current lags behind the applied voltage by a large angle. Therefore, the power factor of a lightly loaded induction motor is very low.
18	**What is cogging of induction motor?**(BTL 1) When the number of teeth in stator and rotor are equal, the stator and rotor teeth have a tendency to align themselves exactly to minimum reluctance position. In such case the rotor may refuse to accelerate. This phenomenon is called "magnetic locking, or cogging.
19	**Write the advantages of double squirrel cage induction motor. (Nov/Dec 2012 & 2014)**(BTL 1) ➢ Improves the starting torque ➢ Low I^2R loss under running conditions and hence high efficiency.
20	**How the direction of rotation of a three-phase induction motor can be reversed? (April/May 2012)**(BTL 2) The direction of rotation of three phase induction motor can be changed by interchanging any two terminal of input supply (R&Y,R&B, etc.,).The direction of the synchronously rotating field reverses and hence the direction of rotor reverses.
21	**How do change in supply voltage and frequency affect the performance of a 3-phase induction motor?(May/June 2014)**(BTL 2) (i)This large change in voltage will result in a large change in the flux density thereby seriously disturbing the magnetic conditions of the motor. (ii)If the supply frequency is changed, the value of air gap flux also gets affected. This may results in to saturation leads to the sharp rise in the no load current of the motor.
22	**State the condition formaximum torque under running condition. (Nov/Dec 2015)**(BTL 1) R_2=SX_2; R_2 = rotor resistance; X_2 = Rotor reactance; s = slip
23	**What are the losses occurring in an IM and on what factors do they depend?**(BTL 1) Magnetic losses $W_{i,}$ Electrical losses $W_{cu}$and Mechanical losses W_m. For IM operating in normal condition (with constant voltage and frequency) magnetic and mechanical losses remain constant whereas electrical losses vary in square proportion to the current.
24	**What is meant by synchronous watts?**(BTL 1) The torque developed in an induction motor is proportional to rotor input. By defining a new unit of torque (instead of the force at radius unit) we can say that the rotor torque equals rotor input. The new unit is synchronous watts. Synchronous wattage of an induction motor equals the power transferred across the air-gap to the rotor.

25 **How much torque is developed in an induction motor at synchronous speed? (May/June 2015)**(BTL 1)

The torque developed in an induction motor at synchronous speed is zero. If the rotor runs at synchronous speed, then there would be no relative speed between the two; hence no rotor EMF, no rotor current and so no rotor torque to maintain rotation. That is why the rotor runs at a speed, which is always less than synchronous speed.

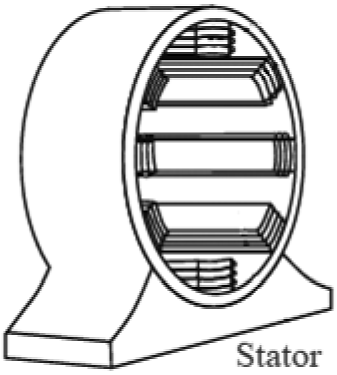
26 **State a method by which starting torque of the induction motor can be increased. (May/June 2015)**(BTL 1)

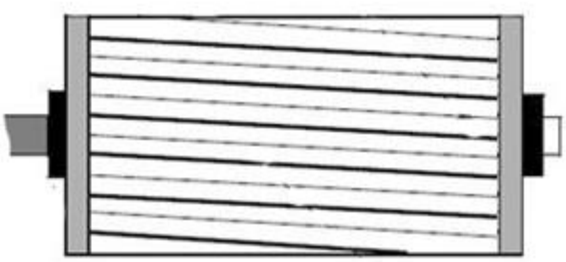
By adding external resistance to the rotor circuit to improve the starting torque of induction motor.

PART * B

1 **Explain the construction and working of three phase induction motor. (Nov/Dec 2011), (April/May 2012) & (Nov/Dec 2012)&(Nov/Dec 2013 & 2014) (13 M)** (BTL 1)

Answer: Page - 3.1 to 3.3 & 3.9 to 3.10.- J. Gnanavadivel





Rotor (4 M)

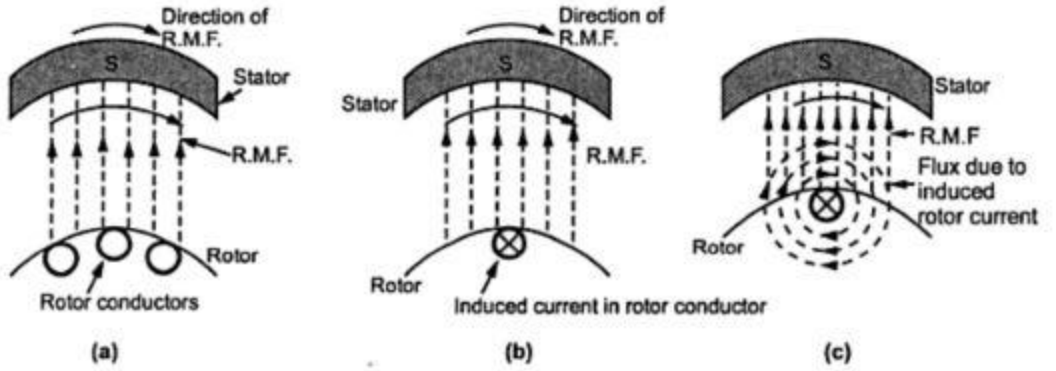
Stator: (3 M)

- It is made up with number of stamping.
- Stator is wound with a 3 phase winding which is fed from a 3 phase supply.
- It is wound for a defined number of poles.
- Number of poles is determined from the required speed.
- Stator windings are supplied with 3 phase ac supply.
- They produce alternating flux which revolves with synchronous speed.
- The synchronous speed is inversely proportional to number of poles (Ns = 120f / P).
- This rotating magnetic flux induces current in rotor windings according to Faraday's law of mutual induction.

Rotor: (3 M)

- It consists of cylindrical laminated core with parallel slots that can carry conductors.
- Conductors are heavy copper or aluminum bars which fits in each slot.
- They are short circuited by the end rings.
- The slots are not exactly made parallel to the axis of the shaft.
- But slots are slotted a little skewed because this arrangement reduces magnetic humming noise & can avoid stalling of motor.

Working Principle (3 M)



(a) (b) (c)

- Rate of change of magnetic flux linkage through the circuit.
- As the rotor winding in an induction motor are either closed through an external resistance or directly shorted by end ring.
- Cut the stator rotating magnetic field.
- An emf is induced in the rotor copper bar.
- Due to this emf a current flows through the rotor conductor.
- Here the relative speed between the rotating flux and static rotor conductor is the cause of current generation
- Hence as per Lenz's law the rotor will rotate in the same direction.
- Reduce the causethe rotor speed should not reach the synchronous speed produced by the stator.
- If the speeds equals, there would be no such relative speed, so no emf induced in the rotor.
- No current would be flowing, and therefore no torque would be generated.
- Rotor cannot reach the synchronous speed.
- The difference between the stator and rotor speeds is called the slip.

2

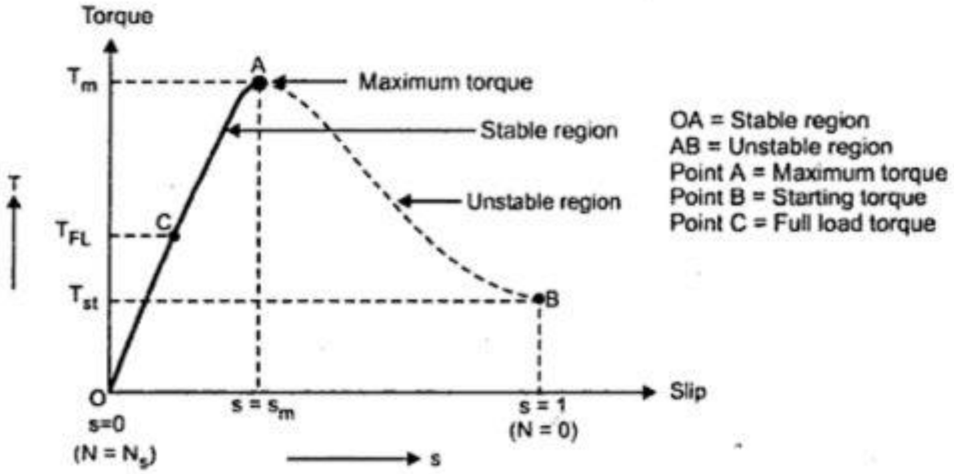
Explain torque slip characteristics of induction motor.(Nov/Dec 2014) (13 M) (BTL 2)
Answer: Page - 3.53 to 3.54 - J. Gnanavadivel

<u>Torque-Slip Characteristics</u>:

- The motor torque under running conditions is given by;
- The following points may be noted carefully:
- At s = 0, T = 0 so that torque-slip curve starts from the origin.
- At normal speed, slip is small so that s X_2 is negligible as compared to R_2.

  T α s/R_2

  T α sas R_2 is constant.
- Hence torque slip curve is a straight line from zero slip to a slip that corresponds to full-load.
- As slip increases beyond full-load slip, the torque increases andmaximum at s = R_2/X_2.
- This maximum torque in an induction motor is called pull-out torque.
- Its value is at least twice the full-load value when the motor is operated at rated voltage and frequency.



(4 M)

- Maximum torque, the term $s^2 X_2^2$ increases very rapidly so that R_2^2 may be neglected as compared to $s^2 X_2^2$
- $T \alpha \;\; s / s^2 X_2^2$
- $\alpha \;\; 1/ s$ ... as X_2 is constant
- Thus the torque is now inversely proportional to slip.
- Hence torque-slip curve is a rectangular hyperbola. (9 M)

3

Derive the torque equation of a three-phase induction motor. (Nov/Dec 2013) &(Nov/Dec 2015) (8 M) (BTL 1)

Answer: Page - 3.32 to 3.34 - J. Gnanavadivel

- The torque produced by three phase induction motor depends upon the following three factors:
- Magnitude of rotor current,
- EMF in the rotor part of induction motor,
- Power factorof rotor of the three-phase induction motor.
- Equation of torque as- $T \propto \phi I_2 \cos \theta_2$(4 M)
- Where, T is the torque produced by the induction motor.
- φ is flux responsible for producing induced emf,
- I_2 is rotor current,
- $\cos\theta_2$ is the power factor of rotor circuit.
  - The flux φ produced by the stator is proportional to stator emf E_1. i.e $\varphi \propto E_1$

$$K = \frac{E_2}{E_1}$$

$$or,\ K = \frac{E_2}{\phi}$$

$$or,\ E_2 = \phi$$

$$i.e\ I_2 = \frac{sE_2}{Z_2}$$

- sE_2 to total impedance, Z_2 of rotor side, (4 M)
- $Z_2 = \sqrt{R_2^2 + (sX_2)^2}$ Putting this value in above equation we get,

$$I_2 = \frac{sE_2}{\sqrt{R_2^2 + (sX_2)^2}}$$

- s = slip of induction motor

$$\cos\theta_2 = \frac{R_2}{Z_2} = \frac{R_2}{\sqrt{R_2^2 + (sX_2)^2}}$$

- $$T \propto E_2 \frac{sE_2}{\sqrt{R_2^2 + (sX_2)^2}} \times \frac{R_2}{\sqrt{R_2^2 + (sX_2)^2}}$$

$$T \propto sE_2^2 \frac{R_2}{\sqrt{R_2^2 + (sX_2)^2}}$$

- Removing proportionality constant we get,

$$T = KsE_2^2 \frac{R_2}{\sqrt{R_2^2 + (sX_2)^2}}$$

$$This\ comstant\ K = \frac{3}{2\pi n_s}$$

- Where, n_s is synchronous speed in r. p. s, $n_s = N_s / 60$. So, finally the equation of torque becomes,

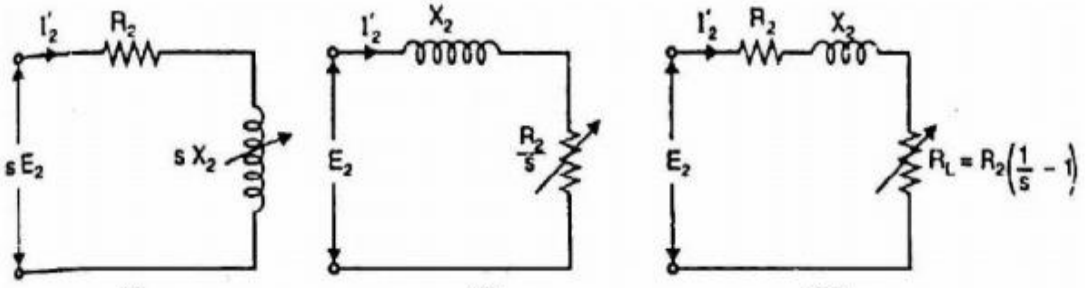
$$T = sE_2^2 \times \frac{R_2}{R_2^2 + (sX_2)^2} \times \frac{3}{2\pi n_s} N - m$$

- Derivation of K in torque equation. (5 M)

4

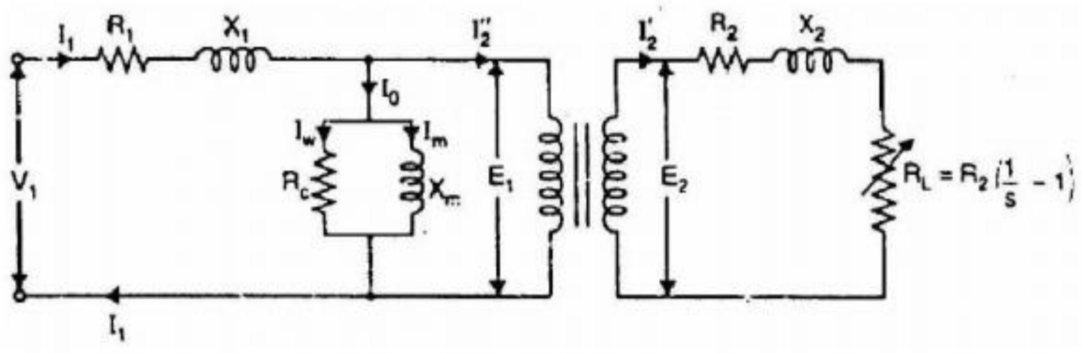
Develop an equivalent circuit for three phase induction motor. Nov/Dec 2011)&(Nov/Dec 2012) &(Nov/Dec 2015) (13 M) (BTL 6)

Answer: Page - 3.84 to 3.89 - J. Gnanavadivel

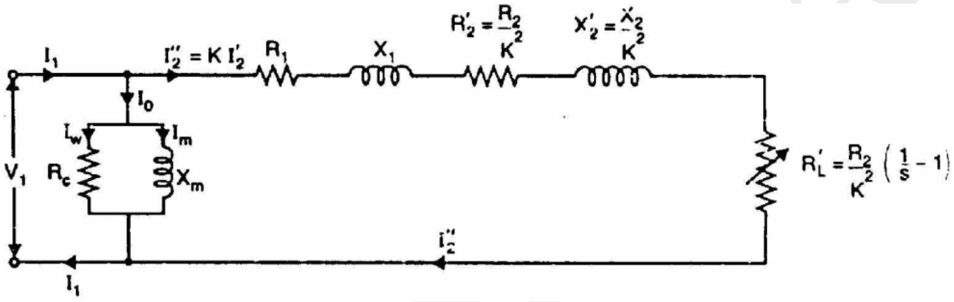


(i) (ii) (iii)

- (4 M)

- 

(4 M)

- 

(5 M)

5. **A 6 pole, 50Hz, 3 phase, induction motor running on full load develops a useful torque of 160Nm. When the rotor emf makes 120 complete cycle per minute. Calculate the shaft power input. If the mechanical torque lost in friction and that for core loss is 10 Nm, compute.**

The copper loss in the rotor windings.

The input of motor.

The efficiency. The total stator loss is given to be 800W. (Nov/Dec 2011)&(Nov/Dec 2015) (13 M) (BTL 5)

Answer: Page - 3.83 - J. Gnanavadivel

- Frequency of rotor emf = fr = 120/60 = 2 Hz
- Slip = s = fr/f = 2/50 = 0.04
- Ns = 120f/P = 1000 rpm
- Motor Speed N= Ns(1 – s) = 1000(1 – 0.04) = 960 rpm (4 M)
- Tsh = Pout * 60 / (2 π N) = 16085 W
- Pm = Tg * 2πN/60 = 17291 N-m (4 M)
- Pcu = 720.45 W
- P2 = 18011.4 W
- Pin = 18211.4 W
- Efficiency = 88.32 % (5 M)

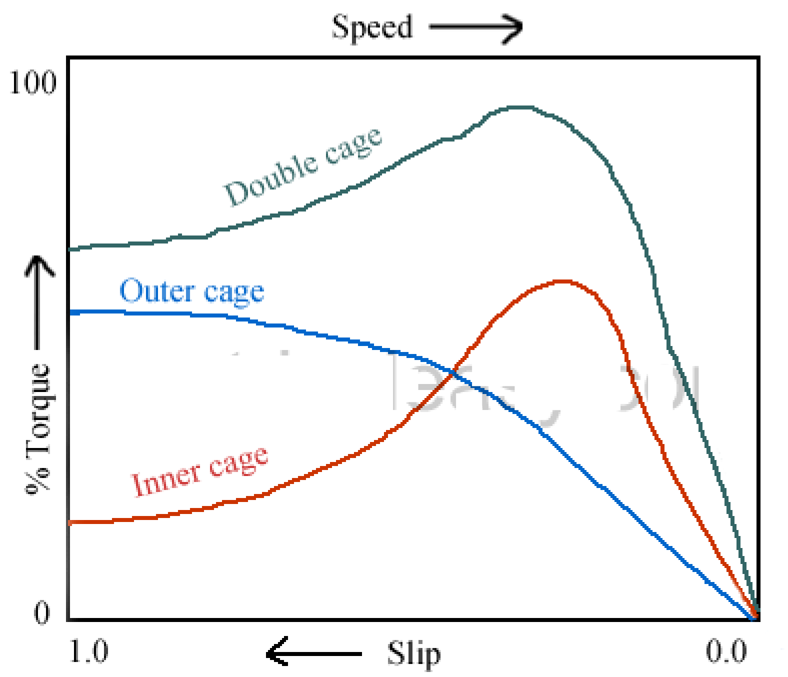
6 **Describe the no load and blocked rotor tests in a three-phase induction motor. (13 M)** (BTL 4)

Answer: Page - 3.102 - J. Gnanavadivel

Calculation of No Load Test of Induction Motor: (6 M)

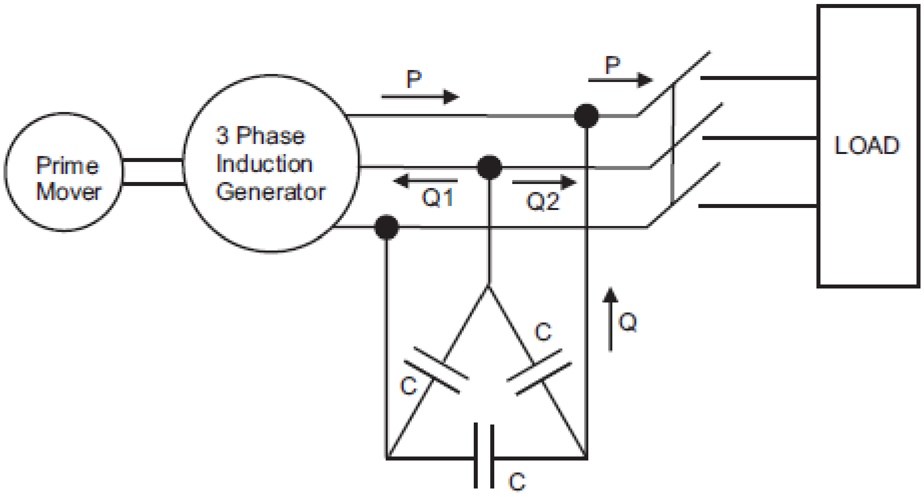
- Let the total input power supplied to induction motor be W_0 watts.

	➢ $W_0 = \sqrt{3}V_1 I_0 Cos\Phi_0$ ➢ Where, V_1 = line voltage ➢ I_0 = No load input current ➢ Rotational loss = $W_0 - S_1$ ➢ Where, S_1 = stator winding loss = $N_{ph} I^2 R_1$ ➢ N_{ph} = Number phase ➢ The various losses like windage loss, core loss, and rotational loss are fixed losses ➢ Stator winding loss = $3I_o^2R_1$ ➢ Where, I_0 = No load input current ➢ R_1 = Resistance of the motor ➢ Core loss = $3G_oV^2$ Calculations of Blocked Rotor Test of Induction Motor: (7 M) ➢ $W_{cu} = W_s - W_c$ ➢ Where, W_c = core loss ➢ $W_{cu} = 3I^2R_{01}$ ➢ Where, R_{01} = Motor winding of stator and rotor as per phase referred to stator. $R_{01} = \frac{W_{cu}}{3I_s^2} \ldots\ldots\ldots\ldots(1)$ ➢ Now let us consider I_s = short circuit current ➢ V_s = short circuit voltage ➢ Z_0 = short circuit impedance as referred to stator $Z_{01} = \frac{short\ circuit\ voltage\ per\ phase}{short\ circuit\ current} = \frac{V_s}{I_s} \ldots\ldots\ldots\ldots(2)$ $X_{01} = \sqrt{Z_{01}^2 - R_{01}^2}$ ➢ Stator reactance X_1 and rotor reactance per phase referred to stator X_2 are normally $X_1 = X_2 = \frac{X_{01}}{2}$ assumed equal. Th ➢ stator resistance per phase R_1 ➢ rotor resistance per phase referred to stator R_2 ➢ $R_2 = R_{01} - R_1$
7.	**Write brief notes on (i) Double Cage rotor (ii) Induction Generator (13 M) (May 2006)** (BTL 2) **Answer: Page –3.116 & 3.119 - J. Gnanavadivel**



(3 M)

- At starting of the motor, frequency of induced emf is high because of large slip.
- Reactance of inner cage will be very high, increasing its total impedance.
- Hence at starting most of the current flows through outer cage despite its large resistance
- This will not affect the outer cage because of its low reactance.
- And because of the large resistance of outer cage starting torque will be large.
- As speed of the motor increases, slip decreases, and hence the rotor frequency decreases.
- Reactance of inner cage will be low, and most of the current will flow through the inner cage which is having low resistance.
- Hence giving a good efficiency.
- When the double cage motor is running at normal speed,
- Frequency of the rotor emf is so low that the reactance of both cages is negligible.
- The two cages being connected in parallel, the combined resistance is lower. (4 M)
- **Induction Generator:**



(3 M)

- ➢ This type of generator is also known as self-excited generator.
- ➢ Capacitor bank which is connected across its stator terminals
- ➢ The function of the capacitor bank is to provide the lagging reactive power to the induction generator as well as load.
- ➢ Total reactive power provided by the capacitor bank is equals to sum of reactive power and load.
- ➢ There is generation of small terminal voltage oa across the stator terminal.
- ➢ Due the residual magnetism when the rotor of the induction machine runs at the required speed.
- ➢ Due to this voltageoa the capacitor current ob is produced.
- ➢ The currentbc sends current od which generates the voltage de. (3 M)

PART * C

1. **A 746 KW, 3-phase,50 Hz, 16-pole induction motor has a rotor impedance of (0.02+j0.15)Ω at standstill. Full load torque is obtained at 360 rpm. Calculate (i)The ratio of maximum to full-load torque (ii) The speed at maximum torque and (iii) The rotor resistance to be added to get maximum starting torque. (15 M)(May/June 2014)()**BTL 5)

Answer:Page - 3.48 - J. Gnanavadivel

- ➢ Ns = 120f/P = 375 rpm
- ➢ Sf = (Ns – N)/Ns = 0.04 (4 M)
- ➢ a = R2/X2 = 0.133
- ➢ $Tf/Tm = 2as_f / (a^2 + s_f^2) = 0.55$
- ➢ Tm/Tf = 1.818 (4 M)
- ➢ $Sm = R_2/X_2 = 0.02/0.15 = 0.133$
- ➢ N = Ns(1-s) = 325 (4 M)
- ➢ For maximum torque $R_2 = X_2$. Total resistance = 0.156 ohm
- ➢ External resistance required /phase = 0.13 ohm (3 M)

2.

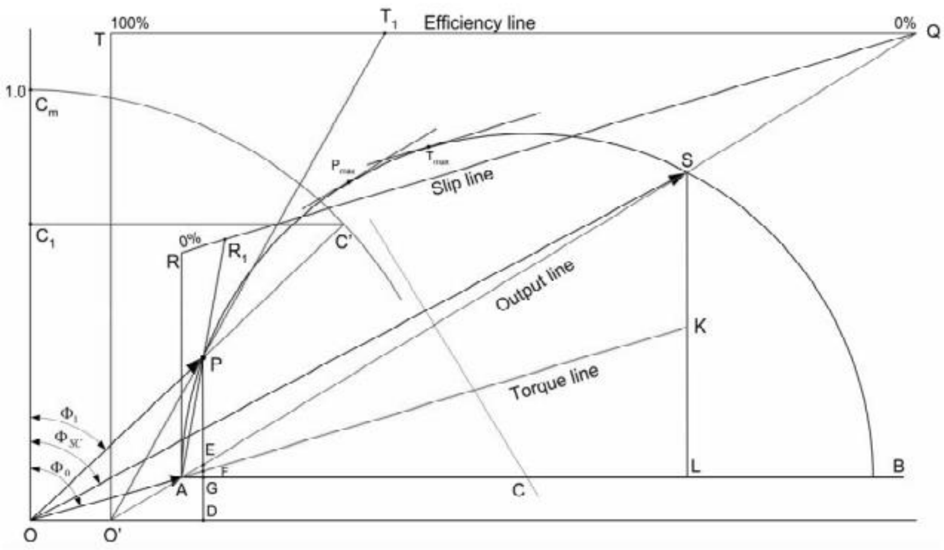
A 29.84 KW,415V,50Hz,3 phase delta connected induction motor gave the following test results:

No load test: 415V, 21A, 1250 W

Blocked rotor test: 100V,45A,2730 W

Stator and rotor ohmic losses at standstill are assumed equal. Draw the induction motor circle diagram and calculate (i)Line current (ii)Power Factor. (15 M)(May/June 2014)(BTL 5)

Answer: Page - 3.110 - J. Gnanavadivel



(8 M)

- Cos φ0 = 0.0918
- φ0 = 84.44
- φb = 69.3
- power scale 1 cm = 7120 W
- full load output = 29840 W (4 M)
- Current scale = 4.19 cm
- Phase current = OP = 6 cm = 60 A
- Line current = 104 A
- Power factor = 0.819 (3 M)

3.

The power input to a 3phase induction motor is 60 kW. The stator losses are 1 kW. Find the mechanical power developed and rotor copper loss per phase if the motor is running with a slip or 3 %. (7 M) (BTL 5)

Answer: Page – 3.73 - J. Gnanavadivel

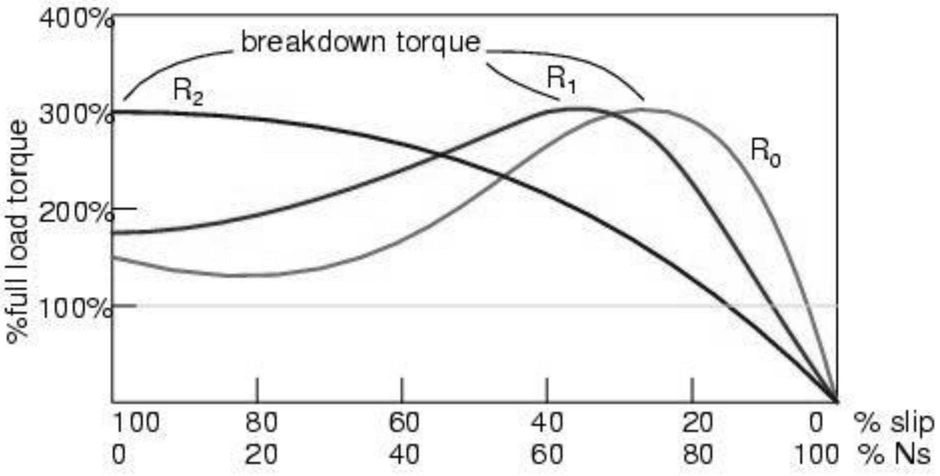
- Input to rotor P2 = 59 kW
- Rotor copper loss Pcu = 1.77 kW(4 M)
- Rotor copper loss per phase = 0.59 kW
- Mechanical power developed = 57.23 kW.(3 M)

4.	**A 3 phase 500 V, 50 Hz induction motor with 6 pole gives an output of 20 kW at 950 rpm with a power factor of 0.8. The mechanical losses are equal to 1 kW. Calculate for this load slip, rotor copper loss, input, if the stator losses are 1.5 kW. (8 M) (**BTL 5) **Answer: Page – 3.73 - J. Gnanavadivel** ➢ Slip = 0.05 ➢ Pm = Pout +Pml = 20 + 1 = 21 kW ➢ P2 = pm/(1-s) = 21.05 kW(4 M) ➢ Pcu = s*P2 = 1.05 kW ➢ Pin = P2 + Stator losses = P2 + Psl = 22.55 kW(4 M)

	UNIT IV - STARTING AND SPEED CONTROL OF THREE PHASE INDUCTION MOTOR
	Need for starting – Types of starters – DOL, Rotor resistance, Autotransformer and Star-delta starters – Speed control – Voltage control, Frequency control and pole changing – Cascaded connection-V/f control – Slip power recovery scheme-Braking of three phase induction motor: Plugging, dynamic braking and regenerative braking.
Q.No	**PART * A**
1	**What is the need of starter for induction motor? (April/May 2012)**BTL 1 The plain induction motor is similar in action to poly phase transformer with a short-circuited rotating secondary. Therefore, if normal supply voltage is applied to the stationary motor, then, as in case of a transformer, a very large initial current about 5-7 times full load current is drawn taken by the stator.
2	**What is the magnitude of starting current & torque for induction motor?(Nov/Dec 2014)**BTL 1 Induction motors, when direct-switched take five to seven times the full load current and develop only 1.5 to 2.5 times their full- load torque.
3	**Name the different types of starters used for induction motor. (Nov/Dec 2013)**BTL 1 ➢ Primary resistor ➢ Autotransformer starter ➢ Star-delta starter ➢ Rotor rheostat
4	**Brief the over –load protection of autotransformer starter.** BTL 1 When the load on the motor is more than the rated value the supply to motor will be cut off.
5	**How the starting current is reduced using rotor resistance starter? (Nov/Dec 2011)** BTL 2 The controlling resistance is in the form of a rheostat, connected in star. The resistance being gradually cut-out of the rotor circuit as the motor gathers speed. Increasing the rotor resistance, not only in the rotor current reduced at starting, but at the same time starting torque is also increased due to improvement in power factor.
6	**Mention the methods of speed control on stator side of induction motor. (Nov/Dec 2011) & (Nov/Dec 2012)** BTL 1 ➢ By changing the applied voltage ➢ By changing the applied frequency ➢ By changing the number of stator poles.
7	**Mention the methods of speed control from rotor side of induction motor. (Nov/Dec 2011) & (Nov/Dec 2012).**BTL 1 ➢ Rotor rheostat control. ➢ By operating two motors in concatenation or cascade. ➢ By injecting an e.m.f in the rotor circuit.

8	**Why speed control is simpler by changing the applied voltage?** BTL 2 ➢ A large change in voltage is required for a relatively small change in speed. ➢ This large change in voltage will result in a large change in the flux density thereby seriously disturbing the magnetic conditions of the motor.
9	**What are the applications of speed control of induction motor by pole changing method?** BTL 1 ➢ Elevator motors ➢ Traction motors ➢ Small motors driving machine tools.
10	**How the speed control is achieved by changing the number of poles?** BTL 2 Synchronous speed of induction motor could also be changed by changing the number of stator poles. This change of number of poles is achieved by having two or more entirely independent stator windings in the same slots.
11	**What are the limitations of rotor rheostat speed control of induction motor?** BTL 2 ➢ With increase in rotor resistance, I^2R losses also increase which decrease the operating efficiency of the motor. In fact, the loss is directly proportional to the reduction in the speed. ➢ Double dependence of speed, not only on R_2 but also on load as well.
12	**What are the advantages of slip power scheme?** BTL 1 Advantages ➢ Easier power control. ➢ Higher efficiency. Disadvantage ➢ Reactive power consumption. ➢ Low power factor at reduced speed.
13	**Mention types of slip power recovery schemes.** BTL 1 ➢ Scherbius system. ➢ Kramer drive.
14	**What is effect of increasing rotor resistance in starting current and torque? (Nov/Dec 2012)** BTL 2 Starting current can be reduced and starting torque can be increased by increasing the rotor resistance of an induction motor.
15	**Why most of the three phase induction motors constructed with delta are connected stator winding? (April/May 2012)** BTL 2 Squirrel cage induction motor started with star to delta starter, therefore stators winding in delta connection.
16	**What is meant by slip power recovery scheme? (Nov/Dec 2013)** BTL 2 Some amount of power is wasted in the rotor circuit, wasted power is recovered by using converter.
17	**What is meant by plugging? (May/June 2014)** BTL 2 The reversal of direction of rotation of motor is the main principle in plugging of motor. In case of an induction motor, it can be quickly stopped by interchanging any two stator leads. Due to this, the direction of rotating magnetic field gets reversed and this produces a torque in reverse direction and the motor tries to rotate in opposite direction.

<table>
<tr><td>18</td><td>While controlling the speed of an induction motor, how is super-synchronous speed achieved? (Nov/Dec 2014) BTL 2
In the super synchronous speed operation, the power flow is from supply to the transformer and the slip power is injected in to the rotor circuit.</td></tr>
<tr><td>19</td><td>What is the relationship between staring torque and full load torque of DOL Starter? BTL 2
$T_{st}/ T_f = (I_{sc}/I_f)^2. s_f$</td></tr>
<tr><td>20</td><td>What are the advantages of autotransformer starter? BTL 1
➢ reduced voltage is applied across the motor terminal.
➢ There is a provision for no-voltage and over-load protection.</td></tr>
<tr><td>21</td><td>How the tandem operations of induction motor start? BTL 2
When the cascaded set is started, the voltage at frequency f is applied to the stator winding of main motor. An induced emf of the same frequency is produced in main motor (rotor) which is supplied to the auxiliary motor. Both the motors develop a forward torque. As the shaft speed rises, the rotor frequency of main motor falls and so does the synchronous speed of auxiliary motor. The set settles down to a stable sped when the shaft speed become equal to the speed of rotating field of Auxiliary motor.</td></tr>
<tr><td>22</td><td>What is the effect of change in supply voltage on starting torque of induction motor? (Nov/Dec 2015) BTL 1
Starting torque of an induction motor will becomes double when slight change in the supply voltage.</td></tr>
<tr><td>23</td><td>State an important distinguishing factor of induction generator and alternator. (May/June 2015) BTL 1
<table>
<tr><th>Induction Generator</th><th>Alternator</th></tr>
<tr><td>Induction machine is single excited.</td><td>Alternator is doubly excited machine.</td></tr>
<tr><td>Induction Generator, the field is induced in the rotor.</td><td>Alternators use a separate excitation field.</td></tr>
<tr><td>Induction Generator the rotor speed need only be above rated synchronous speed.</td><td>The alternator output frequency is intimately connected to rotor rpm and poles.</td></tr>
</table></td></tr>
<tr><td>24</td><td>Draw the torque speed characteristics of an induction motor. (May/June 2015) BTL 1</td></tr>
</table>



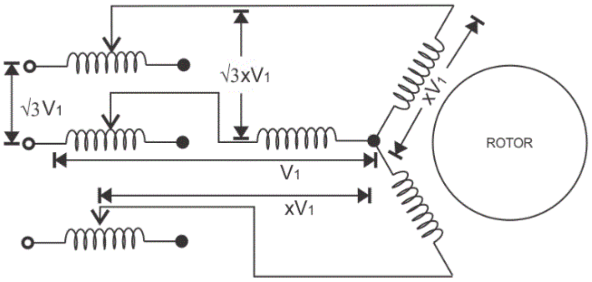
PART * B

1

With neat diagrams explain the working primary resistor starter used for squirrel cage type 3 phase induction motor. (Nov/Dec 2013) (8 M) BTL 1

Answer: Page :4.03 -Gnanavadivel

Using Primary Resistors:



(2 M)

Explanation: (6 M)

- Thus by adding resistor we can control the supply voltage.
- Only a fraction of the voltage (x) of the supply voltage is applied at the time of starting of the induction motor.
- The value of x is always less than one.
- Due to the drop in the voltage the starting torque also decreases.
- We will derive the expression for the starting torque in terms of the voltage fraction x in order to show the variation of the starting torque with the value of x.
- As the motor speeds up the reactor or resistor is cut out from the circuit.
- Finally the resistors are short circuited when the motor reaches to its operating speed.
- Now let us derive the expression for starting torque in terms of full load torque for the stator resistor starting method.
- We have various quantities that involved in the expression for the starting torque are written below: we define T_s as starting torque

- T_f as full load torque
  I_f as per phase rotor current at full load
  I_s as per phase rotor current at the time of starting
  s_f as full load slip
  s_s as starting slip
  R_2 as rotor resistance
  W_s as synchronous speed of the motor
  Now we can directly write the expression for torque of the induction motor as

$$T = \frac{1}{W_s} \times I^2 \frac{r}{s}$$

- From the help of the above expression we write the ratio of starting torque to full load torque as

$$\frac{T_s}{T_f} = \left(\frac{I_s}{I_f}\right)^2 \times s_f \cdots\cdots (i)$$

- Here we have assumed that the rotor resistance is constant and it does not vary with the frequency of the rotor current.
- From the above equation we can have the expression for the starting torque in terms of the full load torque.
- Now at the time of starting the per phase voltage is reduced to xV_1, the per phase starting current is also reduced to xI_s.
- On substituting the value of I_s as xI_s in equation 1. We have

$$\frac{T_s}{T_f} = \left(\frac{xI_s}{I_f}\right)^2 \times s_f$$

$$\frac{T_s}{T_f} = \left(\frac{I_s}{I_f}\right)^2 \times s_f \times x^2$$

- This shows the variation of the starting torque with the value of x.

2

Discuss the various starting methods of induction motors. (April/May 2012) (13 M) BTL 1

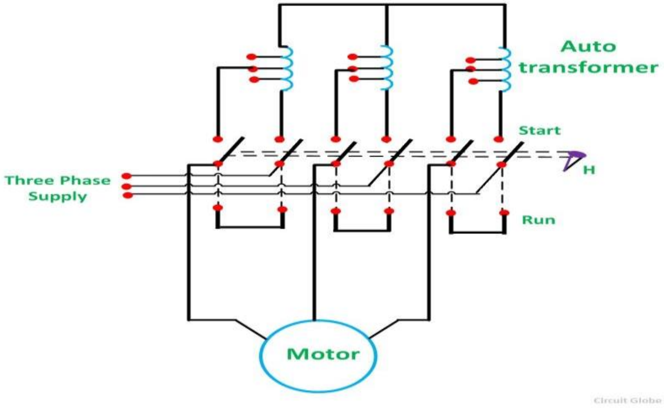
Answer: Page -: 4.01 to 4.08 - Gnanavadivel

Auto transformer Starter (6 M)

- An Auto Transformer Starter is suitable for both star and delta connected motors.
- Starting current is limited by using a three-phase auto transformer to reduce the initial stator applied voltage.
- It is provided with a number of tappings.
- The starter is connected to one particular tapping to obtain the most suitable starting voltage.
- A double throw switch S is used to connect the auto transformer in the circuit for starting.
- When the **handle H** of the switch S in the **START** position.
- The primary of the auto transformer is connected to the supply line, and the motor is connected to the secondary of the auto transformer.
- When the motor picks up the speed of about 80 percent of its rated value, the handle

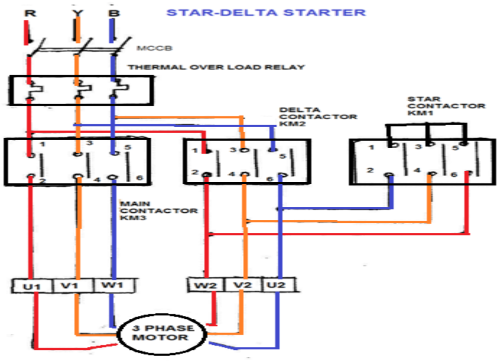
H is quickly moved to the **RUN** position.

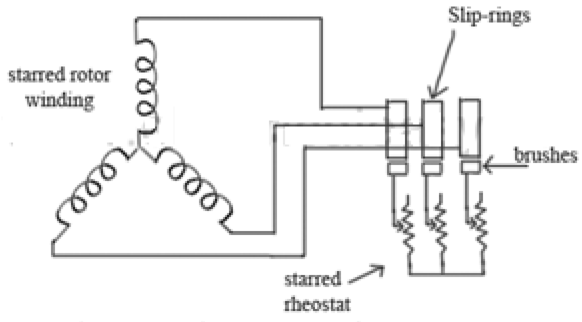
- The handle is held in the **RUN** position by the under- voltage relay.
- If the supply voltage fails or falls below a certain value, the handle is released and returns to the **OFF** position.
- Thermal overload relays provide the overload protection.



Star – Delta Starter:(7 M)

- The main circuit breaker serves as the main power supply switch.
- The main contactor connects the reference source voltage R, Y, B to the primary terminal of the motor U1, V1, W1.
- In operation, Main Contactor (KM3) and the Star Contactor (KM1) are closed initially.
- After a period of time, the star contactor is opened, and then the delta contactor (KM2) is closed.
- The control of the contactors is by the timer (K1T) built into the starter.
- The Star and Delta are electrically interlocked and preferably mechanically interlocked as well.
- The star contactor serves to initially short the secondary terminal of the motor U2, V2, W2 for the start sequence during the initial run of the motor from standstill.
- This provides one third of DOL current to the motor, thus reducing the high inrush current inherent with large capacity motors at startup.
- Controlling the interchanging star connection and delta connection of an AC induction motor is achieved by means of a star delta or wye delta control circuit.
- The control circuit consists of push button switches, auxiliary contacts and a timer.



3	**Describe starter available for 3 phase Slip Ring Induction motor. (8 M) N/D/15, M/J/16|M/J/14,N/D/16** BTL 1 **Answer: Page :4.07 - Gnanavadivel**  Phase wound rotor connections (3 M) Explanation: (5 M) ➢ Slip-ring motors are started with full line voltage, as external resistance can be easily added in the rotor circuit with the help of slip-rings. ➢ Introducing resistance in rotor current will decrease the starting current in rotor. ➢ Also, it improves power factor and the torque is increased. ➢ The connected rheostat may be hand-operated or automatic. ➢ Additional resistance in rotor improves the starting torque. ➢ slip-ring motors can be started on load. ➢ The external resistance introduced is only for starting purposes and is gradually cut out as the motor gathers the speed. ➢ These motors are usually started with full line voltage applied across its terminals. ➢ As these motors have external resistance connected to its rotor circuit. ➢ The value of starting current is adjusted or kept minimum, by increasing the resistance of the rotor circuit. ➢ This external resistance can be assumed to be a form of rheostat, connected in star, thus kept at maximum. ➢ when the motor starts and gradually cut-out as the motor gathers speed. ➢ This implies that the starting current of the motor is reduced when an external resistance is added in the rotor circuit. ➢ Thus because of this, the starting torque is increased due to the improvement in power factor.
4	**Explain briefly the various speed control schemes of induction motors refer to stator side. (13 M)** BTL 2 **Answer: Page:4.09 to 4.19 -Gnanavadivel** The speed control of three phase induction motor from stator side are further classified as : ➢ V / f control or frequency control. ➢ Changing the number of stator poles. ➢ Controlling supply voltage. ➢ Adding rheostat in the stator circuit. **Speed Control from Stator Side** **V / f control or frequency control** (4 M)

Whenever three phase supply is given to three phase induction motor rotating magnetic field is produced which rotates at synchronous speed given by

$$N_s = \frac{120f}{P}$$

- In three phase induction motor emf is induced by induction similar to that of transformer which is given by

$$E\ or\ V = 4.44\phi K.T.f\ or\ \phi = \frac{V}{4.44KTf}$$

Where,
K is the winding constant,
T is the number of turns per phase and
f is frequency.

- Now if we change frequency synchronous speed changes.
- But with decrease in frequency flux will increase and this change in value of flux causes saturation of rotor and stator cores.
- Further cause increase in no load current of the motor .
- So,its important to maintain flux, φ constant and it is only possible if we change voltage.
- If we decrease frequency flux increases but at the same time if we decrease voltage flux will also decease causing no change in flux and hence it remains constant.
- So, here we are keeping the ratio of V/f as constant.
- Hence its name is V/ f method.

Controlling supply voltage:(3 M)

- The torque produced by running three phase induction motor is given by

$$T \propto \frac{sE_2^2R_2}{R_2^2 + (sX_2)^2}$$

- In low slip region $(sX)^2$ is very very small as compared to R_2.
- So, it can be neglected. So torque becomes

$$T \propto \frac{sE_2^2}{R_2}$$

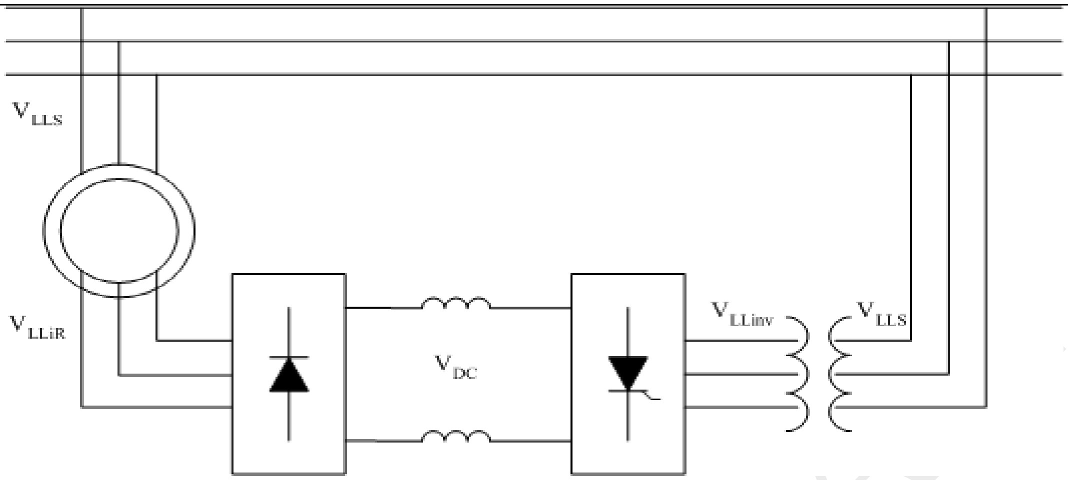
- Since rotor resistance, R_2 is constant so the equation of torque further reduces to

$$T \ \propto \ sE_2^2$$

- We know that rotor induced emf $E_2 \propto V$. So, $T \propto sV^2$.
- If we decrease supply voltage torque will also decrease.
- But for supplying the same load, the torque must remain the same.
- It is only possible if we increase the slip and if the slip increases the motor will run at reduced speed.
- This method of speed control is rarely used because small change in speed requires large reduction in voltage, and hence the current drawn by motor increases, which cause over heating of induction motor.

Changing the number of stator poles: (3 M)

	➢ The stator is provided by two separate winding. ➢ These two stator windings are electrically isolated from each other and are wound for two different pole numbers. ➢ Supply is given to one winding only and hence speed control is possible. ➢ Disadvantages of this method is that the smooth speed control is not possible. ➢ This method is more costly and less efficient as two different stator winding are required. ➢ This method of speed control can only be applied for squirrel cage motor. **Adding rheostat in the stator circuit:** (3 M) ➢ In this method of speed control of three phase induction motor rheostat is added in the stator circuit due to this voltage gets dropped. ➢ In case of three phase induction motor torque produced is given by $T \propto sV_2^2$. ➢ If we decrease supply voltage torque will also decrease. ➢ But for supplying the same load, the torque must remain the same and it is only possible if we increase the slip and if the slip increase motor will run reduced speed.
5	**Explain in detail the slip power recovery scheme. (Nov/Dec 2011&2012& 2013 & 2014) (May/June 2014) (13 M)** BTL 2 **Answer: Page: 4.20 to 4.24 -Gnanavadivel** **SCHERBIUS SYSTEM**(6M) ➢ The scherbius system is similar to Kramer system but only difference is that in the Kramer system the feedback is mechanical and in the scherbius system the return power is electrical. ➢ The different types of scherbius system are: • Conventional scherbius drive • Static scherbius drive CONVENTIONAL SCHERBIUS DRIVE: ➢ This method consists of SRIM, rotary converter, DC motor and induction generator. ➢ Here, the rotary converter converts slip power into DC power and the DC power fed to the DC motor. ➢ The Dc motor is coupled with induction generator. ➢ The induction generator converters the mechanical power into the electrical power and returns it to the supply line. ➢ The SRIM speed can be controlled by varying the field regulator of the DC motor.



STATIC SCHERBIUS DRIVE:

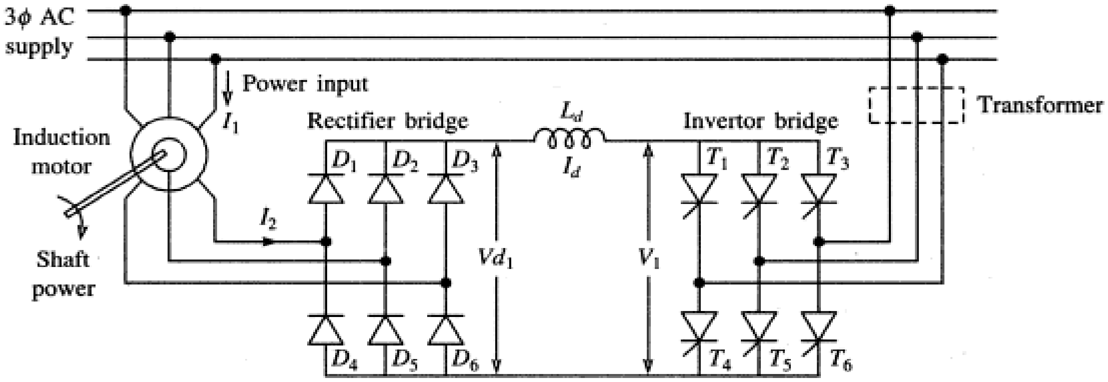
- For the speed control SRIM both below and the above synchronous speed, static scherbius drive is used.
- This system can again be classified as
  - DC link static scherbius drive
  - Cycloconverter static scherbius drive

DC LINK STATIC SCHERBIUS DRIVE (7 M)

- This system consists of SRIM, two numbers of phase controlled bridges, smoothing inductor and step up transformer.
- This system used for sub synchronous and super synchronous speed operation.

Sub synchronous speed operation

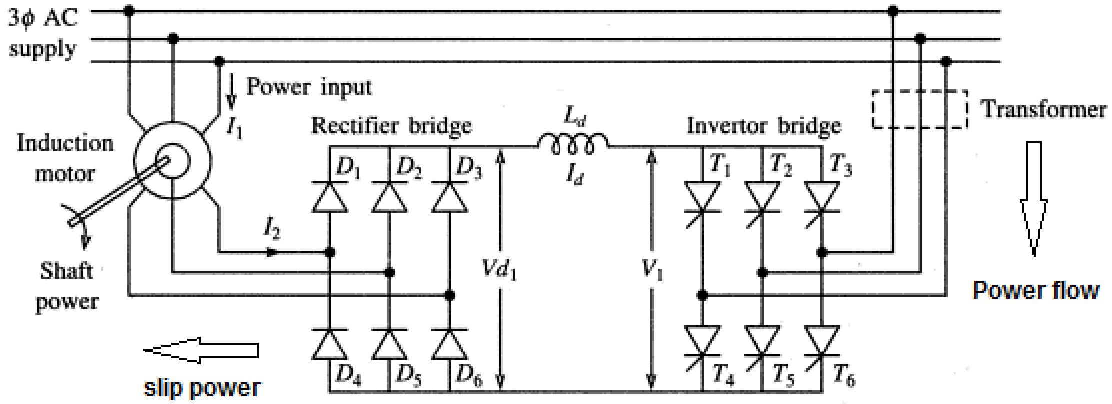
- In sub synchronous speed control of SRIM, slip power is removed from the rotor circuit and is pumped back into the ac supply.
- In the scherbius system, when a machine is operated at sub synchronous speed.
- Phase controlled bridge 1 operates in the rectifier mode and bridge 2 operates in the inverter mode.
- In other words, bridge 1 has firing angle less than the 900 whereas bridge 2 has firing angle more than 900
- The slip power flows from rotor circuit to bridge 1, bridge2, transformer and return to the supply.



- **Slip power→ rectifier (bridge1) → inverter bridge2→transformer→supply**

Super synchronous speed operation

- In super synchronous speed operation, the additional power is fed into the rotor circuit at slip frequency.
- In the scherbius system, when the machine is operated at super synchronous speed,
- Phase controlled bridge 2 should operate in rectifier mode and bridge1 in inverter mode.
- In other words, the bridge2 has firing angle less than 900 and bridge 1 has firing angle more than 900.
- The slip power flows from the supply to transformer, bridge2 (rectifier), bridge1 (line commutated inverter) and to the rotor circuit.



- **Supply → transformer →rectifier (bridge2) → Bridge 1 (inverter) →rotor circuit**
- Near synchronous speed, the rotor voltage is low, and forced commutation must be employed in the inverter.
- The replacement of 6 diodes by 6 thyristors increases the converter cost and also necessitate the introduction of slip frequency gating circuit.
- Difficulty is experienced near synchronous speed when slip frequency emfs are insufficient for line or natural commutation.
- Forced commutation methods are necessary for the passage through synchronism.

PART * C

1.

Explain the various techniques of speed control of induction motor from rotor side control. (April/May 2012) (May/June 2014) (15 M) BTL 2

Answer: Page : 4.15 to 4.20 - Gnanavadivel

Adding external resistance on rotor side: (5 M)

- In this method of speed control of three phase induction motor external resistance are added on rotor side.
- The equation of torque for three phase induction motor is

$$T \propto \frac{sE_2^2 R_2}{R_2^2 + (sX_2)^2}$$

- The three phase induction motor operates in low slip region.
- In low slip region term $(sX)^2$becomes very very small as compared to R_2.
- So, it can be neglected. and also E_2 is constant.
- So the equation of torque after simplification becomes,

$$T \propto \frac{s}{R_2}$$

- Now if we increase rotor resistance, R_2 torque decreases but to supply the same load torque must remains constant.
- So, we increase slip, which will further results in decrease in rotor speed.
- Thus by adding additional resistance in rotor circuit we can decrease the speed of three phase induction motor.

Advantage

- Addition of external resistance starting torque increases.

Disadvantages :

- The speed above the normal value is not possible.
- Large speed change requires large value of resistance and if such large value of resistance is added in the circuit it will cause large copper loss and hence reduction in efficiency.
- Presence of resistance causes more losses.
- This method cannot be used for squirrel cage induction motor.

Cascade control method: (5 M)

- The two three phase induction motor are connected on common shaft and hence called cascaded motor.
- One motor is the called the main motor and another motor is called the auxiliary motor.
- The three phase supply is given to the stator of the main motor while the auxiliary motor is derived at a slip frequency from the slip ring of main motor.
- Let N_{S1} be the synchronous speed of main motor.
  N_{S2} be the synchronous speed of auxiliary motor.
  P_1 be the number of poles of the main motor.
  P_2 be the number of poles of the auxiliary motor.
  F is the supply frequency.
  F_1 is the frequency of rotor induced emf of main motor.
  N is the speed of set and it remains same for both the main and auxiliary motor as both the motors are mounted on common shaft.
- S_1 is the slip of main motor.

$$S_1 = \frac{N_{S1} - N}{N_{S1}}$$

$$F_1 = S_1 F$$

- The auxiliary motor is supplied with same frequency as the main motor i.e

$$F_1 = F_2$$

$$N_{S2} = \frac{120F_2}{P_2} = \frac{120F_1}{P_2}$$

$$N_{S2} = \frac{120S_1F}{P_2}$$

- Now put the value of

$$S_1 = \frac{N_{S1} - N}{N_{S1}}$$

$$We\ get,\ N_{S2} = \frac{120F(N_{S1} - N)}{P_2 N_{S1}}$$

- Now at no load , the speed of auxiliary rotor is almost same as its synchronous speed i.e N = N_{S2}

$$N = \frac{120F(N_{S1} - N)}{P_2 N_{S1}}$$

- Now rearrange the above equation and find out the value of N, we get,

$$N = \frac{120F}{P_1 - P_2}$$

- This cascaded set of two motors will now run at new speed having number of poles (P_1 + P_2).
- In the above method the torque produced by the main and auxiliary motor will act in same direction, resulting in number of poles (P_1 + P_2).
- Such type of cascading is called cumulative cascading.
- There is one more type of cascading in which the torque produced by the main motor is in opposite direction to that of auxiliary motor.
- Such type of cascading is called differential cascading; resulting in speed corresponds to number of poles (P_1 - P_2).

Injecting slip frequency emf into rotor side: (5 M)

- When the speed control of three phase induction motor is done by adding resistance in rotor circuit,
- Therefore the efficiency of three phase induction motor is reduced by this method of speed control.
- This slip power loss can be recovered and supplied back in order to improve the overall efficiency.
- This scheme of recovering the power is called slip power recovery scheme.
- This is done by connecting an external source of emf of slip frequency to the rotor circuit.
- The injected emf can either oppose the rotor induced emf or aids the rotor induced emf.
- If it oppose the rotor induced emf, the total rotor resistance increases and hence speed decreases.
- The injected emf aids the main rotor emf the total decreases and hence speed increases.

Therefore by injecting induced emf in rotor circuit the speed can be easily controlled.

2. **A 3ph 440 V distribution circuit is designed to supply not more than 1200A. Assuming that a 3ph squirrel cage induction motor has full-load efficiency of 0.85 and a full-load power factor of 0.85 and that the starting current at rated voltage is 5 times the rated full load current what is the maximum permissible kW rating of the motor if it is to be started using an auto transformer stepping down the voltage to 80%?N/D/14 (15 M)** BTL 5

- Maximum possible permissible current that induction motor can take from the distribution circuit is 1200A at the time of starting.

- $I_{st} = 5 * I_{rated}$
- $I_{L(rated)} = \frac{I_{st}}{5} = \frac{1200}{5} = 240A$
- Maximum kW rating= $\sqrt{3}V_l I_l \cos\phi * \eta$
    - $= \sqrt{3} * 400 * 240 * 0.85 * 0.8$
    - = 113.068kW (5 M)
- If it is designed to have sta-delta starter ,then star delta starter is equivalent to autotransformer with 57.8% tapping i.e. ratio$\left(\frac{1}{\sqrt{3}}\right)$
- $I_{st} = X_0^2 * 5 * I_L = \left(\frac{1}{\sqrt{3}}\right)^2 * 5 * I_L$
- I_L=$\frac{1200*3}{5} = 720A$
- $(kW)_{max}) = \sqrt{3} * 400 * 720 * 0.8 * 0.85$=339.204kW (5 M)
- For autotransformer starts ,$X^2 * 5 * I_L$
- 1200=$(0.8)^2$)* 5* I_L
- $I_L = 375A$
- $(kW)_{max} = \sqrt{3} * 400 * 720 * 0.8 * 0.85$=176.669Kw (5M)

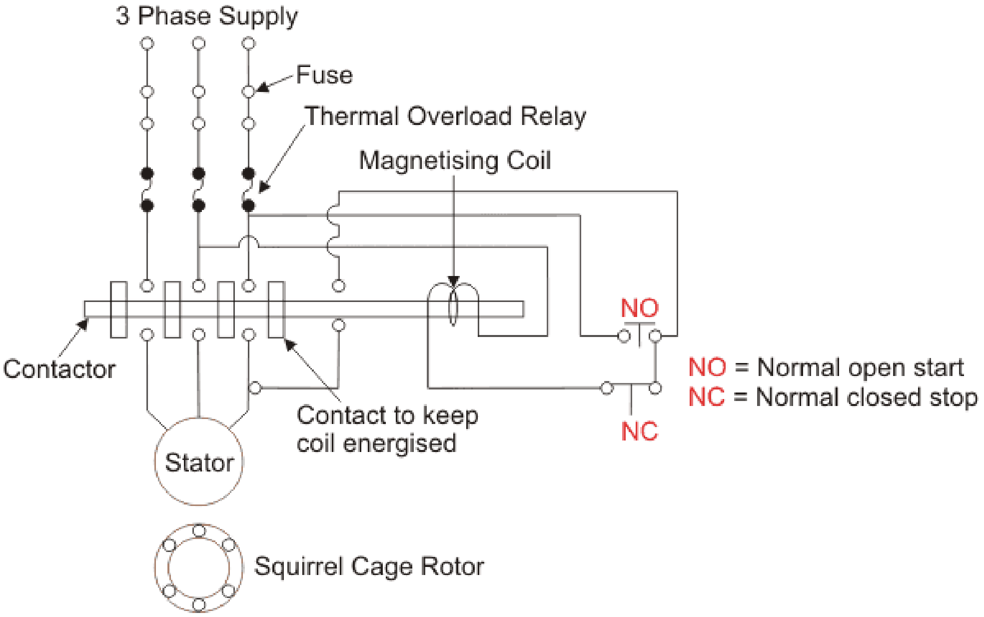
Explain with neat diagram, the construction and working of DOL starter. (15 M) BTL 1

Answer: Page :4.01 -Gnanavadivel

Construction of DOL Starter (5 M)

- It consists of two buttons, GREEN for starting and RED for stopping purpose.
- The DOL starter comprises of an MCCB or circuit breaker, contactor and an overload relay for protection.
- To start the motor, we close the contact by pushing Green Button, and the full line voltage appears to the motor.
- Contactor can be of 3 poles or 4-pole. Below given contactor is of 4-pole type.
- It contains three NO (normally open) contacts that connect the motor to supply lines,
- Fourth contact is "hold on contact" (auxiliary contact) which energizes the contactor coil after the start button is released.
- If any fault occurs, the auxiliary coil gets de-energized.
- Hence the starter disconnects the motor from supply mains.
- Overload Protection When motor draws excessive current to meet the load requirement.
- If load requirement goes beyond the rated limit, termed as Overload.
- Overload protection is a type of security when motor draws over current or excessive current and causes overheating of the equipment.
- Overload is also the type of over current.
- So overload relays are employed to limit the amount of current drawn.
- Fuse or MCB used in the system protects the over current.

Working of DOL Starter(5 M)



Explanation: (5 M)

- The DOL starter connects the 3-phase main with the motor.
- The control circuit is connected to any two phases and energised from them only.
- When we press the start button, the current flows through contactor coil (Magnetizing Coil) and control circuit also.
- The current energises the contactor coil and leads to close the contacts.
- 3-phase supply becomes available to the motor.
- If we press the stop button, the current through the contact becomes discontinued.
- Hence supply to the motor will not be available.
- Similar thing will happen when overload relay operates.
- Since the supply of motor breaks, the machine will come to rest.
- The contactor coil (Magnetizing Coil) gets supply even though we release start button because when we release start button.
- It will get supply from the primary contacts as illustrated in the diagram of the Direct Online Starter**.**

	UNIT V SINGLE PHASE INDUCTION MOTORS AND SPECIAL MACHINES
	Constructional details of single phase induction motor – Double field revolving theory and operation – Equivalent circuit – No load and blocked rotor test – Performance analysis – Starting methods of single-phase induction motors – Capacitor-start capacitor run Induction motor- Shaded pole induction motor - Linear induction motor – Repulsion motor - Hysteresis motor - AC series motor- Servo motors- Stepper motors - introduction to magnetic levitation systems.
Q.No	**PART * A**
1	**Name the two windings of a single-phase induction motor.** BTL 1 ➢ Running winding (main winding) ➢ Starting winding (auxiliary winding)
2	**What are the various methods available for making a single-phase motor self-starting? (Nov/Dec 2012)** BTL 1 ➢ By splitting the single phase ➢ By providing shading coil in the poles ➢ Repulsion starts method. ➢ Capacitor starts capacitor run.
3	**Differentiate "Capacitor start" and "Capacitor start capacitor run" induction motors.** BTL 4 In "capacity, start" motor capacitor is connected in series with the starting winding. But it will be disconnected from the supply when the motor picks up its speed. But in capacitor start, capacitor-run motor the above starting winding and capacitor are not disconnected, but always connected in the supply. So it has high starting and running torque.
4	**Why single-phase induction motor has low power factor?** BTL 2 The current through the running winding lags behind the supply voltage by a very large angle. Therefore power factor is very low.
5	**Why a capacitor run type motor is considered as superior one?** BTL 2 ➢ It has high starting and running torques. ➢ Current drawn is less because of higher power factor ➢ It can be started with some load.
6	**How can a universal motor rotation be reversed?** BTL 2 ➢ The direction of rotation of the concentrated-pole (or salient-pole) type universal motor may be reversed by reversing the flow of current through either the armature or field windings. ➢ The direction of rotation of the distributed field compensating type universal motor may be reversed by interchanging either the armature or field leads and shifting the brushes against the direction in which the motor win rotate.
7	**What is the function of centrifugal switch in a single phase - induction motor? (April/May 2012)** BTL 1 Its function is to automatically disconnect the starting winding from the supply when the motor has reached 70 to 80 percent of its full speed is reached.
8	**Explain why a single-phase induction motor is not self-starting?** BTL 2

	When the motor is fed from a single-phase supply, its stator winding produces an alternating or pulsating flux, which develops no torque. That is why a single-phase motor is not self-starting.
9	**Why should a motor be named as universal motor?** BTL 2 The available supply in the universe is both A.C and D.C. So the rotor, which works on both A.C and D.C, is called universal motor.
10	**What is the use of shading ring in a shaded pole motor?** BTL 1 The shading coil causes the flux in the shaded portion to lag behind the flux in UN shaded portion of pole. This gives in effect a rotation of flux across the pole (ace and under the influence of this moving flux a starting torque is developed.
11	**Stare the advantages of using capacitor start motor over a resistance split phase motor. (April/May 2012)** BTL 1 ➢ The starting current of capacitor start motor is less than resistance split phase motor ➢ Starting torque of the capacitor motor is twice that of resistance start motor.
12	**How will you change the direction of a split phase induction motor? (Nov/Dec 2014)** BTL 2 By changing the direction of current either in the starting winding or in the running winding the direction of rotation can be changed.
13	**State double revolving field theory. (Nov/Dec 2013)** BTL 1 Double revolving theory, formulated by Ferrari, states that a single pulsating magnetic field ϕ_m as its maximum value can be resolved into two rotating magnetic fields of $\phi_m/2$ as their magnitude rotating in opposite direction as synchronous speed proportional to the frequency of the pulsating field.
14	**What type of motor is used for ceiling fan? (Nov/Dec 2011) (May/June 2014)** BTL 2 Singe phase induction motor.
15	**State the application of shaded pole motor. (Nov/Dec 2011)** BTL 1 ➢ Low power household application because the motors have low starting torque and efficiency ratings ➢ Hair dryers, humidifiers and timing devices.
16	**What is meant by single phasing? (Nov/Dec 2012)** BTL 1 Induction motor can operate in single phase supply is called as single phasing.
17	**What is the principle of reluctance motor? (Nov/Dec 2014)** BTL 1 A reluctance torque is the torque produced in a motor in which the reluctance of the airgap is a function of angular position of the rotor, with respect to stator coils. A motor which develops torque only due to the difference in reluctance in two axes is known as reluctance motor.
18	**What could be the reasons if a split-phase motor runs too slow?** BTL 1 Any one of the following factors could be responsible. ➢ Short-circuited or open winding in field circuit. ➢ Over load. ➢ Grounded starting and running winding. ➢ Wrong supply voltage and frequency.
19	**What is the main basic difference between the principle of operation of a 3-phase and single -phase induction motors?** BTL 1

<table>
<tr><td></td><td>When three-phase supply is given to 3-phase induction motor, a rotating magnetic field is produced and the rotor-starts rotating. But when single-phase supply is given to single-phase motor only a pulsating flux is produced. So motor is not self-starting. Therefore to make it self-starting split-phase arrangement is made by providing an auxiliary winding.</td></tr>
<tr><td>20</td><td>What is a universal motor? BTL 1
A universal motor is defined as a motor, which may be, operated either on direct current or single phase A.C supply, at approximately, the same speed and output.</td></tr>
<tr><td>21</td><td>State some applications of universal motor. BTL 1
Used for sewing machines, table fans, vacuum cleaners, hair driers, blowers and kitchen appliances etc.</td></tr>
<tr><td>22</td><td>What are the inherent characteristics of plain 1-phase Induction motor? BTL 1
A plain 1-phase Induction motor is not used in practice due to the following inherent characteristics
➢ A plain 1-phase Induction motor does not have any starting torque.
➢ However, if the rotor is initially given a starting torque, by some means, the motor can pick up its speed in a direction at which the initial torque is given and deliver the required output.</td></tr>
<tr><td>23</td><td>Give the names of three different types of single-phase induction motor. BTL 1
➢ Split-phase motor
➢ Shaded pole motor
➢ Single phase series motor
➢ Repulsion motor
➢ Reluctance motor</td></tr>
<tr><td>24</td><td>How can a universal motor rotation be reversed? BTL 2
➢ The direction of rotation of the concentrated-pole (or salient-pole) type universal motor may be reversed by reversing the flow of current through either the armature or field windings.
➢ The direction of rotation of the distributed field compensating type universal motor may be reversed by interchanging either the armature or field leads and shifting the brushes against the direction in which the motor win rotate.</td></tr>
<tr><td>25</td><td>How can the direction of a capacitor run motor be reversed? (Nov/Dec 2015) BTL 2
The direction of rotation of capacitor run motor can be reversed by reversing the connection of any one of the winding.</td></tr>
<tr><td>26</td><td>Distinguish the terms rotating and pulsating magnetic fields. (May/June 2015) BTL 4
<table>
<tr><td>Rotating magnetic field</td><td>Pulsating magnetic field</td></tr>
<tr><td>Three phase induction motor produce rotating magnetic field.</td><td>Single phase induction motor produce pulsating magnetic field.</td></tr>
<tr><td>Field strength is high</td><td>Field strength is low</td></tr>
<tr><td>Resultant flux will be 1.5 times the maximum flux at starting.</td><td>Resultant flux will be zero at starting.</td></tr>
</table></td></tr>
<tr><td>27</td><td>State the limitations of shaded pole motors. (May/June 2015) BTL 1
➢ Low power factor.
➢ The starting torque is very poor.
➢ The efficiency is very low as, the copper losses are high due to presence of copper</td></tr>
</table>

band.

PART * B

1

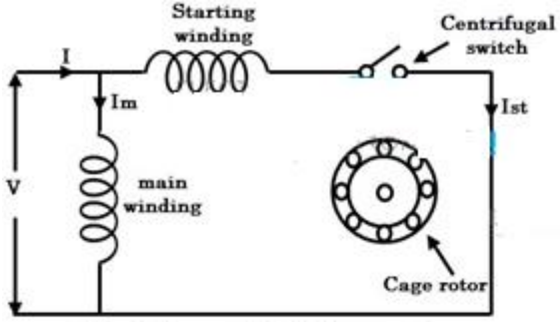
Give the classification of single phase motors. Explain any two types of single phase induction motors. (13M) (Nov/Dec 2013) BTL 1

Answer: Page: 5.07 to 4.15 – J. Gnanavadivel

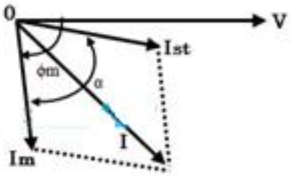
- Split phase induction motor
- Capacitor start induction motor
- Capacitor start capacitor run induction motor
- Shaded pole induction motor (2 M)

The single phase induction motor are classified according to the starting methods,

Resistance start (split phase) induction motor (5 M)



Circuit diagram of split phase motor



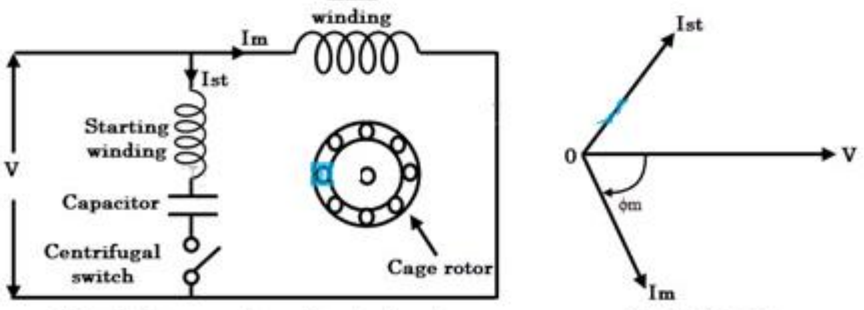
Phasor diagram

- The essential parts of the split phase motor include main winding, auxiliary winding and a centrifugal switch.
- The auxiliary or starting winding carries a series resistance such that its impedance becomes highly resistive in nature.
- It is not wound identical to the main winding but contains fewer turns of much smaller diameter as compared to main winding.
- This will reduce the amount of start current lags the voltage.
- The main winding is inductive in nature in such that current lags the voltage by some angle.
- This winding is designed for the operation of 75 % of synchronous speed and above.
- These two windings are connected in parallel across the supply.
- Due to the inductive nature, current through main winding lags the supply voltage by a large angle.
- Current through starting winding is almost in phase with voltage due to resistive nature.
- Hence there exists a phase difference between these currents and thereby phase difference between the fluxes produced by these currents.
- The resultant of these two fluxes produce rotating magnetic field and hence the starting torque.
- The centrifugal switch is connected in series with the starting winding.
- When the motor reaches 75 to 80 percent of synchronous speed, the centrifugal switch is opened mechanically and thereby auxiliary winding is out of the circuit.
- Therefore, the motor runs only with main winding.

- Split phase motors give poor starting torque due to small phase difference between main and auxiliary currents.
- Also, the power factor of these motors is poor.
- These are mainly used for easily started loads such as blowers, fans, washing machines, grinders, etc.

Capacitor Start Induction Motor (6 M)

- This motor is similar to the split phase motor.
- Capacitor is connected in series to auxiliary winding.
- This is a modified version of split phase motor.
- Since the capacitor draws a leading current, the use of a capacitor increases the phase angle between the two currents (main and auxiliary) and hence the starting torque.
- Here the capacitor is of dry-type electrolytic one which is designed only for alternating current use.
- Due to the inexpensive type of capacitors, these motors become more popular in wide applications.
- These capacitors are designed for definite duty cycle, but not for continuous use.
- The schematic diagram of capacitor start motor is shown in figure below.



Circuit diagram of capacitor start motor

Phasor diagram

- The operation of this motor is similar to the split phase motor where the starting torque is provided by additional winding.
- Once the speed is picked up, the additional winding along with capacitor is removed from the circuit with the help of centrifugal switch.
- But, the difference is that the torque produced by this motor is higher than split phase motor due to the use of capacitor.
- Due to the presence of a capacitor, the current through auxiliary winding will leads the applied voltage by some angle which is more than that of split case type.
- Thus, the phase difference between main and auxiliary currents is increased and thereby starting torque.
- The performance of this motor is identical to the split phase motor when it runs near full load RPM.
- Due to the capacitor, the inrush currents are reduced in this motor.
- These motors have very high starting torque up to 300% full load torque.
- However the power factor is low at rated load and rated speed.
- Owing to the high starting torque, these motors are used in domestic as well as industrial applications such as water pumps, grinders, lathe machines, compressors, drilling machines, etc.

2

Explain the double field revolving theory for operation of single phase induction motor. (13M) (April/May 2012) &(Nov/Dec 2012) (May/June 2014) (Nov/Dec 2014) (Nov/Dec 2015) BTL 6

Answer: Page: 5.03 to 5.06 - J. Gnanavadivel

Double field revolving theory: (6 M)

- According to this theory, any alternating quantity can be resolved into two rotating components.
- Which rotate in opposite directions and each having magnitude as half of the maximum magnitude of the alternating quantity.
- In case of single phase induction motors, the stator winding produces an alternating magnetic field having maximum magnitude of Φ_{1m}.
- According to double revolving field theory, consider the two components of the stator flux.
- Each having magnitude half of maximum magnitude of stator flux i.e. $(\Phi_{1m}/2)$.
- Both these components are rotating in opposite directions at the synchronous speed N_s which is dependent on frequency and stator poles.
- Let Φ_f is forward component rotating in anticlockwise direction.
- Φ_b is the backward component rotating in clockwise direction.
- The resultant of these two components at any instant gives the instantaneous value of the stator flux at the instant.
- So resultant of these two is the original stator flux.

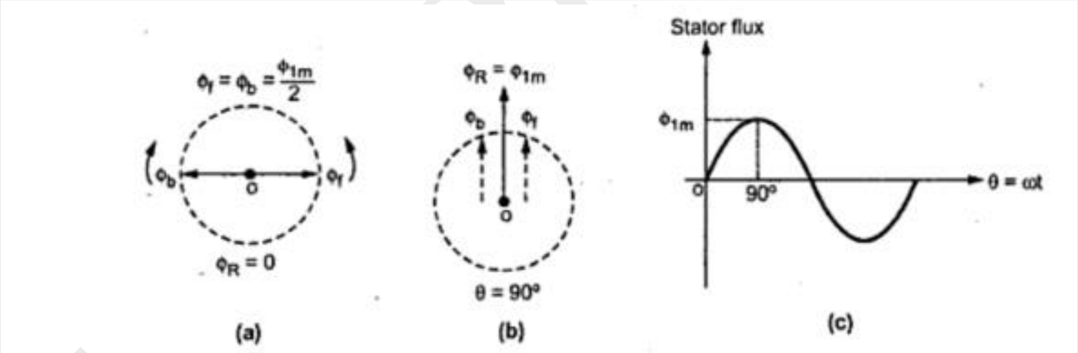


Fig. 1 Stator flux and its two components (2 M)

- The Fig. 1 shows the stator flux and its two components Φ_f andΦ_b.
- At start both the components are shown opposite to each other in the Fig.1(a).
- Thus the resultant $\Phi_R = 0$. This is nothing but the instantaneous value of the stator flux at start.
- After 90°, as shown in the Fig. 1(b), the two components are rotated in such a way that both are pointing in the same direction.
- Hence the resultant Φ_R is the algebraic sum of the magnitudes of the two components. So $\Phi_R = (\Phi_{1m}/2) + (\Phi_{1m}/2) =\Phi_{1m}$.
- This is nothing but the instantaneous value of the stator flux at $\theta = 90^o$ as shown in the Fig 1(c).
- Thus continuous rotation of the two components gives the original alternating stator flux.
- Both the components are rotating and hence get cut by the motor conductors.
- Due to cutting of flux, e.m.f. gets induced in rotor which circulates rotor current.

- The rotor current produces rotor flux.
- This flux interacts with forward component Φ_f to produce a torque in one particular direction say anticlockwise direction.
- While rotor flux interacts with backward component Φ_b to produce a torque in the clockwise direction.
- So if anticlockwise torque is positive then clockwise torque is negative.
- At start these two torque are equal in magnitude but opposite in direction.
- Each torque tries to rotate the rotor in its own direction.
- Thus net torque experienced by the rotor is zero at start.
- And hence the single phase induction motors are not self starting.

Torque speed characteristics **(**5 M)

- The two oppositely directed torques and the resultant torque can be shown effectively with the help of torque-speed characteristics.
- It is shown in the Fig.2.

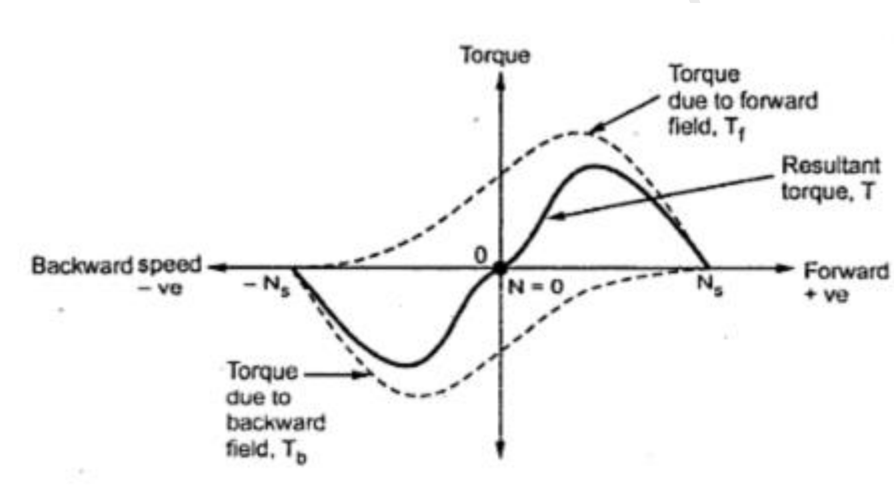


Fig. 2 Torque-speed characteristic

- It can be seen that at start N = 0 and at that point resultant torque is zero.
- So single phase motors are not self starting.
- However if the rotor is given an initial rotation in any direction.
- Resultant average torque increase in the direction in which rotor initially rotated.
- And motor starts rotating in that direction.
- But in practice it is not possible to give initial torque to rotor.
- Externally hence some modifications are done in the construction of single phase induction motors to make them self starting.

3

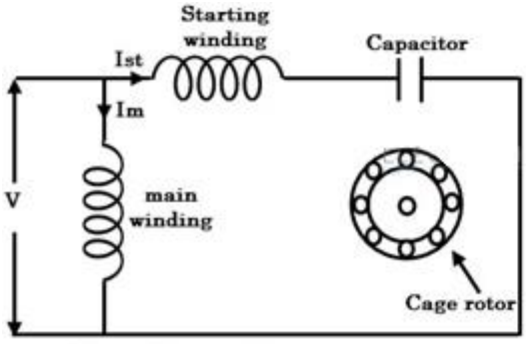
Explain the principle and operation of capacitor run induction motor and capacitor-start capacitor run induction motor. (13 M) BTL 2

Answer: Page: 5.10 - J. Gnanavadivel

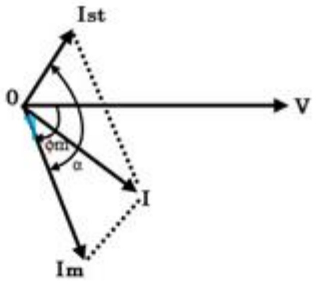
Permanent Capacitor Induction Motor (6 M)

- This motor is also called as a capacitor run motor.
- Low capacitor is connected in series with the starting winding and is not removed from the circuit even in running condition.
- Due to this arrangement, centrifugal switch is not required.

- Here the capacitor is capable of running continuously.
- The low value capacitor produces more leading phase shift bur less total starting current as shown in phasor diagram.
- Hence, the starting torque produced by these motors will be considerably lower than that of capacitor start motor.
- The schematic circuit of this motor is shown in figure below.



Circuit diagram of capacitor run motor

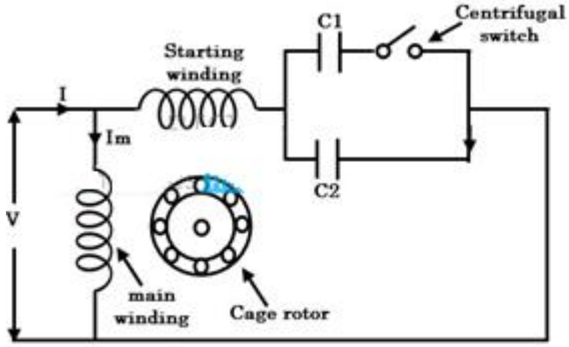


Phasor diagram

- In this, the auxiliary winding and capacitor remains in circuit permanently and produce an approximate two phase operation at rated load point.
- This will result better power factor and efficiency.
- However, the starting torque is much lower in these motors, typically about 80 percent of full load torque.
- Due to the continuous duty of auxiliary winding and capacitor, the rating of these components should withstand running conditions and hence permanent capacitor motor is more than equivalent split phase or capacitor start motors.
- These motors are used in exhaust and intake fans, unit heaters, blowers, etc.

Capacitor Start and Capacitor Run Induction Motor (7 M)

- These motors are also called as two-value capacitor motors.
- It combines the advantages of capacitor start type and permanent capacitor type induction motors.
- This motor consists of two capacitors of different value of capacitance for starting and running.
- A high value capacitor is used for starting conditions while a low value is used for running conditions.
- It is to be noted that this motor uses same winding arrangement as capacitor-start motor during start-up and permanent capacitor motor during running conditions.
- The schematic arrangement of this motor is shown in figure below.

	 Circuit diagram of capacitor start capacitor run motor ➢ At starting, both starting and running capacitors are connected in series with the auxiliary winding. ➢ Thus the motor starting torque is more compared with other types of motors. ➢ Once the motor reaches some speed, the centrifugal switch disconnects the starting capacitor and leaves the running capacitor in series with auxiliary winding. ➢ Thus, both running and auxiliary windings remain during running condition, thereby improved power factor and efficiency of the motor. ➢ These are the most commonly used single phase motors due to high starting torque and better power factor. ➢ These are used in compressors, refrigerators, air conditioners, conveyors, ceiling fans, air circulators, etc.
4	**Explain the working principle of single phase induction motor. Mention its four applications. (13 M)** BTL 2 **Answer: Page: 5.02 - J. Gnanavadivel** **Stator:** ➢ As its name indicates stator is a stationary part of induction motor. ➢ Single phase AC supply is given to the stator of single phase induction motor. **Rotor:** ➢ The rotor is a rotating part of an induction motor. ➢ The rotor connects the mechanical load through the shaft. ➢ The rotor in the single-phase induction motor is of squirrel cage rotor type. ➢ The **construction of single phase induction motor** is almost similar to the squirrel cage three-phase induction motor. ➢ But in case of a single phase induction motor, the stator has two windings instead of one three-phase winding in three phase induction motor. Working Principle of Single Phase Induction Motor ➢ When we apply a single phase AC supply to the stator winding of single phase induction motor. ➢ The alternating current starts flowing through the stator or main winding. ➢ This alternating current produces an alternating flux called main flux. ➢ This main flux also links with the rotor conductors and hence cut the rotor conductors. ➢ According to the Faraday's law of electromagnetic induction, emf gets induced in the rotor.

- As the rotor circuit is closed one so, the current starts flowing in the rotor.
- This current is called the rotor current.
- This rotor current produces its flux called rotor flux.
- Since this flux is produced due to the induction principle so, the motor working on this principle got its name as an induction motor.
- Now there are two fluxes one is main flux, and another is called rotor flux.
- These two fluxes produce the desired torque which is required by the motor to rotate. (5 M)

Why Single Phase Induction Motor is not Self Starting? (3 M)

- According to double field revolving theory, we can resolve any alternating quantity into two components.
- Each component has a magnitude equal to the half of the maximum magnitude of the alternating quantity, and both these components rotate in the opposite direction to each other.
- For example - a flux, φ can be resolved into two components.

$$\frac{\phi_m}{2}\ and\ -\frac{\phi_m}{2}$$

- Each of these components rotates in the opposite direction i. e if one $\varphi_m/2$ is rotating in clockwise direction then the other φ_m / 2 rotates in anticlockwise direction.
- When we apply a single phase AC supply to the stator winding of single phase induction motor,.
- it produces its flux of magnitude, φ_m.
- According to the double field revolving theory, this alternating flux, φ_m is divided into two components of magnitude $\varphi_m/2$.
- Each of these components will rotate in the opposite direction, with the synchronous speed, N_s.
- Let us call these two components of flux as forwarding component of flux, φ_f and the backward component of flux, φ_b.
- The resultant of these two components of flux at any instant of time gives the value of instantaneous stator flux at that particular instant.

$$i.e.\phi_r = \frac{\phi_m}{2} + \frac{\phi_m}{2}\ or\ \phi_r = \phi_f + \phi_b$$

- Now at starting condition, both the forward and backward components of flux are exactly opposite to each other.
- Also, both of these components of flux are equal in magnitude.
- So, they cancel each other and hence the net torque experienced by the rotor at the starting condition is zero.
- So, the **single phase induction motors** are not self-starting motors.

Methods for Making Single Phase Induction as Self Starting Motor (3 M)

- We require two alternating flux, having some phase difference angle between them.
- When these two fluxes interact with each other, they will produce a resultant flux.
- This resultant flux is rotating in nature and rotates in space in one particular direction only.
- Once the motor starts running, we can remove the additional flux.
- The motor will continue to run under the influence of the main flux only.

- Depending upon the methods for making asynchronous motor as Self Starting Motor.

Four **types of single phase induction motor** namely, (2 M)

- Split phase induction motor,
- Capacitor start inductor motor,
- Capacitor start capacitor run induction motor,
- Shaded pole induction motor.
- Permanent split capacitor motor or single value capacitor motor.

5

Write the principle and working of hysteresis motor and AC series motor. Explain briefly. (13 M) (Nov/Dec 2011)& (Nov/Dec 2012) (May/June 2014) (Nov/Dec 2014) BTL 2

Answer: Page: 5.46 to 5.49 - J. Gnanavadivel

Constructional features of Hysteresis Motor: (7 M)

It consists of

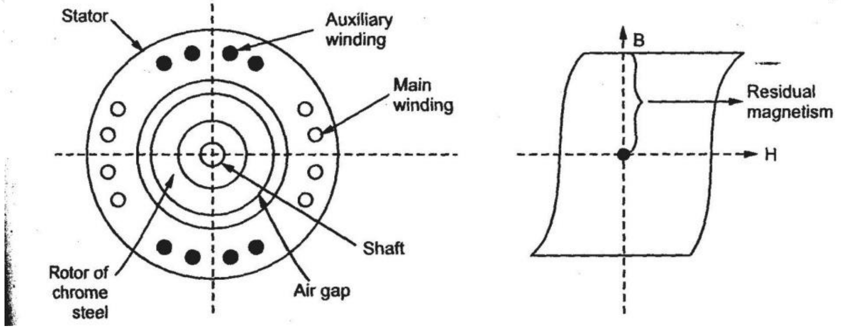
- Stator
- Single phase stator winding
- Rotor
- Shaft
- Shading coil

Stator:

- Stator of hysteresis motor is designed in a particular manner to produce synchronous revolving field from single phase supply.
- Stator carries two windings,
  - main winding
  - auxiliary winding.
- In another type of design of hysteresis motor the stator holds the poles of shaded type.

Rotor:

- Rotor of hysteresis motor is made of magnetic material that has high hysteresis loss property.
- Example of this type of materials is chrome, cobalt steel or alnico or alloy.
- Hysteresis loss becomes high due to large area of hysteresis loop.



OPERATION

- Starting behavior of a hysteresis motor is like a single phase induction motor and running behavior is same as a synchronous motor.

- Step by step its behavior can be realized in the working principle that is given below.
- When stator is energized with single phase AC supply, rotating magnetic field is produced in stator.
- To maintain the rotating magnetic field the main and auxiliary windings must be supplied continuously at start as well as in running conditions.
- At the starting, by induction phenomenon, secondary voltage is induced in the rotor by stator rotating magnetic field.
- Hence eddy current is generated to flow in the rotor and it develops rotor.
- Thus eddy current torque is developed along with the hysteresis torque in the rotor.
- Hysteresis torque in the rotor develops as the rotor magnetic material is with high hysteresis loss property and high retentivity.
- The rotor goes under the slip frequency before going to the steady state running condition.
- So it can be said that when the rotor starts to rotate with the help of these eddy current torque due to induction phenomenon, it behalves like a single phase induction motor.

APPLICATIONS

- Sound producing equipments
- Sound recording instruments
- High quality record players
- Timing devices
- Electric clocks
- Tele-printers.

AC series motors (6 M)

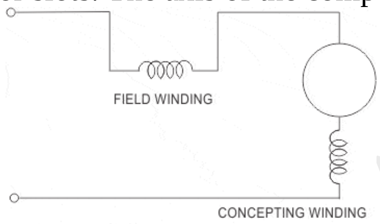
- It is also known as the modified DC series motor as their construction is very similar to that of the DC series motor.
- An AC supply will produce an unidirectional torque because the direction of both the currents (i.e. armature current and field current) reverses at the same time.
- Due to presence of alternating current, eddy currents are induced in the yoke and field cores which results in excessive heating of the yoke and field cores.
- Due to the high inductance of the field and the armature circuit, the power factor would become very low.
- There is sparking at the brushes of the DC series motor.
- So considering above points we can say that we don’t have good performance of DC series motor on the application of AC supply.
- Now in order to reduce the eddy currents there is need to laminate the yoke and field core.
- Power factor is directly related to reactance of the field and armature circuit.
- We can reduce the field winding reactance by reducing the number of turns in the field winding.
- On reducing the number of turns, field mmf will decrease and due to this the air gap flux decrease.
- The overall result of this is that there is an increase in the speed of the motor but decrease in the motor torque which is not desired.

TYPES

- Conductively compensated type of motors.
- Inductively compensated type of motors.

Conductively Compensated Type of Motors

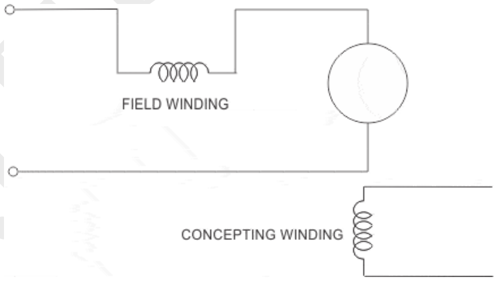
- Given below is the circuit diagram of the conductively compensated type of motors.
- In this type of motor, the compensating winding is connected in series with the armature circuit.
- The winding is put in the stator slots. The axis of the compensating winding is 90^o (electrical) with main field axis.



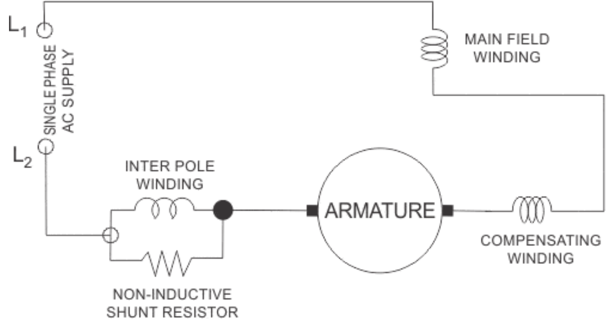
(a)

Inductively Compensated Type of Motors

- Given below is the circuit diagram of the inductively compensated type of motors.
- In this type of motor, the compensating winding has no interconnection with the armature circuit of the motor.
- In this case, a transformer action will take place as the armature winding will act as primary winding of the transformer.
- Compensation winding will acts as a secondary winding.
- The current in the compensating winding will be in phase opposition to the current in the armature winding.



- Given below is the complete schematic diagram of the single phase **AC series motor** with all the modifications (i.e. compensating winding and inter pole).



AC Series Motor with Interpoles and compensating Windings

6 **Explain the principle of operation and applications of repulsion motor. (8M) (April/May 2012)** BTL 2

Answer: Page: 5.44 to 5.47 - J. Gnanavadivel

Repulsion Motor:

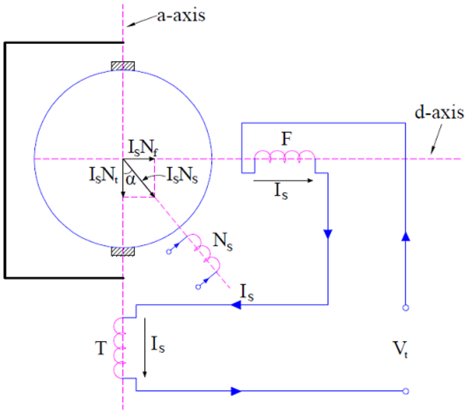
- It is a special kind of single phase AC motor which works due to the repulsion of similar poles.
- The stator of this motor is supplied with 1 phase AC supply and rotor circuit is shorted through carbon brush.

Construction of Repulsion Motor: (3 M)

- The main components of repulsion motor are stator, rotor and commutator brush assembly.
- The stator carries a single phase exciting winding similar to the main winding of single phase induction motor.
- The rotor has distributed DC winding connected to the commutator at one end just like in DC motor.
- The carbon brushes are short circuited on themselves.
- Stator winding have single phase AC winding which produces the working mmf in the air gap.
- The brushes on rotor are shown to be shorted.
- As the rotor circuit is shorted, the rotor receives power from stator by transformer action.

Working principle of Repulsion Motor: (5 M)

- The basic principle behind the working of repulsion motor is that “similar poles repel each other.”
- This means two North poles will repel each other.
- Similarly, two South poles will repel each other.
- When the stator winding of repulsion motor is supplied with single phase AC, it produces a magnetic flux along the direct axis.
- This magnetic flux when link with the rotor winding, creates an emf.
- Due to this emf, a rotor current is produced.
- This rotor current in turn produces a magnetic flux which is directed along the brush axis due to commutator assembly.
- Due to the interaction of stator and rotor produced fluxes, an electromagnetic torque is produced.
- In the above figure, the angle α between the stator produced field and brush axis is 90°.
- This means, the brush axis is in quadrature with the direct.
- Under this condition, there will not be any mutual induction between the stator and rotor windings.
- Therefore, no emf and hence no rotor current is produced. Thus no electromagnetic torque is developed.
- This means that motor will not run when $\alpha = 90°$.
- As the stator produced flux is unaffected by the zero rotor mmf, this condition is similar to the open circuit transformer.
- This is the reason, the brush position of $\alpha = 90°$ is called open-circuit, no-load, high impedance or neutral position.



PART * C

1

Explain the no-load test and blocked rotor test for obtaining the equivalent circuit parameters of a single phase induction motor. (15M) (Nov/Dec 2014) BTL 3

Answer: Page: 5.18 to 5.21- J. Gnanavadivel

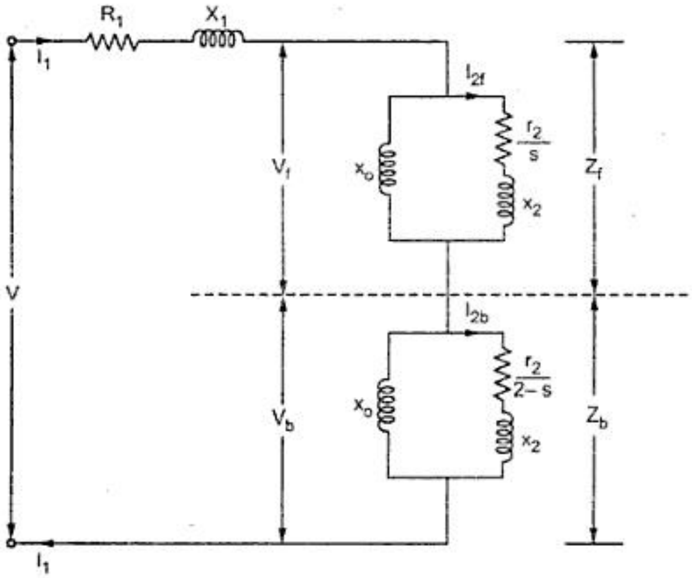
EQUIVALENT CIRCUIT OF SINGLE PHASE INDUCTION MOTOR

Without core loss (7 M)

- Let the stator impedance be Z Ω

  $Z = R_1 + j X_1$
  R_1 = Stator resistance
  X_1 = Stator reactance
  X_2 = rotor reactance referred to stator
  R_2 = rotor resistance referred to stator
- Hence the impedance of each rotor is $r_2 + j x_2$ where

  $x_2 = X_2/2$
- The resistance of forward field rotor is r_2/s while the resistance of backward field rotor is $r_2 /(2 - s)$.
- The r_2 value is half of the actual rotor resistance referred to stator.
- As the core loss is neglected, R_o is not existing in the equivalent circuit.
- The $x_o$is half of the actual magnetising reactance of the motor.
- So the equivalent circuit referred to stator is shown in the Fig.1.



- Now the impedance of the forward field rotor is Z_f which is parallel combination of $(0 + j\, x_o)$ and $(r_2 /s) + j\, x_2$

$$\therefore \qquad Z_b = \frac{j x_o \left[\left(\frac{r_2}{2-s} \right) + j\, x_2 \right]}{\frac{r_2}{2-s} + j\,(x_o + x_2)}$$

- While the impedance of the backward field rotor is Z_b which is parallel combination of $(0 + j\, x_o)$ and $(r_2 / 2\text{-}s) + j\, x_2$

$$\therefore \qquad Z_b = \frac{j x_o \left[\left(\frac{r_2}{2-s} \right) + j\, x_2 \right]}{\frac{r_2}{2-s} + j\,(x_o + x_2)}$$

- Under standstill condition, s = 1 and 2 - s = 1 hence $Z_f = Z_b$ and hence $V_f = V_b$.
- But in the running condition, V_f becomes almost 90 to 95% of the applied voltage.

$\therefore \qquad Z_{eq} = Z_1 + Z_f + Z_b$ = Equivalent impedance

and $\qquad I_{2b} = /((r_2/2\text{-}s) + j\, x_2)$

P_f = Power input to forward field rotor

$= (I_{2f})^2\, (r_2/s)$ watts

P_b = Power input to backward field rotor

$= (I_{2b})^2\, (r_2/2\text{-}s)$ watts

$P_m = (1 - s)$\{ Net power input\}

$= (1 - s)\, (P_f - P_b)$ watts

$P_{out} = P_m$ - mechanical loss - core loss

$\therefore$ T_f = forward torque = $P_f/(2\pi N/60)$ N-m

and Tb = backward torque = $P_b/(2\pi N/60)$ N-m

T = net torque = $T_f - T_b$

while T_{sh} = shaft torque = $P_{out}/(2\pi N/60)$ N-m

$$\%\eta = (\text{net output / net input}) \times 100$$

With core loss (8 M)

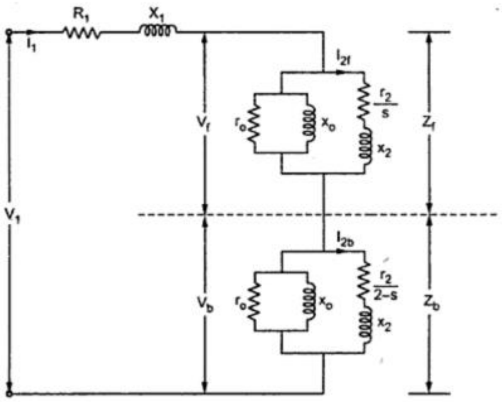
- If the core loss is to be considered then it is necessary to connect a resistance in parallel with, in an exciting branch of each rotor is half the value of actual core loss resistance.
- Thus the equivalent circuit with core loss can be shown as in the Fig. 2.
- Let Z_{of} = Equivalent impedance of exciting branch in forward rotor

$= r_o \| (j\, x_o)$

and Z_{ob} = Equivalent impedance of exciting branch in backward rotor

$= r_o \| (j\, x_o)$

$\therefore$ $Z_f = Z_{of} \| (r_2/s + j\, x_2)$



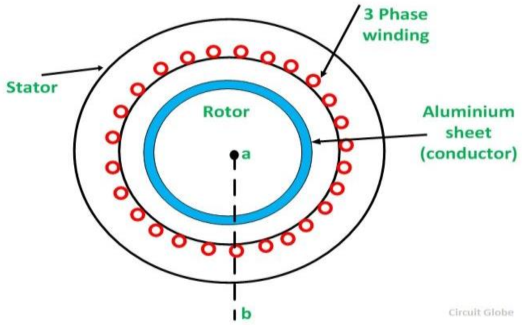
2 **Explain the operating principle of Linear Induction Motor with neat diagram. (Nov/Dec 2015) (Nov/Dec 2015) (15 M)** BTL 2

Answer: Refer Notes

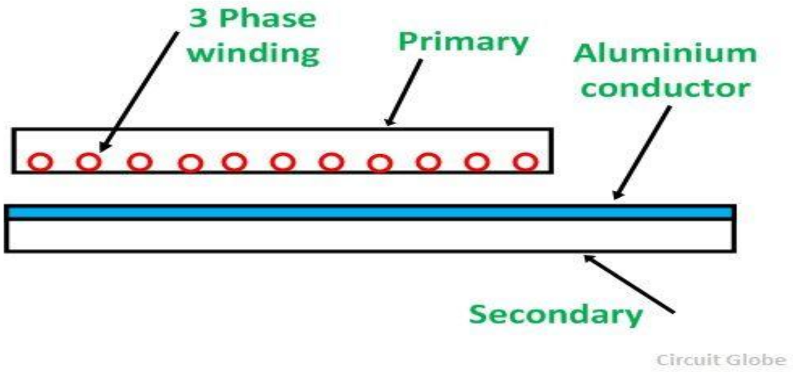
- A **Linear Induction Motor** is an advanced version of rotary induction motor.
- It gives a linear translational motion instead of the rotational motion.
- The stator is cut axially and spread out flat.
- In this type of motor, the stator and rotor are called primary and secondary

respectively.

- The secondary of the linear induction motor consists of a flat aluminium conductor with a ferromagnetic core.
- The polyphase rotator induction motor is shown below. (5 M)

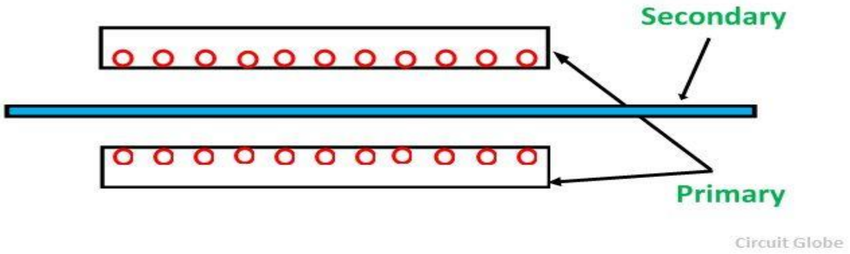


  - If the stator is cut along the line ab and spread out flat the figure formed is shown below.



(8 M)

- If a three phase supply is connected to the stator of an induction motor, a rotating flux is produced.
- This flux rotates at a synchronous speed in the air gap.
- Similarly, if the primary of the linear induction motor is connected to the three phase supply.
- A flux is produced which travel across the length of the primary.
- A current is generated in the conductor which is made of the aluminium material.
- The current, which is induced in the linear induction motor interacts with the travelling flux produces a linear force.
- If secondary of the linear induction motor is fixed and the primary is free to move, the force will move the primary in the direction of the travelling wave.
- The double sided linear induction motor (DLIM) is shown in the figure below.



- The Double sided linear induction motor has primary on both the sides of the secondary.
- The linear synchronous speed of the travelling wave is given by the equation shown below.

$$v_s = 2f\,(\text{pole pitch})\,\frac{m}{s} \dots\dots..(1)$$

Where f is the supply frequency in hertz.

- In the rotary induction motor, the speed of the secondary in the linear induction motor is less than the synchronous speed v_s and is given as

$$v_r = v_s\,(1 - s) \dots\dots..(2)$$

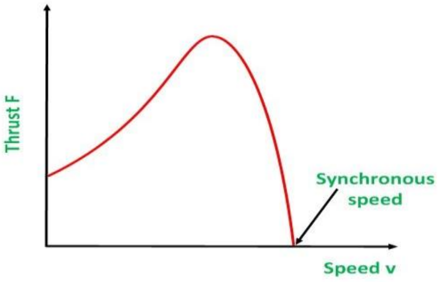
- Where s is the slip of the linear induction motor and is given as

$$s = \frac{v_s - v_r}{v_s} \quad \text{pu} \quad \dots\dots\dots.(3)$$

- The linear force is given by the equation shown below.

$$F = \frac{\text{air gap power}}{\text{linear synchronous velocity } (v_s)}$$

- The thrust velocity curve of the linear induction motor is similar to that of the speed torque curve of the rotary induction motor.
- It is shown in the figure below.



Applications of the Linear Induction Motor (2 M)

- The main application of the LIM is in transportation and in electric traction system.
- Primary is mounted on the vehicle and the secondary is laid on the track.
- It is used in the cranes
- Pumping of liquid metals
- Actuators for the movement of doors
- Used in High voltage circuit breakers and also in accelerators.

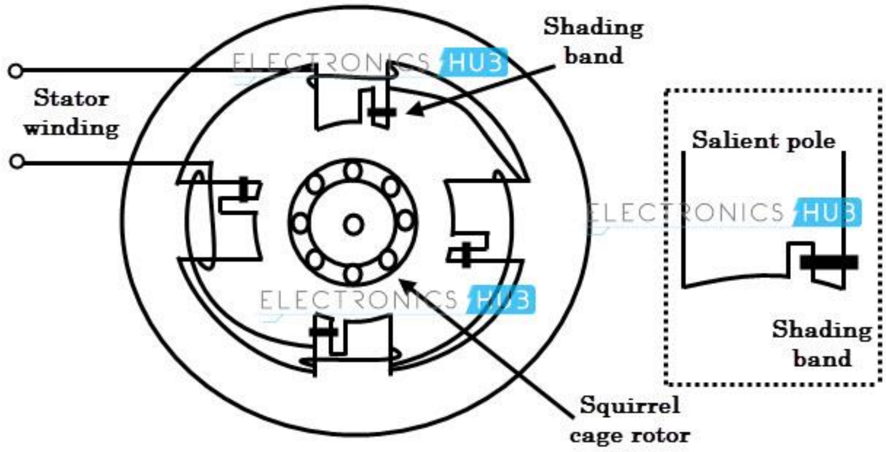
3

Explain shaded pole induction motor with neat diagram. (15 M) BTL 2

Answer: Page: 5.13 - J. Gnanavadivel

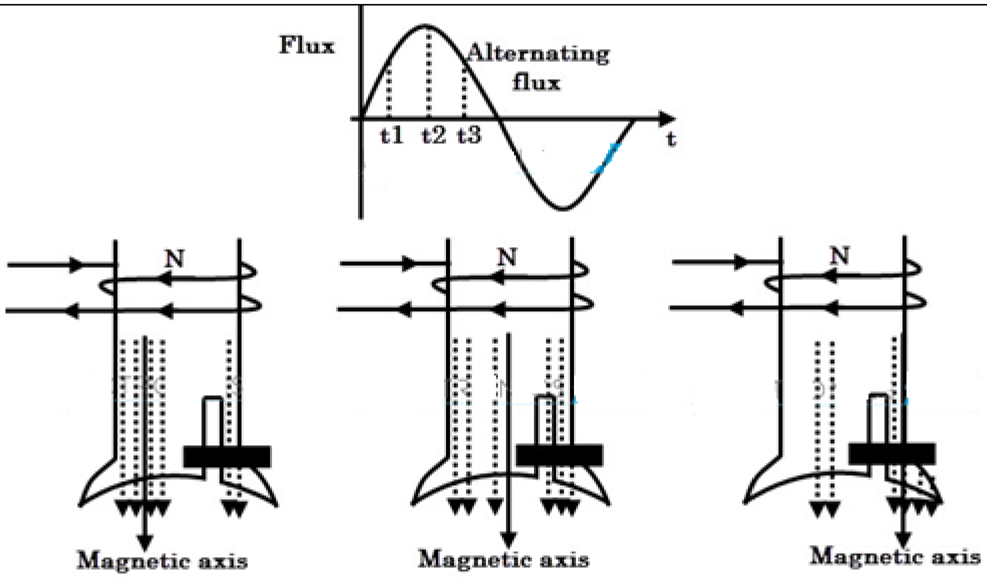
Shaded Pole Induction Motor

- This motor uses entirely different technique to start the motor as compared with other motors so far we have discussed now.
- This motor doesn’t use any auxiliary winding or even it doesn’t have a rotating field, but a field that sweeps across the pole faces is enough to drive the motor.
- So the field moves from one side of the pole to another side of the pole.
- Although these motors are of small ratings, inefficient and have low starting torque.
- These are used in a variety of applications due to its outstanding features like ruggedness, low initial cost, small size and simple construction.
- A shaded pole motor consists of a stator having salient poles (or projected poles), and a rotor of squirrel cage type.
- In this, stator is constructed in a special way to produce moving magnetic field.
- Stator poles are excited with its own exciting coils by taking the supply from a single phase supply.
- A 4-pole shaded pole motor construction is given in below figure. (5 M)



4-Pole Shaded pole motor construction

- Each salient pole is divided into two parts; shaded and un-shaded.
- A shading portion is a slot cut across the laminations at about one third distance from one edge, and around this a heavy copper ring is placed.
- This part where shading coil is placed is generally termed as shaded part of the pole and remaining portion is called as un-shaded part as shown in figure.
- When an alternating supply is given to the stator coils, an alternating flux will be produced.
- The distribution of flux in the pole face area is influenced by the presence of copper shading band.
- Let us consider the three instants, t1, t2, and t3 of alternating flux for an half cycle of the flux as shown in figure.



(a).t= t1 (b).t= t2 (c).t= t3

(5 M)

- At instant t= t1, the rate of change of flux (rising) is very high.
- Due to this flux, an emf is induced in the copper shading band and as the copper shading band is shorted, current circulates through it.
- This causes current to create its own field. According to Lenz's law, the current through copper shading band opposes the cause.
- Therefore the flux produced by shading ring opposes the main flux.
- So there is weakening of flux in the shaded part while crowding of flux in un-shaded part.
- So the axis of overall flux shifts to non-shaded part of the pole as shown in the figure.
- At instant t=t2, the rate of rise of flux is almost zero, and hence very little emf is induced in the shaded band.
- It results negligible shaded ring flux and hence there is no much affect on distribution of main flux.
- Therefore, the distribution of flux is uniform and the overall flux axis lies at the center of the pole as shown in figure.
- At instant t=t3, the rate of change of flux (decreasing) is very high, and induces emf in copper shading band.
- The flux produced by the shading ring is now opposes the cause according to Lennz's law.
- Here, the cause is decreasing flux, and opposing means its direction is same as that of main flux.
- Hence, this flux strengthens the main flux.
- So there will be crowding of flux in the shaded part compared to the non shaded part.
- Due to this overall flux axis shifts to the middle of shaded part.
- This sequence will repeat for negative cycle too and consequently it produce moving magnetic field for every cycle from non shaded part of the pole to shaded

	part of the pole. ➢ Due to this field, motor produces the starting torque. This starting torque is low about 40 to 50 percent of full load torque. ➢ Therefore, these motors are used in low starting torque applications such as fans, toy motors, blowers, hair dryers, photocopy machines, film projectors, advertising displays, etc. (5 M)

UNIT I SYNCHRONOUS GENERATOR

1.The advantage of salient poles in an alternator is
a) Reduced windage loss
b) Reduced noise
c) Reduced bearing loads and noise
d) Adaptability to low and medium speed operations
Ans: (d)

2. The emf generated in alternator depends on
a) Frequency
b) Flux per pole
c) Coil span factor
d) All of these
Ans: (d)

3. The rotor of a salient pole alternator has 12 poles. The number of cycles of emf per revolution would be
a) 4
b) 3
c) 6
d) 12
Ans: (c)

4. Salient pole type rotors are
a) Larger in diameter and smaller in axial length
b) Larger in diameter and larger in axial length
c) Smaller in diameter and larger in axial length
d) Smaller in diameter and smaller in axial length
Ans: (a)

5. The exciter for a generator is a
a) Shunt motor
b) Series motor
c) Shunt generator
d) Compound motor
Ans: (c)

6. The frequency of voltage generated in an alternator depends on
a) Number of poles
b) Speed of alternator
c) Both (a) and (b)
d) Type of winding
Ans: (c)

7. The frequency per pole in an alternator is equal to
a) Number of poles
b) Number of armature conductors
c) Number of pair of poles
d) None of these
Ans: (c)

8. In alternators, cylindrical pole type rotors are generally used with prime movers of
a) High speed
b) Low speed
c) Medium speed
d) Both low and high speed
Ans: (a)

9. An alternator is said to be overexcited when it is operating at
a) Unity power factor
b) Leading power factor
c) Lagging power factor
d) Either lagging or leading power factor
Ans: (b)

10. In alternators, salient pole type rotors are generally used with prime movers of
a) Low speed
b) Medium speed
c) High speed
d) Any speed
Ans: (a)

11. As the speed of an alternator increases, the frequency
a) Increases
b) Decreases
c) Remains constant
d) May increases or decreases depending on the power factor
Ans: (a)

12. The generator which gives dc supply to the rotor of an alternator is called
a) Convertor
b) Exciter
c) Inverter
d) Rectifier
Ans: (b)

13. The number of electrical degrees passed through in ouerevoltion of a four pole synchronous alternator is
a) 360°
b) 720°
c) 1440°
d) 2880°
Ans: (a)

14. The rotor of alternator has
a) No slip rings
b) Two slip rings
c) Three slip rings
d) Four slip rings
Ans: (b)

15. Alternator works on the principle of
a) Self and mutual induction
b) Self mutual induction
c) Faraday's law of electromagnetic induction
d) Mutual induction
Ans: (c)

16. In an alternator, when the load increases due to armature reaction, the terminal voltage
a) Rises
b) Drops
c) Remains unchanged
d) May drop or rise
Ans: (d)

17. In a rotating electrical machine, the chording angle for eliminating fifth harmonic should be
a) 38°
b) 36°
c) 33°
d) 30°
Ans: (b)

18. The exciting field coil of an alternator is generally excited by
a) A separate dc generator driver by some source
b) A separate ac generator drive by some source
c) A dc generator coupled directly to the armature shaft
d) A battery
Ans: (c)

19. The material used for the manufacture of large turbo-alternator is
a) Cold rolled grain-oriented steel
b) Hot rolled grain oriented steel
c) Wrought iron
d) Cast steel
Ans: (c)

20. The ratio of armature leakage reactance to synchronous reactance of large size modern alternator is about
a) 0.05
b) 0.2
c) 0.4
d) 0.6
Ans: (b)

21. Use of damped winding in alternators results in
a) Elimination of harmonic effects
b) A low resistance path for the currents due to unbalancing of voltage
c) Oscillations when two alternators operate in parallel
d) All of these
Ans: (d)

22. High speed alternators usually have
a) Salient pole rotors
b) Cylindrical rotors
c) Both salient pole and cylindrical rotors
d) None of these
Ans: (b)

23. In a synchronous machine, if the field flux axis ahead of the armature field axis in the direction of rotation, the machine is working as
a) Asynchronous generator
b) Asynchronous motor
c) Synchronous generator
d) Synchronous motor
Ans: (c)

24. Cylindrical rotor alternators have
a) Large length to diameter ratio
b) Small length to diameter ratio
c) Vertical configuration
d) None of these
Ans: (a)

25. In an alternator, the armature reaction is completely magnetizing when the load power factor is
a) Unity
b) 0.7
c) Zero lagging
d) Zero leading
Ans: (d)

26. To ensure effective cooling, cylindrical rotor alternators use
a) Axial ducts only
b) Radial dusts only
c) Forced air cooling
d) Both radial and axial ducts
Ans: (d)

27. Which of the following is not an integral path of a synchronous generator system?
a) Prime mover
b) Excitation system
c) Distribution transformer
d) Protection system
Ans: (c)

28. The main advantage of using fractional pitch winding in an alternator is to reduce
a) Amount of copper in the winding
b) Size of the machine
c) Harmonics in the generated emf
d) Cost of the machine
Ans: (c)

29. Cross magnetization in an alternator field results in output which is
a) True sinusoidal
b) Non-sinusoidal
c) Harmonic free
d) None of these
Ans: (b)

30. The pitch factor in rotating electrical machines is defined as the ratio of the resultant emf of a
a) Full pitch to the phase emf
b) Full pitched coil to the of a chorded coil
c) Chorded coil to the of a full pitched coil
d) Chorded coil to the phase emf
Ans: (c)

UNIT II SYNCHRONOUS MOTOR

1. Synchronous motor can operate at
(A) Lagging power factor only
(B) Leading power factor only
(C) Unity power factor only
(D) Lagging, leading and unity power factor only.
Ans: D

2. An unexcited single phase synchronous motor is
(A) reluctance motor
(B) repulsion motor
(C) universal motor
(D) AC series motor.
Ans: A

3. The maximum power developed in the synchronous motor will depend on
(A) rotor excitation only
(B) maximum value of coupling angle
(C) supply voltage only
(D) rotor excitation supply voltage and maximum value of coupling angle.
Ans: D

4. In case the field of a synchronous motor is under excited, the power factor will be
(A) leading
(B) lagging
(C) zero
(D) unity.
Ans: B

5. A synchronous motor is switched on to supply with its field windings shorted on themselves. It will
(A) not start
(B) start and continue to run as an induction motor
(C) start as an induction motor and then run as synchronous motor
(D) bum immediately.
Ans: C

6. When the excitation of an unloaded salient pole synchronous motor gets disconnected
(A) the motor will bum
(B) the motor will stop
(C) the motor will ran as a reluctance motor at the same speed
(D) the motor will run as a reluctance motor at a lower speed.

Ans: B

7. The damping winding in a synchronous motor is generally used
(A) to provide starting torque only
(B) to reduce noise level
(C) to reduce eddy currents
(D) to prevent hunting and provide the starting torque.
Ans: D

8. The back emf set up in the stator of a synchronous motor will depend on
(A) rotor speed only
(B) rotor excitation only
(C) rotor excitation and rotor speed
(D) coupling angle, rotor speed and excitation.
Ans: B

9. A synchronous motor is a useful industrial machine on account of which of the following reasons?
I. It improves the power factor of the complete installation
II. Its speed is constant at all loads, provided mains frequency remains constant
III. It can always be adjusted to operate at unity power factor for optimum efficiency and economy.
(A) I only
(B) II only
(C) III only
(D) I, II and III.
Ans: D

10. Which of the following is an unexcited single phase synchronous motor ?
(A) A.C. series motor
(B) Universal motor
(C) Reluctance motor
(D) Repulsion motor.
Ans: C

11. An over excited synchronous motor draws current at
(A) lagging power factor
(B) leading power factor
(C) unity power factor
(D) depends on the nature of load.
Ans: B

12. With the increase in the excitation current of synchronous motor the power factor of the motor will
(A) improve
(B) decrease
(C) remain constant
(D) depend on other factors.
Ans: A

13. The armature current of a synchronous motor has large values for
(A) low excitation only
(B) high excitation only
(C) both low and high excitation
(D) depends on other factors.
Ans: C

14. A synchronous motor is switched on to supply with its field windings shorted on themselves. It will
(A) not start
(B) start and continue to run as an induction motor
(C) start as induction motor and then run as a synchronous motor.
Ans: C

15. If the field of a synchronous motor is under excited, the power factor will be
(A) lagging
(B) leading
(C) unity.
Ans: A

16. When the excitation of an unloaded salient-pole synchronous motor suddenly gets disconnected
(A) the motor stops
(B) it runs as a reluctance motor at the same speed
(C) it runs as a reluctance motor at a lower speed.
Ans: A

17. The armature current of the synchronous motor has large values for
(A) low excitation only
(B) high excitation only
(C) both high and low excitation.
Ans: C

18. What is the ratio of no load speed to full load speed of a 200 kVA, 12 pole, 2200 V, 3 phase, 60 Hz synchronous motor?

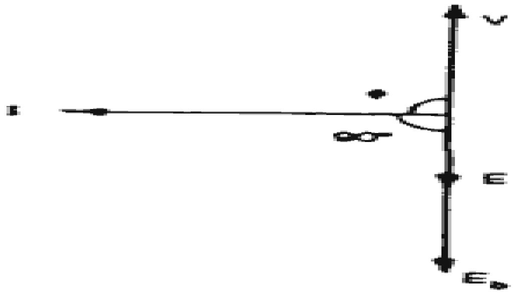
(A) 1
(B) 1.1
(C) 1.21
(D) infinite.
Ans: A

19. If a synchronous motor drops too far behind, the power it takes from the supply also increases too much, and the armature tries to get accelerated, until it is in correct position. Sometimes, some motor overshoots the marks and then the process of acceleration-retardation continues. This phenomenon is known as
(A) synchronization
(B) hunting
(C) pulling out
(D) swinging.
Ans: B

20. The maximum value of torque that a synchronous motor, can develop without losing its synchronism, is known as
(A) breaking torque
(B) synchronizing torque
(C) pull out torque
(D) slip torque.
Ans: B

21. In a synchronous motor if the back emf generated in the armature at no load is approximately equal to the applied voltage, then
(A) the torque generated is maximum
(B) the excitation is said to be zero percent
(C) the excitation is said to be 100%
(D) the motor is said to be fully loaded.
Ans: C

22. A synchronous motor is connected to supply voltage V drawing current /. Resultant of v and back emfE_b is represented by E in the figure. From this diagram it can be concluded that



(A) power factor it lagging
(B) the resultant of V and E_b is consumed by synchronous impedance
(C) current I leads the applied voltage by I
(D) motor is running on full load.
Ans: B

23. A 3 phase, 400 V, 50 Hz salient pole synchronous motor is fed from an infinite bus and is running at no load. Now if the field current of the motor is reduced to zero
(A) the motor will stop
(B) the motor will run
(C) the motor will run at synchronous speed
(D) the motor will run at less than synchronous speed.
Ans: C

24. The purpose of embedding the damper winding in the pole face is to
(A) eliminate hunting and provide adequate starting torque
(B) reduce windage losses
(C) eliminate losses on account of air friction
(D) reduce bearing friction.
Ans: A

25. A synchronous motor is switched on to supply with its field windings shorted on themselves. It will
(A) not start
(B) start but continue to run as an induction motor
(C) start as an induction motor and then run as a synchronous motor.
Ans: B

26. In case of a synchronous motor we have
I. Load
II. Speed
III. DC excitation.
The magnitude of stator back emf depends on
(A) I only
(B) I and II only
(C) III only
(D) I, II and III.
Ans: C

27. Which of the following motors is non-self starling ?
(A) squirrel cage induction motor
(B) wound rotor induction motor
(C) synchronous motor

(D) DC series motor.
Ans: C

28. The back emf in the stator of a synchronous motor depends on
(A) speed of rotor
(B) rotor excitation
(C) number of poles
(D) flux density.
Ans: B

29. Which motor can conveniently operate on lagging as well as leading power factor ?
(A) squirrel cage induction motor
(B) wound rotor induction motor
(C) synchronous motor
(D) any of the above.
Ans: C

30. A synchronous motor working on leading power factor and not driving any mechanical, is known
(A) synchronous induction motor
(B) spinning motor
(C) synchronous condenser
(D) none of the above.
Ans: C

UNIT III THREE PHASE INDUCTION MOTOR

1.At zero in an induction motor
a) Motor runs as a generator
b) Motor does not run
c) The motor runs an at synchronous speed
d) Slip produced is zero
Ans: (b)

2. In an induction motor, rotor slots are usually not quite parallel to the shaft but are given a slight skew
a) To reduce the magnetic hum
b) To reduce the locking tendency of the rotor
c) Both (a) and (b) above
d) To increase the speed of the motor
Ans: (c)

3. The field of an induction motor rotor rotates relative to the stator at

a) Rotor speed
b) Synchronous speed
c) Slip speed
d) Very low speed
Ans: (b)

4. In an induction motor, rotor runs at a speed
a) Equal to the speed of stator field
b) Lower than the speed of stator field
c) Higher than the speed of stator field
d) Having no relation with the speed of stator field
Ans: (b)

5. Starters are used in induction motor because
a) Its starting torque is high
b) It is run against heavy load
c) It can not run in reverse direction
d) Its starting current is five times or more than its rated current
Ans: (d)

6. When an induction motor runs at rated load and speed, the iron losses are
a) Negligible
b) Very heavy
c) Independent of supply frequency
d) Independent of supply voltage
Ans: (a)

7. By synchronous wattage of an induction motor is meant
a) Stator input in watts
b) Rotor output in watts
c) Rotor input in watts
d) Shaft output in watts
Ans: (c)

8. The emf induced in the rotor of an induction motor is proportional to
a) Voltage applied to stator
b) Relative velocity between flux and rotor conductors
c) Both (a) and (b) above
d) Slip
Ans: (c)

9. The synchronous speed of an induction motor is defined as

a) Natural speed at which a magnetic field rotates
b) The speed of a synchronous motor
c) The speed of an induction motor at no load
d) None of these
Ans: (a)

10. The starting torque of an indication motor is maximum when
a) Rotor resistance equals rotor reactance
b) Rotor resistance is twice the rotor reactance
c) Rotor resistance is half the rotor reactance
d) Rotor resistance is R_2 times the rotor reactance
Ans: (a)

11.Three-phase induction motor is mainly suitable for which of the following application
a) For running different machine tools where several speeds are required
b) For running paper machine requiring exact speed control
c) For running electric vehicles
d) For running rolling mills needing exact speed control
Ans: (a)

12. Wattmeter reading in no-load test of induction motor gives
a) Copper losses in the stator
b) Friction and winding losses
c) Sum of (a) and (b) above
d) Total losses in the rotor on no load
Ans: (d)

13. The slip frequency of an induction motor is
a) The frequency of rotor currents
b) The frequency of stator currents
c) Difference of the frequencies of the stator and rotor currents
d) Sum of the frequencies of the stator and rotor currents
Ans: (a)

14. The field winding of a three-phase synchronous machine is excited by
a) Single-phase ac supply
b) Three- phase ac supply
c) Dc supply
d) Supply obtained from an inverter
Ans: (c)

15. With increase of load, the speed of induction motor operating in the stable region

a) Increases
b) Decreases
c) Remains constant
d) Increases and then becomes constant
Ans: (b)

16. When a polyphase induction motor is loaded
a) Increases and its frequency decreases
b) Increases and its frequency increases
c) Decreases and its frequency increases
d) Decreases and its frequency decreases
Ans: (a)

17. In the following motor, external resistance can be added to start the motor
a) Slip ring induction motor
b) Squirrel cage induction motor
c) Salient pole synchronous motor
d) Wound rotor synchronous motor
Ans: (a)

18. If in a 3-phase induction motor, two phases open accidently, the motor will
a) Run at dangerously high speed
b) Stop
c) Continue to run depending on load
d) None of these
Ans: (c)

19. An induction motor is running at its rated torque and rated applied voltage of 440 volts. The effect of reducing the applied voltage to say 350 volts is
a) That the motor stops
b) Current decreases slightly
c) Speed reduces slightly
d) Motor heats up with passage of time
Ans: (d)

20. A three-phase synchronous machine is a
a) Single excited machine
b) Double excited machine
c) Machine in which three-phase supply is fed to both stator and rotor winding
d) None of these
Ans: (c)

The disadvantage of starting an induction motor with a star-delta starter is that
a) The starting torque is one-third of the torque in case of delta connection
b) During starting high losses result
c) The starting torque increases, and the motor runs with jerks
d) None of these
Ans: (a)

22. Squirrel cage induction motor has
a) Zero starting torque
b) Very small starting torque
c) Medium starting torque
d) Very high starting torque
Ans: (b)

23. Improvement of the power factor in an induction motor results in
a) Decreased torque
b) Increased torque
c) Increased torque current
d) Increased torque and decreased current due to increased impedance
Ans: (d)

24. The purpose of blades in a squirrel cage induction motor is
a) To reduce the magnetic resistance of the rotor
b) To cool the rotor
c) To reduce the electrical resistance of rotor cage
d) None of these
Ans: (b)

25. Which of the following function is served by the resistance placed in parallel with one phase of three-phase induction motor?
a) Smooth starting
b) Higher starting torque
c) Higher maximum torque
d) Higher reduced starting torque
Ans: (a)

26. Which of the following is the advantage of double squirrel cage rotor as compared to the round bar cage rotor?
a) Large slip
b) Lower starting torque
c) Higher power factor
d) Higher efficiency
Ans: (b)

27. The rotor output of an induction motor is 15 kW and the slip is 4%. Then the rotor copper loss is
a) 600 watts
b) 300 watts
c) 700 watts
d) 1200 watts
Ans: (a)

28. On open circuiting the rotor of a squirrel cage induction motor, the rotor
a) Makes noise
b) Does not run
c) Does not run
d) Runs at dangerously high speed
Ans: (c)

29. Number of different speed that can be obtained from two induction motors in cascade is
a) 6
b) 4
c) 3
d) 2
Ans: (b)

30. The drawback of speed control of a slip ring induction motor with the help of resistance in the circuit is that
a) It is applicable only to motors having power of more than 100 kW
b) It results in high losses
c) With reduction in speed, the torque decreases significantly
d) The speed can be controlled only very broadly
Ans: (b)

31.Advantage of slip ring induction motor over squirrel cage induction motor is
a) Suitability of high speeds
b) Higher efficiency
c) Higher power factor
d) That it can be started using factor resistance
Ans: (d)

32. In an induction motor, the rotor input is 600 W and slip is 4%. The rotor copper loss is
a) 700 W
b) 625 W
c) 600 W
d) 650 W
Ans: (b)

33. The starting torque of a cage rotor induction motor can be increased by using rotor having
a) Low inductance and low resistance
b) Low inductance and high resistance
c) High inductance and high resistance
d) High inductance and low resistance
Ans: (c)

34. For smooth starting of three-phase squirrel cage induction motor, the starting method preferred is
a) Rotor resistance
b) Star-delta
c) Auto-transformer
d) Stator resistance
Ans: (c)

35. Large air gap in an induction motor results in
a) Reduced noise
b) Reduced pulsation losses
c) Better cooling
d) Increased overload capacity
Ans: (b)

36. The power factor of star connected induction motor is 0.5. On being connected in delta, the power factor will?
a) Increase
b) Reduce
c) Remain the same
d) Become zero
Ans: (b)

37. Simplest method of eliminating the harmonic induction torque is
a) Integral slot winding
b) Chording
c) Skewing
d) None of these
Ans: (b)

38. Any odd harmonic in the current of an induction motor will result in magnetic field which
a) Is stationary relative to the field of the fundamental
b) Rotates in forward direction at the harmonic speed
c) Rotates in backward direction
d) Oscillates at harmonic frequency
Ans: (c)

39. The drive generally used for lathe machines are
a) Dc shunt motors
b) Slip ring induction motors
c) Synchronous motors
d) Squirrel cage induction motors
Ans: (d)

40. Cogging of motor implies that motor
a) Refuses to start at load
b) Refuses to start at no load
c) Runs at low speed and then stops
d) Runs at very low speed
Ans: (b)

UNIT IV – STARTING AND SPEED CONTROL OF THREE PHASE INDUCTION MOTOR

1. The complete circuit diagram of a 3-phase induction motor can be drawn with the help of
a) Block rotor test alone.
b) Running-light and blocked-rotor and stator-resistance tests
c) Both running-light and blocked-rotor tests
d) Running-light test alone
Ans: (b)

2. Which of the following motors is most suitable for best speed control?
a) Dc shunt motor
b) Dc series motor
c) Induction motor
d) Synchronous motor
Ans: (a)

3. A SCIM runs at constant speed only so long as
a) Stator flux remains constant
b) Its torque exactly equals the mechanical load
c) Its supply voltage remains constant
d) Torque developed by it remains constant
Ans: (b)

4. If the frequency of input power to an induction motor increases, the rotor copper loss
a) Decreases
b) Increases
c) Remains the same
d) None of these
Ans: (b)

5. The synchronous speed of a linear induction motor does NOT depend on
a) Width of pole pitch
b) Number of poles
c) Supply frequency
d) Any of the above
Ans: (a)

6. The stator frame in an induction motor is used
a) To provide ventilation to the armature
b) To protect the whole machine
c) To hole the armature stampings/stator
d) As a return path for the flux
Ans: (d)

7.If the stator voltage and frequency of an induction motor are reduced proportionately, its
a) Locked rotor current is reduced
b) Torque developed is increased
c) Magnetizing current is decreased
d) Both (a) and (b)
Ans: (d)

8. Motor A has deeper and narrow slots, whereas motor B. It has shallow and wide slots. Induction motor A, as compared to motor B, has
a) More operating slip
b) Lass starting torque
c) More pull-out torque
d) More starting torque
Ans: (b)

9. If a single-phase motor runs hot. The probable cause may be
a) Overload
b) Low voltage
c) High voltage
d) Amu pf the above
Ans: (d)

10. Which of the following single-phase motors is relatively free from mechanical and magnetic vibration?
a) Reluctance motor
b) Hysteresis motor
c) Universal motor
d) Shaded pole motor
Ans: (b)

11. Single phase induction motor can be made self-starting by
a) Adding series combination of capacitor and auxiliary winding in parallel with the main winding
b) Adding an auxiliary winding in parallel with the main winding
c) Adding an auxiliary winding in series with a capacitor and the main winding
d) None of these
Ans: (a)

12. Which of the following single-phase motors does not have constant speed characteristic?
a) Reluctance motor
b) Hysteresis motor
c) Universal motor
d) All of the above
Ans: (c)

13. For the same rating which of the following motors has the highest starting torque?
a) Universal motor
b) Split phase motor
c) Synchronous motor
d) All have identical starting torque
Ans: (a)

14. All single-phase motors have
a) Large starting torque
b) Zero starting torque
c) Medium starting torque
d) Very small starting torque
Ans: (b)

15. If a single-phase motor fails to start, the probable cause may be
a) Open circuit in auxiliary winding
b) Open circuit in many winding
c) Blown fuses
d) Any of the above
Ans: (d)

16. Single phase motors generally get overheated due to
a) Overloading
b) Short winding
c) Bearing troubles
d) Any of above
Ans: (d)

17. The speed of the split phase induction motor can be reversed by reversing the leads of
a) Auxiliary winding
b) Mani winding
c) Either (a) or (b)
d) Speed cannot be reversed
Ans: (c)

18. If a single-phase motor runs slow, it may be due to
a) Overload
b) Low frequency
c) Low voltage
d) Any of these
Ans: (d)

19. A capacitor start single phase induction motor will usually have power factor of
a) Units
b) 0.6 leading
c) 0.8 leading
d) 0.6 lagging
Ans: (d)

20. Which of the following single-phase motors is cheapest?
a) Capacitor run motor
b) Capacitor start motor
c) Reluctance motor
d) All have almost the same cost
Ans: (d)

UNIT V SINGLE PHASE INDUCTION MOTOR

1. A capacitor start single phase induction motor will usually have a power factor of
(A) unity
(B) 0.8 leading
(C) 0.6 leading
(D) 0.6 lagging.
Ans: B

2. A capacitor start, capacitor run single phase induction motor is basically a
(A) ac series motor
(B) dc series motor
(C) 2 phase induction motor
(D) 3 phase induction motor.
Ans: C

3. The starting torque of a capacitor start motor is
(A) zero
(B) low
(C) same as rated torque
(D) more than rated torque.
Ans: B

4. The torque developed by a split phase motor is proportional to
(A) Sine of angle between l_m and l_s
(B) Cosine of angle between l_m and I_s
(C) Main winding current, I_m
(D) Auxiliary winding current,I_s
Ans: A

5. A capacitor start single phase induction motor is switched on the supply with its capacitor replaced by an inductor of equivalent reactance value. It will
(A) not start
(B) start and run
(C) start and then stall
(D) none of the above.
Ans: D

6. The starting capacitor of a single-phase motor is
(A) Electrolytic capacitor
(B) Ceramic capacitor
(C) Paper capacitor
(D) None of the above.
Ans: A

7. Which of the following is the most economical method of starting a single phase motor ?
(A) Resistance start method
(B) Inductance start method
(C) Capacitance start method
(D) Split-phase method.
Ans: C

8. The number of turns in the starting winding of a capacitor start motor as compared to that for split phase motor is
(A) same
(B) more
(C) less
(D) none of the above.
Ans: B

9. In a split phase motor, the ratio of number of turns for starting winding to that for running winding is
(A) 2.0
(B) more than 1
(C) 1.0
(D) less than 1.
Ans: D

10. A single phase motor generally used for small air compressor is
(A) capacitor start capacitor run motor
(B) reluctance motor
(C) universal motor
(D) shaded pole motor.
Ans: A

11. Out of the following motors, which will give the highest starting torque?
(A) Universal motor
(B) Capacitor start motor
(C) Shaded pole motor
(D) All have zero starting torque.
Ans: B

12. Which single phase ac motor will you select for record players and tape recorders?
(A) Hysteresis motor
(B) Shaded pole motor
(C) Reluctance motor
(D) Two value capacitor motor.
Ans: A

13. A universal motor is one
(A) which can run on any value of supply voltage
(B) which has infinitely varying speed
(C) which can operate on ac as well as dc voltage
(D) which can work as single phase or three phase motors.
Ans: C

14. Under normal operating conditions which motor can run at 5000 rpm?
(A) Synchronous motor
(B) Induction motor
(C) Universal motor
(D) No motor can give 5000 rpm.
Ans: C

15. The motor used in household refrigerators is
(A) dc series motor
(B) dc shunt motor
(C) universal motor
(D) single phase induction motor.
Ans: D

16. The power factor of a single-phase induction motor is usually
(a) lagging
(b) always leading
(c) unity
(d) unity to 0.8 leading
Ans: a

17. A shaded pole motor can be used for
(a) toys
(b) hair dryers
(c) circulators
(d) any of the above
Ans: d

18. A hysteresis motor works on the principle of
(a) hysteresis loss
(b) magnetisation of rotor
(c) eddy current loss
(d) electromagnetic induction
Ans: a

19. Which of the following motor will give the highest starting torque?
(a) D.C. shunt motor
(b) Schrage motor
(c) Repulsion start and induction run motor
(d) Universal motor
Ans: b

20. For which of the applications a reluctance motor is preferred?
(a) Electric shavers
(b) Refrigerators
(c) Signalling and timing devices
(d) Lifts and hoists
Ans: c

21. The motor used on small lathes is usually
(a) universal motor
(b) D.C. shunt motor
(c) single-phase capacitor run motor
(d) 3-phase synchronous motor
Ans: c

22. Which of the following motors is preferred for tape-recorders?
(a) Shaded pole motor
(b) Hysteresis motor
(c) Two value capacitor motor
(d) Universal motor
Ans: b

23. A single-phase induction motor is
(a) inherently self-starting with high torque
(b) inherently self-starting with low torque
(c) inherently non-self-starting with low torque
(d) inherently non-self-starting with high torque
Ans: c

24. A universal motor can run on
(a) A.C. only
(6) D.C. only
(c) either A.C. or D.C.
(d) none of the above
Ans: c

25. Which of the following single-phase motors is suitable for timing and control purposes?
(a) Reluctance motor
(b) Series motor
(c) Repulsion motor
(d) Universal motor
Ans: a

ME6701 POWER PLANT ENGINEERING L T P C
3 0 0 3

OBJECTIVES:

- Providing an overview of Power Plants and detailing the role of Mechanical Engineers in their operation and maintenance.

UNIT I COAL BASED THERMAL POWER PLANTS **10**

Rankine cycle - improvisations, Layout of modern coal power plant, Super Critical Boilers, FBC Boilers, Turbines, Condensers, Steam & Heat rate, Subsystems of thermal power plants – Fuel and ash handling, Draught system, Feed water treatment. Binary Cycles and Cogeneration systems.

UNIT II DIESEL, GAS TURBINE AND COMBINED CYCLE POWER PLANTS **10**

Otto, Diesel, Dual & Brayton Cycle - Analysis & Optimisation. Components of Diesel and Gas Turbine power plants. Combined Cycle Power Plants. Integrated Gasifier based Combined Cycle systems.

UNIT III NUCLEAR POWER PLANTS **7**

Basics of Nuclear Engineering, Layout and subsystems of Nuclear Power Plants, Working of Nuclear Reactors : Boili*ng Water Reactor* (BWR), P*ressurized Water Reactor* (PWR), CANada Deuterium- Uranium reactor (CANDU), Breeder, Gas Cooled and Liquid Metal Cooled Reactors. Safety measures for Nuclear Power plants.

UNIT IV POWER FROM RENEWABLE ENERGY **8**

Hydro Electric Power Plants – Classification, Typical Layout and associated components including Turbines. Principle, Construction and working of Wind, Tidal, *Solar* Photo Voltaic (SPV), Solar Thermal, Geo Thermal, Biogas and Fuel Cell power systems.

UNIT V ENERGY, ECONOMIC AND ENVIRONMENTAL ISSUES OF POWER PLANTS **10**

Power tariff types, Load distribution parameters, load curve, Comparison of site selection criteria, relative merits & demerits, Capital & Operating Cost of different power plants. Pollution control technologies including Waste Disposal Options for Coal and Nuclear Power Plants.

TOTAL : 45 PERIODS

OUTCOMES:

- Upon completion of this course, the Students can able to understand different types of power plant, and its functions and their flow lines and issues related to them.
- Analyse and solve energy and economic related issues in power sectors.

TEXT BOOK:

1.P.K. Nag, Power Plant Engineering, Tata McGraw – Hill Publishing Company Ltd., Third Edition, 2008.

REFERENCES:

1. M.M. El-Wakil, Power Plant Technology, Tata McGraw – Hill Publishing Company Ltd., 2010.

2. Black & Veatch, Springer, Power Plant Engineering, 1996.

3. Thomas C. Elliott, Kao Chen and Robert C. Swanekamp, Standard Handbook of Power Plant Engineering, Second Edition, McGraw – Hill, 1998.

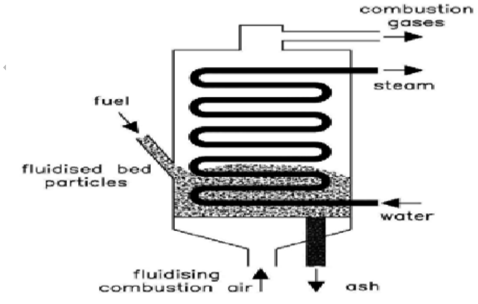
4. Godfrey Boyle, Renewable energy, Open University, Oxford University Press in association with the Open University, 2004.

REGULATION:2013 **ACADEMIC YEAR:2018-2019**

Subject Code: ME6701 **Year/Semester: III/05**
Subject Name: Power Plant Engineering **Subject Handler: Mrs.A.Ramya**

	UNIT I – COAL BASED THERMAL POWER PLANTS
	Rankine cycle - improvisations, Layout of modern coal power plant, Super Critical Boilers, FBC Boilers, Turbines, Condensers, Steam & Heat rate, Subsystems of thermal power plants – Fuel and ash handling, Draught system, Feed water treatment. Binary Cycles and Cogeneration systems.
	PART*A
1	**Name the processes of Rankine Cycle.** BTL1 ➢ Process 1-2 : Reversible adiabatic or isentropic expansion in the turbine ➢ Process 2-3 : Constant Pressure or isobaric heat rejection in the condenser ➢ Process 3-4 : Reversible adiabatic or isentropic pumping process in the feed pump ➢ Process 4-1 : Constant Pressure or isobaric heat supplied in the boiler.
2	**List the four important circuits of Steam Power Plant.** BTL1 ➢ Coal and ash circuit ➢ Air and flue gas circuit ➢ Water and steam circuit ➢ Cooling water circuit
3	**Define steam rate and heat rate. AU DEC 2016** BTL2 ➢ **Steam rate (also called Specific Steam Consumption(SSC))** - It is defined as the rate of steam flow (kg/h) required for producing unit shaft output (1 kW) Steam rate indicates the capacity of a steam plant. Steam rate, SSC = Mass of steam / Work Output in kg/kWh ➢ **Heat rate** – It is defined as the heat input needed to produce one unit of power output. It indicates the amount of fuel required to generate one unit of electricity. Heat rate = Heat supplied / Work output
4	**Why thermal power plants are not suitable for supplying fluctuating loads?** BTL4 Thermal plants are not suitable for supplying fluctuating loads because any change in load demand requires the corresponding change in the output energy. In thermal plants, the input energy is produced by burning the coal. So, there is always a large time lapse between change in energy output and input which is not desirable. Therefore, such power stations are used only as base load stations and it supplies the constant power.
5	**Define the function of boiler and turbine.** BTL2 ➢ Boiler – A boiler is a closed vessel in which the steam is generated from water by applying heat.

	➢ Turbine – Steam turbine is a device which is used to convert the kinetic energy of steam into mechanical energy.
6	**Define superheated steam.** BTL2 If the dry steam is further heated, then the process is called superheating and the steam is known as superheated steam. **Uses:** ➢ It has more heat energy and more work can be obtained using it. ➢ Thermal efficiency increases as the temperature of superheated steam is high. ➢ Heat losses are due to condensation of steam and cylinder wall friction.
7	**What is super critical boilers? AU DEC-2015** BTL2 ➢ Boilers only with economizer and superheater are called super critical boilers. ➢ It operates at supercritical pressure. ➢ The supercritical boilers are above 300 MW capacity. ➢ Ex – Velox Boiler and Loeffler boiler Advantages: ➢ High thermal efficiency ➢ Heat transfer rate is high ➢ Erosion and corrosion are minimized.
8	**Define the merits of pulverized fuel firing system.** BTL1 ➢ Coal is pulverized to increase its surface exposure and complete combustion. ➢ High combustion temperature can be obtained. ➢ It has more heating surface area. ➢ Low grade fuel can also be used. ➢ Clean combustible gases can be produced. ➢ Fuel feed rate is increased.
9	**What is stoker? Classify it.** BTL2 Stoker is a feeding device which feeds solid fuels into the furnace in medium and large size power plants. Types: ➢ Overfeed stoker ➢ Underfeed stoker
10	**What is the necessity of feed pump in thermal power plant?** BTL2 Feed pump is a pump which is used to deliver the feed water to the boiler. The quantity of water supplied should be at least equal to the amount of evaporation which is supplied to the engine.
11	**Mention the various modern ash handling systems.** BTL1 ➢ Gravitational separator ➢ Cyclone separator ➢ Packed type scrubber ➢ Spray type wet collector ➢ Electrostatic precipitator(ESP)
12	**List the methods used for handling of coal.** BTL1 ➢ Out plant handling of coal done by sea or river, ropes, rail, road, pipeline etc ➢ In plant handling of coal.

13	**State the function of cooling tower.** BTL2 ➢ Cooling tower discharges the warm water from the condenser and feed the cooled water back to the condenser. ➢ There are two types: (a)Wet type (b) Dry type
14	**List the requirements of a modern surface condenser.** BTL2 ➢ The steam should be evenly distributed over the whole cooling surface of the condenser with minimum pressure loss. ➢ The deposition of dirt on the outer surface of tubes should be prevented. It is achieved by passing the cooling water through tubes and allowing the steam to flow over tubes. ➢ There should be no under cooling of condensate. ➢ There should be no air-leakage into the condenser because it destroys the vacuum in the condenser. So, it reduces the work obtained per kg of steam.
15	**Define the term boiler draught. AU DEC-2016** BTL2 Draught is defined as the movement of air through full bed which produces a flow of hot gases through the boiler and the chimney, which requires a pressure difference between gas pressure and atmospheric pressure. This difference in pressure required to maintain the constant flow of air and discharge the gases known as draught.
16	**Define pulveriser and why it is used**? **AU DEC-2015** BTL2 A pulveriser or grinder is a mechanical device for grinding many different types of materials. Pulveriser mill is used to pulverize the coal for combustion in the steam generating furnaces of fossil fuel power plants.
17	**List the factors affecting cooling of water in cooling tower.** BTL1 ➢ The exposing time ➢ Amount of water surface exposed ➢ Relative humidity of air ➢ Velocity of air ➢ Accessibility of air to various parts of cooling tower.
18	**What is compounding of steam turbine?** BTL2 ➢ Compounding is a method of absorbing the jet velocity in stages when the steam flows over moving blades. ➢ It reduces the velocity of steam at the exit of turbine and also the speed of rotor.
19	**Draw a neat sketch of basic principle of FBC.** BTL5 
20	**What is Cogeneration systems?** BTL4 Cogeneration is also called combined heat power. Cogeneration works based on the concept of producing two different forms of energy by using a single source of fuel. Out of these two forms, one must be heat or thermal energy and other one is either electrical or mechanical energy.

21	**What is reheat cycle?** BTL2 In reheat cycle, the steam is extracted from a suitable point in the turbine and it is reheated with the help of flue gases in the boiler.
22	**List the advantages of reheat cycle.** BTL1 ➢ The reheating reduces from 4 to 5% fuel consumption. ➢ The reheat cycle reduces the steam flow of 15% to 20% with corresponding reduction in boiler, turbine and feed heating equipment capacity.
23	**Name the methods of reheating.** BTL1 ➢ Gas reheating ➢ Live steam reheating ➢ Combined gas and live steam reheating
24	**What is regenerative cycle?** BTL2 The feed water is heated with the help of steam in a reversible manner. Steam temperature and water temperature are same at any section. Such type of heating is known as regenerative cycle.
25	**Where is reheat-regenerative cycle used?** BTL2 Reheat – regenerative cycle is used in the actual thermal power plant with high steam pressure (above 90kgf/cm^2), which increases the overall efficiency of the cycle.
	PART*B
1	**Draw a general layout of thermal power plant and explain the working of different circuits. (13 M) AU DEC-2015/2016** BTL2 **Answer: Page: 1.2 - Dr.G.K.Vijayaraghavan** **Principle:** Heat Energy → Mechanical Energy → Electrical Energy **(1 M)** **Layout**: **(4 M)** **Working:** Steam power plant consists of four main circuits ➢ Coal and Ash circuit **(2 M)** ➢ Air and Flue gas circuit **(2 M)** ➢ Water and steam circuit **(2 M)** ➢ Cooling water circuit **(2 M)**
2.	**Write short notes on: AU DEC-2015** BTL2 **(i)Ash handling system (6 M)** **Answer: Page: 1.46 - Anup Goel** The Disposal of ash and dumping it at a distance from the power plant is important for the following reasons: **(2 M)** 1). The ash is very hot when it comes out of the boiler furnace. 2). The ash is dusty, therefore it is irritating and annoying to handle. 3). When mixed with water, the ash produces poisonous gases and corrosive acids. **Types of ash handling system:** 1). Mechanical handling system. 2). Hydraulic system. 3). Pneumatic system. 4). steam jet system. 1). **Mechanical hand ling system: (1 M)** This system is applied for low capacity power plants using coal as fuel.

2). **Hydraulic system: (1 M)**
In this system the ash is carried with the flow of water with high velocity through a channel and finally dumped in the sump.

3). **Pneumatic system**: **(1 M)**
This system can handle abrasive ash, fly-ash and soot.

4). **Steam jet system: (1 M)**
In this system, the high velocity steam is passed through a pipe.

(ii)Different draught systems (7 M)
Answer: Page: 1.52 - Anup Goel
Draught is defined as the difference between absolute gas pressure at any point in a gas flow passage and the ambient (same elevation) atmospheric pressure.

Necessity of Draught: (2 M)
- To supply required amount of air to the furnace for the combustion of fuel.
- The amount of fuel that can be burnt per square root of grate area depends upon the quantity of air circulated through fuel bed.
- To remove the gaseous products of combustion.

Classification of Draught: (5 M)
- **Natural Draught:** The draught is produced by this tall chimney due to temperature difference of hot gases in the chimney and cold external air outside the chimney.
- **Artificial Draught:** The draught is produced by steam jet or fan.
- **Steam jet draught:** The draught is produced by steam.
- **Mechanical draught:** The draught is produced by blowers or fan.
- **Induced draught:** The flue is drawn(sucked) through the system by a fan or steam jet.
- **Forced draught:** The air is forced into system by a blower or steam jet.

3. **Explain the following with neat diagram: AU DEC-2016** BTL2
(i)Benson boiler (6 M)
Answer: Page: 1.22 - Anup Goel
Diagram: (3 M)
Explanation: (3 M)
- The feed pump circulates the water to the evaporator through economizer.
- The drum is eliminated in this type of boiler
- The major portion of water is converted into the steam in radiant evaporator
- The remaining portion of water is evaporated in the convective evaporator and pressure of steam rises up to 225 bar.

Advantages:
Easy and quick erection of boiler, require less floor space, lower explosion hazards

(ii)Cogeneration plant (7 M)
Answer: Page: 1.10 - Anup Goel
Explanation: (3 M)
- A cogeneration system is the simultaneous generation of multiple forms of useful energy in a single integrated system.
- The useful energy usually is in the form of mechanical/electrical and thermal(heat) energy. It is also known as combined Heat and Power (CHP) system.

Classification of Cogeneration systems: (4 M)
A cogeneration system can be classified on the basis of the sequence of energy use as follows:

	A topping cycle In a topping cycle, the fuel supplied is first used to produce power and thermal energy. Types: Combined – cycle topping system, Steam – turbine topping system, Heat recovery topping system, Gas turbine topping system. **A bottoming cycle** In a bottoming cycle, the primary fuel produces high temperature thermal energy.
4.	**Explain the following: (13 M)** BTL2 **(i) Types of Turbines** **(ii) Types of Condensers** **(i)Types of Turbines (7 M)** **Answer: Page: 1.110 – Dr.G.K.Vijayaraghavan** Steam turbines are classified as follows. **1.On the basis of method of steam expansion** (a)Impulse turbine (b)Reaction turbine (c)Combination of impulse and reaction turbine **2.On the basis of number of stages** (a)Single stage turbines (b)Multi-stage turbines **3.On the basis of steam flow directions** (a)Axial turbine (b)Radial turbine (c)Tangential turbine (d)Mixed flow turbine **4.On the basis of pressure of steam** (a)High pressure turbine (b)Low pressure turbine (c)Medium pressure turbine **(ii)Types of Condensers (6 M)** **Answer: Page: 1.157 – Dr.G.K.Vijayaraghavan** **1.Based on the contact shell and tube fluid** (a)Direct Contact Condenser (b)Indirect Contact Condenser **2.Based on the type of cooling** (a)Water cooled condenser (b)Air cooled condenser **3.Based on the type of flow** (a)Down flow type (b)Central flow condenser (c)Evaporation condenser
5.	**Analyze the following:** BTL 4 **(i) Coal Handling System (7 M)** **(ii)Feed water treatment (6 M)** **(i)Coal Handling System (7 M)** **Answer: Page: 1.172 – Dr.G.K.Vijayaraghavan**

	Two Types: **(1 M)** ➢ Out plant handling of coal ➢ In plant handling of coal The out plant handling of coal is done by **(3 M)** ➢ Transportation by sea or river ➢ Transportation by ropes ➢ Transportation by rail ➢ Transportation by road ➢ Transportation by pipelines ➢ In plant handling of coal Steps in Inplant handling of coal: **(3 M)** ➢ Coal Delivery ➢ Unloading ➢ Transfer ➢ Outdoor storage ➢ Covered storage ➢ In plant handling ➢ Weighing and measuring ➢ Furnace **(ii)Feed water treatment (6 M)** **Answer: Page: 1.238 – Dr.G.K.Vijayaraghavan** **Necessity to treat the Raw water: (3 M)** ➢ The deposition of dissolved salts and suspended impurities will form a scale on the inside wall of different heat exchangers. So, it will create excessive pressure and thermal stress inside heat exchangers. It may lead to the explosion and serious hazards to boilers. ➢ The harmful dissolved salts may react with various parts of boilers. So, it might corrode the surfaces. ➢ Corrosion damage may occur to turbine blades. **Two Types: (3 M)** ➢ Demineralization Plant (DM plant) - It employs a chemical method to separate the dissolved salt in fresh water. ➢ Reverse Osmosis Plant (RO plant) - It employs a simple physical method to separate salts.
	PART*C
1.	**Analyze the working of binary vapour cycle with a neat diagram. (15 M)** BTL4 **Answer: Page: 1.245 - Dr.G.K.Vijayaraghavan** Two working fluids – Mercury and water **(2 M)** **Characteristics of working fluid & Diagram: (8 M)** ➢ High enthalpy of vaporization ➢ Good heat transfer characteristics ➢ High critical temperature with a low corresponding saturation temperature. ➢ High condenser temperature ➢ Freezing temperature should be below room temperature **Types: (5 M)** ➢ Topping cycle - Condenser at the high temperature region

	➢ Bottoming cycle – Condenser at the low temperature region
2.	**(i) With a neat diagram explain the function of FBC boilers. (7 M) AU DEC-2017** BTL2 **Answer: Page: 1.17 - Anup Goel** A fluidized bed may be defined as the bed of solid particles behaving as a fluid. **Principle: (2 M)** ➢ When a gas is passed through a packed bed of finely divided solid particles, it experiences a pressure drop across the bed. ➢ At low velocity, this pressure drop is small and does not disturb the particles. ➢ But if the gas velocity is increased further, a stage will come when the particles are suspended in the gas stream and the packed bed becomes a fluidized bed. **Types: (5 M)** Pressurised FBC boilers – Double shell design is used Circulating FBC boilers – It has three zones of furnace – lower zone, upper zone, solid –separator zone Atmospheric fluidized bed combustor boilers – They are known as fully developed boiler and therefore are widely used. Two types – Underfeed and Overfeed. **(ii) Super critical boilers (8 M)** **Answer: Page: 1.21 - Anup Goel** **Explanation: (5 M)** ➢ Generates steam above critical pressure are called super critical once through boilers. ➢ At critical pressure latent heat vapourization becomes zero. In this case, the saturated liquid is directly converted into superheated steam. ➢ The separator vessel cannot be used in these boilers. ➢ They are also known as “drumless boilers”. **Advantages: (3 M)** ➢ Rate of heat transfer is more ➢ Higher thermal efficiency ➢ Pressure is more stable.
3.	**Explain the working of Rankine cycle with a neat diagram. (15 M)** BTL 2 **Answer: Page: 1.3 - Anup Goel** **Explanation: (5 M)** ➢ Rankine cycle is a modified cycle of carnot. ➢ In Rankine cycle heat supplied and heat rejection occurs at constant pressure. ➢ This cycle is practically used in steam power plant. **Working principle: (5 M)** ➢ Process 1-2: Reversible isentropic ➢ Process 2-3: Heat supplied (P=C) ➢ Process 3-4: Reversible isentropic ➢ Process 4-1: Heat rejection (P=C) **Diagram: (5 M)**

	UNIT – II DIESEL, GAS TURBINE AND COMBINED CYCLE POWER PLANTS
	Otto, Diesel, Dual & Brayton Cycle - Analysis & Optimisation. Components of Diesel and Gas Turbine power plants. Combined Cycle Power Plants. Integrated Gasifier based Combined Cycle systems.
	PART*A
1	**List the applications of diesel engine power plant.** BTL1 ➢ Peak load plant ➢ Mobile plants ➢ Stand by units ➢ Emergency plant ➢ Starting station ➢ Nursery station
2	**Analyze the purpose of air intake system in a diesel engine power plant.** BTL4 The purpose of air intake system conveys fresh air through pipes or ducts to ➢ Air intake manifold of four stroke engine ➢ Scavenging pump inlet of a two stroke engine ➢ Supercharge inlet of a supercharged engine
3	**Name the commonly used fuel injection system in a diesel power station.** BTL3 ➢ Common rail injection system ➢ Individual pump injection system ➢ Distributor
4	**Write the processes of Otto cycle.** BTL5 ➢ Process 1-2: Isentropic Compression process ➢ Process 2-3: Constant Volume heat addition process ➢ Process 3-4: Isentropic Expansion process ➢ Process 4-1: Constant Volume heat rejection process
5	**List the processes of dual cycle.** BTL2 ➢ Process 1-2: Isentropic Compression process ➢ Process 2-3: Constant Volume heat addition process ➢ Process 3-4: Constant pressure heat addition process ➢ Process 4-5: Isentropic Expansion process ➢ Process 5-1: Constant Volume heat rejection process
6	**Name the various gas power cycle.** BTL1 ➢ Carnot cycle ➢ Otto cycle ➢ Diesel cycle ➢ Brayton cycle ➢ Dual combustion cycle ➢ Atkinson cycle
7	**Write the different types of Engines used in diesel power plants.** BTL1 ➢ Small size Diesel engine ➢ Medium size Diesel engine ➢ Large size Diesel engine

8 **List the processes of diesel cycle.** BTL5

- Process 1-2: Isentropic Compression process
- Process 2-3: Constant pressure heat addition process
- Process 3-4: Isentropic Expansion process
- Process 4-1: Constant Volume heat rejection process

9 **List the various processes of Brayton cycle.** BTL6

- Process 1-2: Isentropic Compression process
- Process 2-3: Constant pressure heat addition process
- Process 3-4: Isentropic Expansion process
- Process 4-1: Constant pressure heat rejection process

10 **Classify the various types of cooling system used in diesel power plant.** BTL4

- Air cooling
- Liquid cooling
    - (a)Thermo – syphon cooling
    - (b)Forced or pump cooling
    - (c)Cooling with thermostatic regulator
    - (d)Pressurised water cooling
    - (e)Evaporative cooling

11 **Write any two drawbacks of a stationary gas turbine power plant for generation of electricity**. BTL1

- The part load efficiency is poor
- The unit is operated at high temperature and pressure, so special metals are required to maintain the unit.
- Major part of the work (about 66%) developed in the turbine is used to drive the compressor.
- The devices that are operated at high temperature are complicated.

12 **Name the Components of Gas Turbine Power plants**. BTL1

- Air compressor
- Combustion chamber
- Gas Turbine
- Generator

13 **Point out the major difference between Otto cycle and Diesel cycle.** BTL4

S.NO	OTTO CYCLE	DIESEL CYCLE
1	It consists of two adiabatic and two constant volume processes.	It consists of two adiabatic, one constant pressure and one constant volume processes.
2	Compression ratio is equal to expansion ratio.	Compression ratio is not equal to expansion ratio.
3	Heat addition takes place at constant volume processes	Heat addition takes place at constant pressure processes
4	Efficiency depends on compression ratio only	Efficiency depends on compression ratio and cut off ratio
5	Heat rejected is less	Heat rejected is more

14 **Write the effect of inter cooling in a gas turbine plant.** BTL1

- Heat supply is increased

	➢ It decreases the thermal efficiency ➢ Work ratio will be increased ➢ Specific volume of air is reduced
15	**List the advantages and disadvantages of a diesel power plant.** BTL1 Advantages: ➢ The location of the plant is near the load center. ➢ It has no stand by losses. ➢ It provides quick starting and easy pick-up of loads. ➢ Skilled manpower is not required. Disadvantages: ➢ Noise is a serious problem. ➢ High operating cost ➢ The plant capacity is limited to about 50MW of power. ➢ The efficiency of the Diesel engine is about 33% only.
16	**Analyze the process in combined cycle power plant.** BTL4 The combined power cycles are introduced by superposing a high temperature power plant as a topping unit and the low temperature power plant as a bottoming unit. It increases the efficiency and reduces the fuel consumption. Eg: Gas Turbine – Steam Turbine plant in which Gas turbine as bottoming unit and steam turbine as topping unit.
17	**List the advantages of combined cycle power plants.** BTL2 ➢ It produces low environmental effect ➢ It needs less amount of water ➢ Investment cost is low ➢ It gives high ratio of power output to fuel ➢ It produces less smoke when compared with ordinary steam plant. ➢ High efficiency than open cycle power plant.
18	**Give examples of combined cycle power plant.** BTL1 ➢ Gas turbine – steam turbine power plant ➢ Thermionic – steam power plant ➢ Thermo electric-steam power plant ➢ M.H.D – steam power plant ➢ Nuclear – steam combined power plant ➢ MHD – gas turbine power plant
19	**Illustrate the advantages of Integrated Gasifier based combined cycle power plants.** BTL3 ➢ It produces higher efficiencies and lower emissions ➢ Improvements in efficiency dramatically reduce the emissions from coal combustion. ➢ Product flexibility is ensured.
20	**Define air standard efficiency of Diesel cycle.** BTL1 Air standard efficiency is defined as the ratio of work done by the cycle to the heat supplied to the cycle.
21	**What is Compression ratio?** BTL1 It is the ratio of volume when the piston is at BDC to the Volume when the piston is at TDC.

PART*B

1. **Explain the working of open cycle and closed cycle gas turbine power plant and discuss its advantages and disadvantages. (13 M) AU DEC-2015** BTL2

Answer: Page: 2.31 - Anup Goel

A simple gas turbine cycle consists of the following components **(3 M)**

- Compressor
- Combustion chamber
- Turbine

Open cycle gas turbine power plant: (5 M)

- Consists of air compressors, combustion chamber and turbine.
- Air is drawn from the atmosphere to compressor.
- The compressed air is passed to combustion chamber where heat is added by spraying fuel into the air stream.
- The hot gases expand through the turbine and the product of combustion which is coming out of the turbine is exhausted to the atmosphere.

Advantages:

- Low maintenance

Disadvantages:

- Turbine blades wear out earlier

Closed cycle gas turbine power plant: (5 M)

- Consists of compressor, Combustion chamber, cooling chamber (cooler) and turbine.
- The product of combustion which is coming out of the turbine is cooled in the cooling chamber and sent again to the compressor.

Advantages:

- Improves the heat transmission and part load efficiency.

Disadvantages:

- Large amount of cooling water is required.
- Requires the use of heater.

2. **(i) Explain in detail about the construction and working of IGCC. (7 M) AU DEC-2015** BTL1

Answer: Page: 2.182 - Dr.G.K.Vijayaraghavan

- One of the most promising technologies in power generation.
- Extremely clean and more efficient than traditional coal-fired gasification systems.

Construction of IGCC: (3 M)

Consists of the following four major units.

- ASU (Air separation Unit)
- Gasification
- Gas clean up
- Combined power block

Working: (4 M)

- First coal is gasified either partially or fully.
- The synthetic gas is produced.
- Then, it is cleaned.
- After that, it is burnt in the combustion chamber.

(ii) Draw and explain PV and TS diagrams of Brayton cycle. (8 M) AU DEC-2015 BTL1

Answer: Page: 2.76 - Dr.G.K.Vijayaraghavan

Brayton cycle - theoretical cycle for gas turbine.

	Four Processes: Two reversible adiabatic Processes and two constant pressure Processes. Therefore this cycle is also called constant pressure cycle. **(4 M)** ➢ Process 1-2: Isentropic Compression Process ➢ Process 2-3: Constant Pressure heat addition Process ➢ Process 3-4: Isentropic expansion process ➢ Process 4-1: Constant pressure heat rejection process. **PV and TS diagram: (4 M)**
3 .	**Discuss the essential components of the diesel power plant with neat layout. (13 M)** BTL2 **Answer: Page: 1.3 - Anup Goel** **Diagram: (5 M)** **Components: (8 M)** The essential components of diesel power plant are (i) Diesel Engine – Main component to generate the mechanical energy from the heat energy which is obtained by burning diesel fuel. (ii) Air Intake system – It provides the air required for the combustion of fuel. (iii) Exhaust system – To reduce the noise produced by the exhaust gases coming out of the engine. (iv) Cooling system – To lower the temperature of the burning fuel (v) Fuel supply system – It supplies the fuel required for combustion. (vi) Lubrication system – To reduce the wear of the moving parts of the engine. (vii) Diesel engine starting system – To start the engine from cold condition with the help of an air compressor. (viii) Governing system – Used to control the flow of the fuel.
	PART*C
1 .	**(i)Derive an expression for the work ratio using Brayton cycle. (8 M)** BTL4 **Answer: Page: 2.79 - Dr.G.K.Vijayaraghavan** **Work Ratio: (3 M)** It acts as useful parameter for power plant cycles. It is defined as the ratio of net work transfer in a cycle to the positive work transfer or turbine work in the cycle. **Expression: (5 M)** Work ratio = Net work transfer / Positive work transfer $= [mC_p(T_3 - T_4) - mC_p(T_2 - T_1] / mC_p(T_3 - T_4)$ $= 1- (T_1/T_3)\,(R_P)^{\gamma-1}\gamma$ The work ratio depends not only on the pressure ratio but also on the ratio of the minimum and maximum temperatures. **(ii)Discuss the working of any one type of combined cycle power plant. (8 M)** BTL2 **Answer: Page: 2.17 - Dr.G.K.Vijayaraghavan** **Explanation: (3 M)** To increase the efficiency and reduce the fuel consumption, the combined power cycles are introduced by superposing a high temperature power plant as a topping unit and the low temperature power plant as a bottoming unit. **Types: (2 M)** ➢ Gas turbine – steam turbine power plant ➢ Thermionic – steam power plant ➢ Thermo electric – steam power plant

- M.H.D – steam power plant
- Nuclear – steam combined power plant
- MHD – gas turbine power plant

Gas Turbine – Steam Turbine plant: (3 M)

- Bottoming Unit – Gas Turbine plant
- Topping Unit – Steam Power plant

The efficiency of this combined unit is 45%.

2. **(i)Enlist the advantages and disadvantages of a diesel engine power plant. (8 M)** BTL1

Answer: Page: 2.31 - Anup Goel

Advantages: (4 M)

- Very simple in design and also simple in installation.
- Limited Cooling water requirement.
- Standby losses are less as compared to the other Power plants.
- Low fuel cost.
- Quickly started and put on load.

Disadvantages: (4 M)

- High maintenance and operating cost
- Fuel cost is more, since in India diesel is costly.
- The plant cost per KW is comparatively low.
- The life of diesel power plant is small due to high maintenance.
- Noise is a serious problem in diesel power plant.

(ii)Compare the merits and demerits of open and closed cycle gas turbine power plant. (8 M) BTL4

Answer: Page: 2.162 - Dr.G.K.Vijayaraghavan

Open Cycle Gas Turbine Power Plant	**Closed Cycle Gas Turbine Power Plant**
Merits: (4 M) No pre-cooler is required. Size and weight of the open cycle gas turbine unit are less. Combustion efficiency is more. Response to load variation is greater than closed cycle gas turbine. **Demerits: (4 M)** Part load efficiency rapidly decreases for the considerable % of power developed by the turbine and it is used to drive the compressor. Turbine blades are fouled by combustion products. Starting of the plant is difficult. Thermal stresses are high.	**Merits:** Efficiency is same throughout the cycle. Starting of the plant is easy. Thermal stresses are low. There is no need for internal cleaning. **Demerits:** A separate pre-cooler arrangement is necessary. The size and weight are more. Initial cost and maintenance are more. The response to load variation is less

3. **(i) Explain the PV and TS diagrams of Otto cycle. (8 M)** BTL4

Answer: Page: 2.3 - Dr.G.K.Vijayaraghavan

Four Processes: (4 M)

Two reversible adiabatic or isentropic processes and
Two constant volume processes

- Process 1-2: Isentropic Compression Process.
- Process 2-3: Constant Volume heat addition Process
- Process 3-4: Isentropic expansion process
- Process 4-1: Constant Volume heat rejection process.

Diagram: (4 M)

(ii) Explain the PV and TS diagrams of diesel cycle. (8 M) BTL4

Answer: Page: 2.27 - Dr.G.K.Vijayaraghavan

- This cycle is used in Diesel engines.

Four processes: (4 M)

Two reversible adiabatic or isentropic
One Constant Volume and
One Constant Pressure processes.

- Process 1-2: Isentropic Compression Process.
- Process 2-3: Constant Pressure heat addition Process
- Process 3-4: Isentropic expansion process
- Process 4-1: Constant Volume heat rejection process.

Diagram: (4 M)

	UNIT III – NUCLEAR POWER PLANTS
	Basics of Nuclear Engineering, Layout and subsystems of Nuclear Power Plants, Working of Nuclear Reactors: Boil*ing Water Reactor* (BWR), P*ressurized Water Reactor* (PWR), CANada Deuterium- Uranium reactor (CANDU), Breeder, Gas Cooled and Liquid Metal Cooled Reactors. Safety measures for Nuclear Power plants.
	PART * A
1	**Write the advantages of nuclear power plant.** BTL1 ➢ There is no atmospheric pollution by combustion products. ➢ They are not affected by adverse weather conditions. ➢ Water requirement is very less. ➢ Space requirement is less as compared to other conventional power plants of equal size. ➢ It is well suited to meet large power demands. They give better performance at high load factors (80 to 90%)
2	**Name the three moderators used in nuclear power plants.** BTL1 ➢ Heavy water (D_2O) ➢ Water (H_2O) ➢ Beryllium (Be) ➢ Graphite (C) ➢ Helium (He)
3	**Write the function of the moderator.** BTL2 Moderator is a material which is used to slow down the neutrons from high velocities without capturing them. The fast moving neutrons are far less effective in causing the fission and for the escape from the reactor.
4	**List the function of control rods.** BTL1 ➢ To control the rate of fission. ➢ To start the nuclear chain reaction when the reactor is started from cold. ➢ To shut down the reactor under emergency condition.
5	**What is nuclear fission?** BTL2 Nuclear fission is the process of splitting the nucleus into two almost equal fragments accompanied by the release of heat. In other words, it is the process of splitting the unstable heavy nucleus into two fragments of approximately equal mass when bombarded with neutrons.
6	**Mention the fuels used in nuclear power plants.** BTL1 ➢ U^{235} – Primary fuel ➢ U^{233} and PU^{239} – Secondary fuels
7	**Write the conditions satisfied to sustain nuclear fission process (or) Requirements of Fission process**. BTL2 ➢ The chain reaction should be self – sustaining or self – propagating only. ➢ At least one fission neutron becomes available for causing fission of another nucleus. ➢ The fission process must liberate the energy. ➢ The neutrons emitted in fission must have adequate energy to cause fission of other nuclei. ➢ It must be possible to control the rate of energy liberation.
8	**List down the basic factors those are to be considered for the design of a nuclear power reactor.** BTL1 ➢ Proximity to load center ➢ Population distribution

- Land use
- Meteorology
- Geology
- Hydrology
- Seismology

9 **What is “half-life” of nuclear fuels?** BTL2

The radioactive half-life for a given radioisotope is a measure of the tendency of nucleus to “decay” or “disintegrate” and it is based purely upon that probability.

10 **Distinguish between PHWR and LMFBR.** BTL2

S.NO.	PHWR	LMFBR
1	A nuclear power reactor commonly uses enriched natural uranium as its fuel which uses heavy water(D_2O) as its coolant and moderator.	A nuclear reactor is capable of generating more fissile material than it consumes.
2	PHWR running on natural Uranium have a conversion ratio of 0.8	The conversion ratio is higher than 1.
3	It is costly.	Its cost is comparatively less.

11 **Define the term “Breeding”.** BTL2

In a fast breeder reactor, the process of producing energy to self-sustain the nuclear fission chain reaction without using moderator is known as breeding. Enriched Uranium (U^{235}) or Plutonium is used as fuels which are surrounded by a thick blanket of fertile Uranium (U^{238}).

12 **Name the components of pressurized water reactor nuclear power plant**. BTL1

- Reactor
- Pressurizer
- Heat exchanger
- Coolant pump

13 **Classify the nuclear reactors.** BTL2

1.According to the neutrons energy.	**2.According to the fuel used**	**3.According to the type of coolant used**
➢ Fast reactors ➢ Intermediate or epithermal reactors ➢ Low energy or Thermal reactors	➢ Natural fuel reactor ➢ Enriched Uranium reactor	➢ Water cooled reactors ➢ Gas cooled reactors ➢ Liquid metal cooled reactors

4.According to the type of moderators used	**5.According to the construction of core**	
➢ Graphite moderator reactor ➢ Beryllium moderator reactor ➢ Water moderator reactor	➢ Cubical core reactor ➢ Cylindrical core reactor ➢ Spherical core reactor ➢ Annulus core reactor ➢ Slab core reactor	

14	**Write the safety measures of nuclear power plant**. BTL2 Nuclear safety and security cover the actions taken to prevent nuclear and radiation accidents or to limit their consequences. The main safety concern is the emission of uncontrolled radiation into the environment which could cause harm to human both at the reactor and off-site. The nuclear power industry has improved the safety and performance of reactors and it has proposed new and safer reactor designs.
15	**Write down the various types of fast breeders.** BTL2 ➢ GFR: Gas cooled Reactor system cooled with helium ➢ LFR: Lead fast Reactor cooled with lead or lead – bismuth eutectic ➢ MSR: Molten Salt Reactor Fueled with molten salts ➢ SFR: Sodium Fast Reactor ➢ SCWR: Super-Critical Water-cooled Reactor ➢ VHTR: Very High Temperature Reactor cooled with helium at 1000^oC at the core outlet for efficient production of hydrogen.
16	**List some of the disadvantages of Nuclear Power Plant.** BTL1 ➢ Similar to fossil fuels, nuclear fuels are non-renewable energy resources. ➢ If the accident occurs, large amounts of radioactive material could be released into the environment. ➢ Nuclear waste also remains radioactive and it is hazardous to health for thousands of years.
17	**Mention the function of nuclear reactor.** BTL2 A nuclear reactor is similar to the furnace of a steam power plant or combustion chamber of a gas turbine plant. In the nuclear reactor, heat is produced due to nuclear chain reaction.
18	**What is known as moderating ratio?** BTL2 Moderating ratio (also known as multiplication ratio or reproduction ratio) of the system is defined as the ratio of the number of neutrons in any particular generation to the total number of neutrons in the preceding generation. $K = \frac{\text{Number of neutrons in any particular generation}}{\text{Number of neutrons in the preceding generation}}$
19	**What is four factor formula?** BTL2 The four-factor formula is also known as Fermi's four factor formula used in nuclear engineering to determine the multiplication of a nuclear chain reaction in an infinite medium.
20	**What do you mean by mass defect?** BTL2 During the interaction of two or more particles to combine together, the total mass of the system will decrease and it will be less than the sum of the masses of the individual particles. The stronger the

interaction becomes and more the mass will decrease. It decreases the mass of the system called mass defect.

21 **What is known as binding energy?** BTL2

The energy released at the moment of combination of two nucleons to form nucleus of an atom is called binding energy.

PART*B

1. **Explain with a neat diagram the various parts of nuclear power plant and mention the function of each part. (13 M) AU DEC-2015** BTL2

Answer: Page: 3.4 - Anup Goel

Elements of Nuclear power plant: (3 M)

- Nuclear reactor
- Steam generator (Heat Exchanger)
- Steam turbine
- Steam Condenser
- Water and coolant feed pumps
- Electric generator

Diagram: (5 M)

Working: (5 M)

- The nuclear reactor works as a furnace that produces heat.
- The heat generated in the reactor by the nuclear fission is absorbed by the circulating coolant through the reactor core.
- The hot coolant leaving the reactor is passed to the heat exchanger.
- Steam is produced and is supplied to the turbine for expansion to produce work.

2. **(i) Explain CANDU reactor with neat sketch. Give its advantages and disadvantages. (8 M) AU DEC-2015** BTL2

Answer: Page: 3.9 - Anup Goel

Diagram: (3 M)

- Moderator – Heavy water
- Coolant – Heavy water
- Reflector – Heavy water
- Fuel – Natural Uranium

Explanation: (5 M)

- The Coolant heavy water is passed through the pressurized fuel tubes and then to the moderator heat exchanger through the primary circuit.
- The steam is generated first in moderator heat exchanger and then passed to the secondary heat exchanger to improve its quality.
- Control rods are not required because control can be achieved by controlling the flow of heavy water in primary circuit.

Advantages:

- Less cost.
- Very short time period for construction.

Disadvantages:

- Cost of heavy water is high.
- Low power density.

(ii)Explain what is chain reaction in connection with a nuclear reactor. (8 M) BTL4

Answer: Page: 3.2 - Anup Goel

Diagram: (3 M)

Explanation: (5 M)

- It mainly includes splitting and recombining of neutrons and producing sub elements of Uranium.
- The elements whose nucleus easily fusions is $_{92}U^{235}$
- All the other naturally available elements are stable and the nucleus of this cannot split easily.
- If the neutrons enter the nucleus of U^{235}, the nucleus splits into two sub elements and also releases two neutrons per fission.
- The obtained neutrons are having high velocity and to control this velocity, moderators are used.
- This process is continued step by step and product smaller fragments of Uranium by releasing large amount of heat energy.
- This heat energy is used for power generation in power plants.

PART*C

1. **Compare the working, merits and demerits of PWR and BWR. (15 M)** BTL4

Answer: Page: 3.6 - Anup Goel

PWR – Pressurized Water Reactor (8 M)

Diagram: (3 M)

Explanation: (3 M)

- PWR is a water cooled thermal reactor having special core design using natural and highly enriched fuel.
- Moderator – water
- Coolant – water
- Reflector – water
- Fuel – Uranium Oxide

Advantages: (1 M)

- Less quantity of control rods.
- Inspection and maintenance of the components used is easy.
- Reactor is compact in size.
- Power density is high.

Disadvantages: (1 M)

- Thermal efficiency of the plant is low.
- Fabrication of fuel element is costly.
- Requires strong pressure vessel in primary circuit so the capital cost is high.

BWR – Boiling Water Reactor (7 M)

Diagram: (3 M)

Explanation: (2 M)

- Moderator – water
- Coolant – water
- Reflector – water
- Fuel – Enriched Uranium

Advantages: (1 M)

- More stable than PWR.
- Lower pressure vessel can be used for reactor.
- Cost of BWR is also reduced compared to PWR.

Disadvantages: (1 M)

- Power density is 50% of PWR.

- Desired output cannot be achieved with a single pass circuit.

2. **(i)Discuss about the safety measures adopted in modern nuclear plants. (8 M)** BTL2

Answer: Page: 3.81 – Dr.G.K.Vijayaraghavan

Components of Nuclear Safety: (3 M)

- Technical Safety
- Human Factors and Organizational Safety
- Programmatic and cross-cutting Safety

Components of Technical Safety: (2 M)

- Knowledge on the nuclear technology
- Safety assessments of all changes and back fits are made during the life of the facility.
- Radiological protection program

Components of Human Factors and Organizational Safety: (2 M)

- Sufficient properly qualified, trained and fit-for-duty personnel
- Strong Cooperative management organization
- Facility management organization

Components of Programmatic and Cross-Cutting Safety: (1 M)

- Programmes such as fire protection and surveillance testing
- Programme of Operating experience analysis
- Ageing management programme

(ii)Explain the working of Gas Cooled Reactor (GCR) with a neat sketch. (8 M) BTL2

Answer: Page: 3.8 - Anup Goel

Diagram: (3 M)

Explanation: (3 M)

- Moderator – Graphite
- Coolant – Gases like air, helium, CO_2 and H_2.
- Reflector – water
- Fuel – Uranium Oxide

Types: (2 M)

- Gas cooled Graphite Moderator (GCGM) reactor – Uses Natural Uranium as fuel
- High Temperature Gas Cooled (HTGC) reactor – Uses highly enriched Uranium fuel graphite moderator

Advantages:

- Simple fuel processing.
- Less corrosion.

Disadvantages:

- Leakage of gas.
- Fuel loading is very costly.

	UNIT IV – POWER FROM RENEWABLE ENERGY
	Hydro Electric Power Plants – Classification, Typical Layout and associated components including Turbines. Principle, Construction and working of Wind, Tidal, *Solar* Photo Voltaic (SPV), Solar Thermal, Geo Thermal, Biogas and Fuel Cell power systems.
S.NO.	**PART*A**
1	**Mention the necessity of tall tower in horizontal axis wind turbine.** BTL2 ➢ To withstand the power house during heavy wind ➢ Supporting structure for energy house
2	**Write the advantages and disadvantages of hydropower plants.** BTL2 **Advantages:** ➢ There is no air pollution. ➢ Water is the renewable source of energy. It is neither consumed nor converted into something else. ➢ There is no problem of handling the fuel and ash. ➢ The running cost is low when compared to thermal or nuclear power stations. **Disadvantages:** ➢ Hydropower projects are capital-intensive with a low rate of return. ➢ Power generation is dependent on the quantity of water available which may vary season-to-season and year-to-year. ➢ Initial cost of the plant is high. ➢ It takes considerably long time for its installation as compared with thermal power plants.
3	**Define the function of surge tank in hydro plants.** BTL2 Surge tank is used to reduce the sudden rise of water in the penstock, stabilize the velocity and pressure in penstock and reduce water hammer effect.
4	**Classify the hydro-electric turbines with respect to high medium and low head**. BTL1 ➢ High head Turbine. ➢ Medium head Turbine. ➢ Low head Turbine.
5	**List the three main factors of power output of hydroelectric plant**. BTL1 ➢ Available head of water ➢ Speed of the turbine ➢ Pressure of the water flow
6	**Give the main parts of pelton wheel.** BTL1 ➢ Penstock ➢ Spear and nozzle ➢ Runner with buckets ➢ Break nozzle ➢ Outer casing ➢ Governing mechanism
7	**What is the function of spear & nozzle?** BTL2 The nozzle is used to convert the whole hydraulic energy into kinetic energy. Thus, the nozzle delivers the high-speed jet. To regulate the water flow through nozzle and to obtain a good jet of water, spear or nozzle is arranged.

8 **Define water hammer.** BTL2

If water is flowing through a channel and it is stopped abruptly i.e., its momentum is broken so a pressure surge or wave results, this effect produced is called water hammer.

9 **List the essential factors which should be considered while selecting a site for a hydroelectric power plant.** BTL1

- Water availability
- Water Storage
- Water head
- Geological investigations
- Environmental aspects
- Consideration of water pollution effects

10 **Name the basis of classification of turbines**. BTL1

The turbines are classified according to the following basis

- According to the action of the water flowing.
- According to the main direction of flow of water.
- According to head and quantity of water required.
- According to the specific speed.

11 **List the difference between Francis and Kaplan turbine**. BTL5

S.NO	FRANCIS TURBINE	KAPLAN TURBINE
1	Correct disposition of the guide and moving vanes is obtained at full load only.	Correct disposition of the guide and moving blades is obtained at any load.
2	System may have one or two servomotors depending on the size of the unit.	Two servomotors respective of the size of the unit always do governing.
3	Since the guide vanes are only controlled and high efficiency is obtained.	Both guide and runner vanes are controlled and high efficiency is obtained even at partial loads.
4	Servomotors are kept outside the turbine shaft.	Both servomotors are kept inside the hollow shaft of the turbine runner.

12 **Write the limitations of tidal power plant.** BTL1

- The tidal ranges are highly variable and therefore, turbines have to work on a wide range of head variation.
- Construction in sea is found difficult.
- The output is not uniform.
- More corrosion will occur due to corrosive sea water.
- Massive construction leads to more consumption to start the plant.

13 **List the components of Tidal power plants**. BTL1

- The dam or dyke
- Sluice ways

	➢ The power house
14	**Define fuel cell and state its advantages.** BTL4 A fuel cell is a device which uses hydrogen (or a hydrogen – rich fuel) and oxygen to create an electric current. In other words, it can be defined as an electrochemical device in which the chemical energy of a conventional fuel is converted directly and efficiently into low voltage direct current electrical energy. Advantages: ➢ Fuel cells have the potential to replace the internal combustion engine in vehicles. ➢ They can be used in transportation applications such as powering automobiles, buses, cycles and other vehicles. ➢ Many portable devices can be powered by fuel cells such as laptop computers and cell phones ➢ They can also be used for stationary applications such as providing electricity to power homes and businesses.
15	**What is geothermal energy?** BTL2 Geothermal energy is the heat energy from high pressure steam stored in deep earth. It is a renewable source of energy derived from the rain water in the earth heated to over 180^oC by subterranean hot rocks.
16	**Write the applications of geothermal energy.** BTL1 ➢ Generation of electric power ➢ Space heating for buildings ➢ Industrial process heat
17	**List the important criteria while selecting the geothermal energy**. BTL1 ➢ Temperature of geothermal fluid, ^{o}C ➢ Discharge rate, m^3 / day ➢ Useful life of production well, years ➢ Mineral contents gram / m^3
18	**Identify the different types of geothermal fluid and give its temperature range**. BTL1 ➢ Dry steam – Steam-turbine cycle ➢ Hot water, temperature > 180^oC – Steam – Turbine cycle ➢ Hot water, temperature > 150^oC – Binary – cycle ➢ Hot brine (pressurized) – Binary cycle ➢ Hot brine (flashed) – Special turbines, Impact turbines, Screw expander, Bladeless turbine
19	**What is Solar cell?** BTL2 A solar cell is a device which directly converts the energy of light into electrical energy through the process of photovoltaic effect.
20	**List down the performance factors in wind energy generators**. BTL2 ➢ Solidity ➢ Tip speed ratio ➢ Performance Coefficient ➢ Torque
	PART *B
1	**(i) Draw the schematic diagram of hydro plant and explain the operation. (7 M) AU DEC-2015** BTL2 **Answer: Page: 4.2 – Anup Goel** **Diagram: (3 M)** ➢ Hydroelectric power plant is a conventional renewable source of power generation.

- In hydroelectric power plants, kinetic (or potential) energy of water is converted into mechanical energy of the turbines which is further converted into electric energy.
- It is a clean and pollution free way of power generation.

Site selection for Hydroelectric Power plant: (2 M)

- Availability of water
- Storage of water
- Available head of water
- Distance from load centre
- Access of the site
- Type of land of the site

Essential Elements: (2 M)

- The catchment area
- The reservoir
- The dam
- Spillways
- Conduits
- Surge tanks
- Prime movers
- Draft tubes
- Power generation station

Advantages:

- No fuel charges.
- No stand by losses.
- Less supervising staff.

Disadvantages:

- It takes very long time for erection of such plants.
- Initial cost of installation is very high.

(ii) Write a short note on Bio energy. (8 M) AU DEC-2015 BTL2

Answer: Page: 4.190 - Dr.G.K.Vijayaraghavan

Diagram: (3 M)

The energy obtained from organic matter derived from biological organisms (plants and animals) is known as bioenergy.

Explanation: (3 M)

Sources of Biomass energy:

Rural applications of biomass energy

Urban and Industrial applications of biomass energy

Biomass as a primary source for large scale electrical power generation.

Advantages: (1 M)

- Renewable source.
- Reduce the problems of waste disposal.
- Pollutant emissions from combustion of biomass is low.

Disadvantages: (1 M)

- Low energy density.
- Labour intensive.
- Dispersed and land intensive source.

2. **(i)Briefly explain Solar PV system. (8 M) AU DEC-2015** BTL2

Answer: Page: 4.18 – Anup Goel

Diagram: (3 M)

Explanation: (3 M)

- Converts energy from solar radiation directly into electricity using semiconductor materials.
- No mechanical moving parts, so it lasts for decades and requires only minimal maintenance.
- Ranges from small-scale projects for lighting and pumping to large-scale projects for whole buildings and even utility-scale photovoltaic farms.

Working: (2 M)

- When light energy or photons strike a photovoltaic cell, electrons are knocked loose from a layer in the cell designed to give up electrons easily.
- The charge difference that is built into the cell pulls the loose electrons to another cell layer before they can recombine in their originating layer.
- This migration of electrons creates a charge between layers in the photovoltaic cell.
- Electrically connecting the positively and negatively charged layers of a photovoltaic cell through a load will produce electricity.
- This energy is converted through the inverter to be used by electrical machines, appliances, lights, and so on.

(ii)What are the various kinds of fuel cell and explain the working of anyone? (7 M)

AU DEC-2015 BTL2

Answer: Page: 4.245 - Dr.G.K.Vijayaraghavan

Types of Fuel cells: (3 M)

- Hydrogen-oxygen cell
- Polymer Electrolyte Membrane (PEM) fuel cell
- Direct Methanol fuel cell
- Alkaline fuel cell
- Phosphoric acid fuel cell
- Molten Carbonate fuel cell
- Solid Oxide fuel cell
- Regenerative fuel cell

Hydrogen – Oxygen cell: (4 M)

- Anode: Hydrogen
- Cathode: Oxygen
- Electrolyte: Water

<u>Reactions:</u>

Anode: $2H_2 + 4(OH)^- \Longrightarrow 4H_2O + 4e^-$

Cathode: $O_2 + 2H_2O + 4e^- \Longrightarrow 4(OH)^-$

$4KOH \Longrightarrow 4K^+ + 4(OH)^-$

Cell reaction: $2H_2 + O_2 \Longrightarrow 2H_2O$

<u>Two types:</u>

- Low temperature cell
- High pressure cell

3. **Explain the working of solar thermal power plant with a neat diagram. (13 M)** BTL2

Answer: Page: 4.13 – Anup Goel

Diagram: (4 M)

Explanation: (3 M)

Solar energy:

- The energy liberated from solar radiation is known as solar energy.
- If the electrical energy generated from solar energy by using solar collectors is known as

solar power plant.

Important components of Solar Power Plant: (3 M)

- Solar collector
- Heat exchanger
- Steam turbine
- Condenser
- Pump
- Cooling tower

Solar Collectors – Device for collecting solar radiation and transfers the energy to a fluid passing in it.

Types – Flat plate type, cylindrical parabolic collectors, Parabolloid collectors

Solar Ponds – It combines solar energy collection and sensible heat storage

Types of Solar power plant: (3 M)

- Low temperature solar power plant.
  - (a) Using solar pond.
  - (b) Using flat plate collector.
- Medium temperature solar power plant.
- High temperature solar power plant.

PART*C

1. **(i)Explain the construction and working of fuel cell also mention its merits and demerits. (8 M)** BTL2

Answer: Page: 4.238 - Dr.G.K.Vijayaraghavan

Principle: (1 M)

A fuel cell is an electromechanical device in which the chemical energy of a conventional fuel is directly converted and efficiently into low voltage DC electrical energy.

Diagram: (2 M)

Parts of a fuel cell: (3 M)

- **Membrane electrode assembly** – Electrodes, catalyst and polymer electrolyte membrane together form the membrane electrode assembly.
- **Anode** – Negative side of the fuel cell
- **Cathode** – Positive side of the fuel cell
- **Polymer Electrolyte membrane** – Specially treated material which looks similar to ordinary kitchen plastic wrap which conducts only positively charged ions and blocks electrons.
- **Catalyst**-All electromechanical reactions in the fuel cell consist of two separate reactions such as an oxidation half-reaction at the anode and a reduction half-reaction at the cathode.
- **Chemistry of a fuel cell** - Anode, cathode and cell reaction.
- **Hardware**-The backing layers, flow fields and current collectors are designed to maximize the current from a membrane/electrode assembly.

Major sections of Fuel Cell Power Plants:(2 M)

It consists of six major sections which are as follows:

- Fuel processing section
- Fuel cell power pack
- Power conditioning section
- Switchgear and supply section
- Control subsystem section
- Heating section

	(ii)List the advantages and disadvantages of Wind Energy system. (7 M) BTL2 **Answer: Page: 4.8 – Anup Goel** **Advantages: (3 M)** ➢ It is a renewable source of energy ➢ Wind power systems are non-polluting, so it has no influence on the environment ➢ Wind is economically free energy. ➢ The wind blows day and night, which allows windmills to produce electricity throughout the day. **Disadvantages: (4 M)** ➢ Wind energy available is not consistent and steady, fluctuating in nature. ➢ Wind energy requires expensive storage capacity because of its irregularity. ➢ Wind energy systems are noisy in operation; a large unit can be heard many kilometers away. ➢ Requires large open areas for setting up wind farms.
2	**Explain the working of tidal power plant with a neat diagram. (15 M)** BTL2 **Answer: Page: 4.19 – Anup Goel** **Diagram: (3 M)** Tidal power generators derive their energy from movement of the tides. **Explanation: (5 M)** **Types of Tides: (3 M)** ➢ High tide or flood tide: the highest level of tidal water ➢ Low tide or ebb tide: the lowest level of tidal water ➢ The difference between high and low tides is known as tidal range. ➢ The tidal range varies from season to season and location to location. ➢ The maximum tidal range occurs at the time of new moon called spring tide. **Types of Tidal Power Plant: (4 M)** (a)Single basin system or one-way system Components – Dam, Power house, Basin, Sluice ways The power house and turbine located between sea and basin (b)Double basin system or two-way system Components – Dam, Power house, Upper and lower basin, Sluice gate The system contains two basins between these two power house **Advantages:** Renewable source, Pollution free **Disadvantages:** Expensive to build, Barrage has environmental effects.

UNIT V ENERGY, ECONOMIC AND ENVIRONMENTAL ISSUES OF POWER PLANT

Power tariff types, Load distribution parameters, load curve, Comparison of site selection criteria, relative merits & demerits, Capital & Operating Cost of different power plants. Pollution control technologies including Waste Disposal Options for Coal and Nuclear Power Plants.

PART*A

Q.No.	Questions
1	**Define demand factor.** BTL2 Demand factor is the ratio of actual maximum demand of the system to the total connected demand of the system. Demand factor = Actual maximum demand / Total connected demand
2	**Define Load factor.** BTL2 Load factor is the ratio of average load over a given time interval to the peak load during the same time interval. Load factor = Average load over a given time interval / Peak load during the same time interval.
3	**Define demand for electricity.** BTL2 It is defined as the electricity requirement during the period of time of high price or more stress.
4	**Define diversity factor.** BTL2 Diversity factor is defined as the ratio of sum of the individual maximum demands to the actual peak load of the system. Diversity factor = Sum of individual maximum demand / Actual peak load of the system.
5	**What are the main factors that decide the economics of power plants?** BTL2 ➢ Connected load ➢ Demand ➢ Maximum demand ➢ Demand factor ➢ Load factor ➢ Capacity factor or plant capacity factor ➢ Utilisation factor ➢ Reserve factor ➢ Diversity factor ➢ Plant use factor
6	**What do you understand by load duration curves?** BTL2 Re-arrangement of all load elements of load curve is in the order of decreasing magnitude is called load duration curve.
7	**State the importance of load curves.** BTL2 ➢ To obtain the average load on the power station and the maximum demand of the power station ➢ To know the incoming load thereby helping to decide the installed capacity of the power station ➢ To decide the economical sizes of various generating units.

8	**What is the significance of load curve?** BTL2 The load curve gives full information about the incoming load and it helps to decide the installed capacity of the power station. It is also useful to decide the economical sizes of various generating units.
9	**What are the various types of load?** BTL2 ➢ Residential load ➢ Commercial load ➢ Industrial load ➢ Municipal load ➢ Irrigation load ➢ Traction load
10	**How does the fuel cost relate to the load and the cost of power generation?** BTL2 The cost of power generation is directly proportional to the fuel cost because the operating cost is directly linked with the fuel cost.
11	**What are fixed and operating costs?** BTL2 Fixed costs are the cost required for the installation of complete power plant. This cost includes the cost of land, buildings, equipment, transmission and distribution lines, cost of planning and designing the plant and many others. It also consists of interest, taxes, depreciation, insurance etc. Operating cost includes the cost of fuel, cost of lubricating oil, greases, cooling water, cost of maintenance and repairs, operating labour cost, supervision cost and taxes.
12	**Define flat rate tariff.** BTL2 The charging of amount depending only on the connected load and fixed number of hours of use per month or year is called flat tariff.
13	**List the types of tariffs to calculate energy rate.** BTL2 ➢ Flat demand rate ➢ Straight line meter rate ➢ Block-meter rate ➢ Hopkinson demand rate or two-part tariff ➢ Doherty rate or three part tariff
14	**How the tariff for electrical energy is arrived?** BTL2 Tariff is calculated by the following equation. $Z= ax + by + c$ Where, z- Total amount of bill for the period considered a- Rate per KW of maximum demand x- Maximum demand in KW b- Energy rate per KWh y- Energy consumed in KWh during the period considered c- Constant amount charged to the consumer during each billing period
15	**Mention any four methods for calculating depreciation.** BTL2 ➢ Straight line method ➢ Sinking fund method ➢ Diminishing value method ➢ Net percent value method ➢ Double sinking fund method
16	**List down the nuclear waste disposal methods.** BTL2 ➢ Disposal in sea ➢ Disposal in land

	➢ Disposal by reduction process through chemical reaction ➢ Disposal by solidification process
17	**What are the elements of fixed costs?** BTL2 ➢ Land, building and equipment cost ➢ Interest ➢ Depreciation cost
18	**What are the elements of operating costs?** BTL2 ➢ Cost of fuel ➢ Lubricating oil, grease and water cost ➢ Cost of maintenance and repairs ➢ Cost of operating labour ➢ Cost of supervision and ➢ Taxes
19	**What is the significance of two-part tariff and three-part tariff?** BTL2 **Two-part tariff:** This method of charging depends on the maximum demand and energy consumption. **Three-part tariff:** This method is proposed by Henry L. Doherty. In this method of charging, the consumer has to pay some fixed amount in addition to charges for maximum demand and energy consumed. The fixed amount to be charged depends on the occasional increase in price and wage charge of workers etc.
20	**Define depreciation**. BTL2 It is the amount to be set aside per year from income to meet the depreciation caused by the age of service, wear and tear of machinery.
	PART * B
1	**Explain the methods to control pollution in thermal and nuclear power plants. (13 M)** BTL2 **Answer: Page: 5.42 & 5.46 - Anup Goel** **Control of Thermal Pollution: (6 M)** The industrial heated waste water can be controlled by using following measure: ➢ **Use of cooling ponds:** Water is cooled by evaporation, convection and radiation. ➢ **Use of cooling towers:** Heat from the water is transferred to the atmosphere through evaporation. ➢ **Cogeneration:** Heat from the water is utilized for domestic or industrial heating purposes. ➢ Use of spray ponds and artificial lakes. **Control of Nuclear Pollution: (7 M)** ➢ The most reliable technique for disposal and long term storage of nuclear waste is vetrification. ➢ In this process, the waste is mixed with the glass forming chemicals in melter. ➢ After solidification the waste gets trapped inside the coating formed. ➢ The waste can be stored for long term in the containers free from air and water. ➢ The most long lived radioactive wastes including spent nuclear fuel must be isolated from humans and environment in deep underground. ➢ The liquid waste is reprocessed continuously. ➢ Gases waste from low level radioactive waste is filtered, compressed and stored to allow decay, diluted. ➢ They can be discharged at the regulated rate. ➢ Solid waste can be disposed off by placing it where it will not be disturbed for years.

2 **(i)Explain site selection criterion of hydro power plant. (6 M)** BTL2

Answer: Page: 4.2 - Anup Goel

The factors which can be considered for selection of site for a hydro-electric power plant are as follows:

- **Availability of water**: The design of Hydro-electric power plant and the amount of power generation depends upon the availability of water.
- **Storage of water**: Water is stored in the catchment area for continuous power generation.
- **Availability head of water:** To generate required quantity of power, the large quantity of water at sufficient head must be available.
- **Distance from the load centre:** The plant must be commissioned near the load centre which reduces the cost of erection and maintenance of transmission lines.
- **Access of the site:** The site of the plant should be easily accessible.
- **Type of land of the site:** The site should be rocky and the rock must be strong enough to carry the stresses from the dam structures and thrust of water when reservoir is full.

(ii)A peak load on the thermal power plant is 75 MW. The loads having maximum demands of 85 MW, 20 MW, 15 MW and 18 MW are connected to the power plant. The capacity of the plant is 90 MW and annual load factor is 0.53. Calculate the average load on power plant, energy supplied per year, demand factor and diversity factor. (8 M) BTL3

Answer: Page: 5.48 – Dr.G.K.Vijayaraghavan

Formula: (4 M)

Solution: (4 M)

Load factor = Average load / Peak load

Average load = 0.53 * 75 = 39.75 MW

Energy supplied per year = Average load * 24 * 365

= 39.75 * 8760

= 348210 MWh

Demand factor = Maximum demand / Connected load

= 75 / (35+20+15+18)

= 0.852

Diversity factor = Sum of the individual maximum demand / Annual peak load of the system

= (35 + 20 +15 + 18)/ 75

= 1.173

3. (i)**Explain the analysis of pollution from thermal power plants. (6 M)** BTL4

Answer: Page: 5.45 - Anup Goel

The thermal pollution of water refers to the degradation of the water quality due to increase in its temperature.

Sources of Thermal pollution: (2 M)

- Nuclear power plants
- Thermal power plants
- Industrial effluents
- Domestic sewage
- Hydro-electric power plants
- Human activities

Effects of Thermal pollution: (2 M)

- Reduction in dissolved oxygen
- Increase in toxicity of water
- Interference in biological activities of aquatic life such as metabolism, biochemical

processes.
- Interference in reproduction of aquatic life.
- Responsible for extinction of aquatic species.
- Responsible for food shortage for fish.

Control of Thermal Pollution: (2 M)

The industrial heated waste water can be controlled by using following measure:
- Use of cooling ponds: Water is cooled by evaporation, convection and radiation.
- Use of cooling towers: Heat from the water is transferred to the atmosphere through evaporation.
- Cogeneration: Heat from the water is utilized for domestic or industrial heating purposes.
- Use of spray ponds and artificial lakes.

(ii)Elucidate the objectives and requirements to tariff and general form of tariff. (7 M)

Answer: Page: 5.10 - Anup Goel

The different methods of charging the consumers for electricity consumption is known as “Tariffs” or “Energy Rates”.

Objective: (1 M)

The electricity generated by the power plants is to be supplied to consumers. There-fore the total cost of generation has to be recovered from the consumers.

General Tariff form:(4 M)

Z= ax + by + c

Where, z- Total amount of bill for the period considered
c- Rate per KW of maximum demand
x- Maximum demand in KW
d- Energy rate per KWh
y- Energy consumed in KWh during the period considered
c- Constant amount charged to the consumer during each billing period

Types: (2 M)

Flat demand rate, Straight meter rate, Block meter rate, Hopkinson demand rate (two part tariff), Doherty rate (three part tariff), Wright demand rate.

PART*C

1. **(i)Write short note on Nuclear Waste disposal. (7 M)** BTL2

Answer: Page: 5.42 - Anup Goel

The nuclear power plant has an impact on surrounding environment from nuclear waste which comes from a number of sources.

These sources are as follows: (3 M)
- Nuclear explosions performed while conducting nuclear tests.
- Operations performed by nuclear power plant produce radioactive waste.
- Mining and refining radioactive materials such as uranium and thorium.
- Nuclear fuel cycle used in industrial, medical and scientific processes.

Radioactive waste: **(2 M)**

Includes high level and low level waste.

Radioactive Emission: **(2 M)**

Consists of the radiation from the radioactive sources such as nuclear weapons, handled radioactive material, nuclear accidents.

(ii)A central power station has annual factors as follows. Load factor = 60%, Capacity factor = 40% and Use factor = 45%. Power station has a maximum demand of 15000 KW. Determine annual energy production, reserve capacity over and above load and hours per year not in service. (8 M) BTL3

Answer: Page: 5.38 - Anup Goel

Formula: (4 M)

Solution: (4 M)

Load Factor = 60 % = 0.6
Capacity Factor = 40 % = 0.4
Use factor = 45 % = 0.45
Maximum demand = 15000 KW
Average load = Maximum demand * Load Factor
= 15000 * 0.6 = 9000 KW
Energy produced per year = Average load * 365 * 24
= 9000 * 365 * 24
= 78.84 * 10^6 kWhr
Reverse Capacity over and above peak load
Capacity factor = Average load / Installed capacity
Installed capacity = 9000 / 0.4 = 22500 Kw
Reverse capacity = Installed capacity – Maximum demand
= 22500 – 15000
= 7500 Kw

2. **List various pollutants released by the coal based thermal power plants and detail the techniques adopted to mitigate them. (15 M)** BTL2

Answer: Page: 5.39 - Anup Goel

Explanation: (5 M)

The burning of coal in thermal power plant produces number of pollutants. They are as follows:

- Carbon dioxide (CO_2)
- Sulphur dioxide (SO_2)
- Nitrogen Oxides (NO_x)
- Ash
- Particulate matter

Control of Particulate matter: (3 M)

The solid particulate matter can be separated from the gases by using settling chamber or a cyclone collector.

Control of SO_2: (4 M)

- Use of scrubbers.
- Reducing Sulphur content from the fuel.
- Froth floatation Process.
- Use of Fluidized Bed Combustion (FBC).
- Integrated Gasification Combined Cycle (IGCC).

Control of Nitrogen Oxides (NO_x): (3 M)

- By altering temperature and oxygen content.
- Modifying combustion process.
- Converting NO_x to N_2 Using any reducing agent or catalyst such as platinum – rhodium, ammonia etc.

3. **(i) Discuss any four methods adopted for the disposal of radioactive waste materials. (7 M)** BTL2

Answer: Page: 5.42 - Anup Goel

Explanation: (3 M)

- Radioactive waste – Includes high level and low level waste
- High level waste consists of irritated spent fuel at reactor site including fission products and plutonium waste.
- Low level waste is produced through chemical and volume control system. This includes gaseous, liquid and solid waste.

Techniques for the disposal of radioactive waste materials: (4 M)

- The most reliable technique for disposal and long term storage of nuclear waste is vetrification.
- In this process, the waste is mixed with the glass forming chemicals in melter.
- After solidification the waste gets trapped inside the coating formed.
- The waste can be stored for long term in the containers free from air and water.
- The most long lived radioactive wastes including spent nuclear fuel must be isolated from humans and environment in deep underground.
- The liquid waste is reprocessed continuously.
- Gases waste from low level radioactive waste is filtered, compressed and stored to allow decay, diluted.
- They can be discharged at the regulated rate.
- Solid waste can be disposed off by placing it where it will not be disturbed for years.

(ii)A generating station supplies four feeders with maximum demands (in MW) 16, 10, 12 and 7. The overall maximum demand of the station is 20 MW and the annual load factor is 45%. Calculate the diversity factor and number of units generated annually. (8 M) BTL3

Formula: (4 M)

Solution: (4 M)

Diversity factor = sum of the individual maximum demand / peak load of the system
= (16+10+12+7) / 20
= 2.75

Load factor = Average load / Peak load

Average load = 0.45 * 20 = 9 MW

Number of units generated annually = Average load * 24 * 365
= 9 * 24 * 365 = 78840 MWh

REGULATION :2013 **ACADEMIC YEAR : 2018-2019**

IC6501 **CONTROL SYSTEMS** **L T P C**

2 2 0 3

OBJECTIVES:

- To understand the use of transfer function models for analysis physical systems and introduce the control system components.
- To provide adequate knowledge in the time response of systems and steady state error analysis.
- To accord basic knowledge in obtaining the open loop and closed–loop frequency responses of systems.
- To introduce stability analysis and design of compensators.
- To introduce state variable representation of physical systems and study the effect of state feedback.

UNIT I SYSTEMS AND THEIR REPRESENTATION **9**

Basic elements in control systems – Open and closed loop systems – Electrical analogy of mechanical and thermal systems – Transfer function – Synchros – AC and DC servomotors – Block diagram reduction techniques – Signal flow graphs.

UNIT II TIME RESPONSE **9**

Time response – Time domain specifications – Types of test input – I and II order system response – Error coefficients – Generalized error series – Steady state error – Root locus construction- Effects of P, PI, PID modes of feedback control –Time response analysis.

UNIT III FREQUENCY RESPONSE **9**

Frequency response – Bode plot – Polar plot – Determination of closed loop response from open loop response - Correlation between frequency domain and time domain specifications- Effect of Lag, lead and lag-lead compensation on frequency response- Analysis.

UNIT IV STABILITY AND COMPENSATOR DESIGN **9**

Characteristics equation – Routh Hurwitz criterion – Nyquist stability criterion- Performance criteria – Lag, lead and lag-lead networks – Lag/Lead compensator design using bode plots.

UNIT V STATE VARIABLE ANALYSIS **9**

Concept of state variables – State models for linear and time invariant Systems – Solution of state and output equation in controllable canonical form – Concepts of controllability and observability – Effect of state feedback.

TOTAL (L:45+T:15): 60 PERIODS

OUTCOMES:

Ability to understand and apply basic science, circuit theory, theory control theory Signal processing and apply them to electrical engineering problems.

TEXT BOOKS:

1. M. Gopal, 'Control Systems, Principles and Design', 4 th Edition, Tata McGraw Hill, New Delhi, 2012
2. S.K.Bhattacharya, Control System Engineering, 3rd Edition, Pearson, 2013.
3. Dhanesh. N. Manik, Control System, Cengage Learning, 2012.

REFERENCES:

1. Arthur, G.O.Mutambara, Design and Analysis of Control; Systems, CRC Press, 2009.
2. Richard C. Dorf and Robert H. Bishop, " Modern Control Systems", Pearson Prentice Hall, 2012.
3. Benjamin C. Kuo, Automatic Control systems, 7th Edition, PHI, 2010.

4. K. Ogata, ‘Modern Control Engineering’, 5th edition, PHI, 2012.
5. S.N.Sivanandam, S.N.Deepa, Control System Engineering using Mat Lab, 2 nd Edition, Vikas Publishing, 2012.
6. S.Palani, Anoop. K.Jairath, Automatic Control Systems including Mat Lab, Vijay Nicole/ Mcgraw Hill Education, 2013.

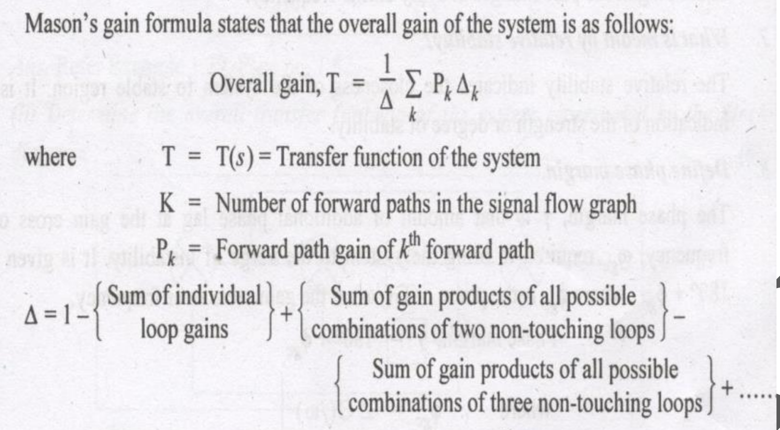
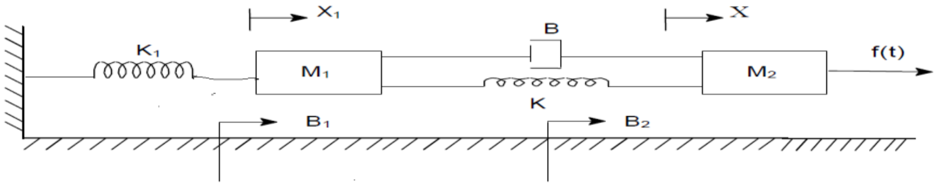
Subject Code : IC 6501 **Year/Sem : III/05**
Subject Name : Control Systems **Subject Handler : Mrs. L. Pattathurani**

<table>
<tr><th colspan="2">UNIT I SYSTEMS AND THEIR REPRESENTATION</th></tr>
<tr><td colspan="2">Basic elements in control systems – Open and closed loop systems – Electrical analogy of mechanical and thermal systems – Transfer function – Synchros – AC and DC servomotors – Block diagram reduction techniques – Signal flow graphs.</td></tr>
<tr><td colspan="2">PART * A</td></tr>
<tr><td>Q.No.</td><td>Questions</td></tr>
<tr><td>1.</td><td>Name any two dynamic models used to represent control systems. (May/June 2013) BTL1
➢ Distributed parameter and Lumped parameter models.
➢ Time varying and time invariant models.
➢ Stochastic and deterministic models.
➢ Non-linear and linear models</td></tr>
<tr><td>2.</td><td>Define transfer function.(Nov/Dec 2010,13) BTL1
The transfer function of a system is defined as the ratio of Laplace transform of output to Laplace transform of input with zero initial conditions.</td></tr>
<tr><td>3.</td><td>Define resistance and capacitance of liquid level system.(Nov/Dec 2013) BTL2
➢ Resistance is a flow of liquid which occurs of a liquid flowing through valves or change in pipe diameter.
➢ Capacitance is the term used to describe energy storage with a liquid where it is stored in the form of potential energy.</td></tr>
<tr><td>4.</td><td>What are the characteristics of negative feedback?(May/June 2014) BTL3
The characteristics of negative feedback are as follows
➢ Accuracy in tracking steady state value.
➢ Rejection of disturbance signals.
➢ Low sensitivity to parameter variations.
➢ Reduction in gain at the expense of better stability.</td></tr>
<tr><td>5.</td><td>Differentiate open loop and closed loop system.(Nov/Dec 2010,14, April/May 2010) BTL4
<table>
<tr><th>S.NO</th><th>Open loop</th><th>Closed loop</th></tr>
<tr><td>1.</td><td>Inaccurate and unreliable</td><td>Accurate and reliable</td></tr>
</table>
</td></tr>
</table>

2.	Simple and economical	Complex and costly
3.	Changes in output due to external disturbances are not corrected automatically	Changes in output due to external disturbances are corrected automatically
4.	They are generally stable	Great efforts are needed to design a stable system

6.	**What is electrical zero position of a synchro transmitter? (May/June 2015)** BTL2 Electrical is the reference point for alignment of all synchro units. The mechanical reference point for the units connected to the synchros depends upon the particular application of the synchro system.
7.	**List the advantages of closed loop system.(Nov/Dec 2015, May/June 2012)** BTL1 ➢ Closed loop systems are accurate and reliable. ➢ Changes in output due to external disturbances are corrected automatically.
8.	**What is Block diagram? What are its basic components? (May 17, Nov/Dec 2015, Nov 11)** BTL2 A block diagram of a system is a pictorial representation of the functions performed by each components of the system and shows the flow of signals. The basic elements of the block diagram are blocks, branch points and summing points.
9.	**Define open loops and closed loop control system.(April/May2011, Nov/Dec 11)** BTL1 The control systems in which the output quantity has no effect upon the input quantity are called open loop control system. This means that the output is not feedback to the input for correction. The control systems in which the output quantity has an effect upon the input quantity in order to maintain the desired output value are called closed loop control system.
10.	**What are the advantages of open loop control system?(Nov/Dec 2012)** BTL1 ➢ Simple and economical ➢ Stable system
11.	**What are the properties of signal flow graph? (May/June 2012)** BTL1 The basic properties of signal flow graph are ➢ Signal flow graph is applicable to linear systems. ➢ It consists of nodes and branches. A node is a point representing a variable or signal. A branch indicates functional dependence of one signal to other. ➢ A node adds the signals of all incoming branches and transmits this sum to all other

	branches. ➢ Signals travel along branches only in the marked direction and when it travels it gets multiplied by the gain or transmittance of the branch. ➢ The algebraic equations must be in the form of cause and effect relationship.
12.	**Why negative feedback is preferred in control system?(May 17, Nov/Dec 2016)** BTL2 The negative feedback results in better stability in steady state and rejects any disturbance signals. It also has low sensitivity to parameter variations. Hence negative feedback is preferred in closed loop control system.
13.	**What are the differences between synchro transmitter and synchro control transformer?(Nov/Dec 2016)** BTL4 ➢ Rotor of synchro transmitter is of dumb bell shape. But rotor of control transformer is cylindrical. ➢ The rotor winding of synchro transmitter is excited by an AC voltage. In control transformer, the induced emf in the rotor is used as an output signal (error signal).
14.	**Give practical example of open loop systems. (Dec 11)** BTL2 The practical examples of open loop control systems are, sprinkler used to water a lawn, automatic toaster, traffic light controller, automatic door opening and closing system.
15.	**Give practical example of closed loop systems. (Dec 11)** BTL2 The practical examples of closed loop control systems are, human being, home heating system, speed control systems, ship stabilization system, missile launching system, voltage stabilizer, temperature control systems.
16.	**Name three functional components used in control system. (May 03, Dec 14)** BTL2 The three functional components used in control systems are: ➢ Error detectors ➢ Controller ➢ Feedback
17.	**State Mason's Gain formula. (APRIL/MAY 15 and Repeated question, will be there in all AU question papers)** BTL1

	 Mason's gain formula states that the overall gain of the system is as follows: $\text{Overall gain, } T = \frac{1}{\Delta}\sum_k P_k \Delta_k$ where T = T(s) = Transfer function of the system K = Number of forward paths in the signal flow graph P_k = Forward path gain of k^{th} forward path $\Delta = 1 - \left\{\begin{matrix}\text{Sum of individual}\\ \text{loop gains}\end{matrix}\right\} + \left\{\begin{matrix}\text{Sum of gain products of all possible}\\ \text{combinations of two non-touching loops}\end{matrix}\right\} - \left\{\begin{matrix}\text{Sum of gain products of all possible}\\ \text{combinations of three non-touching loops}\end{matrix}\right\} + ...$ $\Delta_k = \Delta$ for that part of the graph which is not touching k^{th} forward path.
18.	**Write the analogous electrical elements in force voltage analogy for the elements of mechanical translational system.** BTL3 ➢ Force-voltage e ➢ Velocity v-current i ➢ Displacement x-charge q ➢ Frictional coefficient B-Resistance R ➢ Mass M- Inductance L ➢ Stiffness K-Inverse of capacitance 1/C
19.	**Write the analogous electrical elements in force current analogy for the elements of mechanical translational system.** BTL3 ➢ Force-current i ➢ Velocity v-voltage v ➢ Displacement x-flux φ ➢ Frictional coefficient B-conductance 1/R ➢ Mass M- capacitance C ➢ Stiffness K-Inverse of inductance 1/L
20.	**Write the force balance equation of an ideal mass, dashpot and spring element.** BTL2 ➢ $F = M\, d^2x/dt^2$ for mass element ➢ $F = B\, dx/dt$ for dash pot element ➢ $F = kx$ for spring element
	PART * B
1.	**Write the differential equations governing the mechanical translational system shown in the figure. Draw the electrical equivalent analogy circuits. (13M)** BTL3 

Answer : Page 1.29 – Nagoor Kani

- **Draw free body diagram (2M)**
- ✓ Mechanical translational system can be obtained using three basic elements Mass (M), Spring (K), Damper (B).
- ✓ $F = M\, d^2x/dt^2$ for mass element
- ✓ F = B dx/dt for dash pot element
- ✓ F = kx for spring element
- **Write differential equations (2M)**

$$M1\frac{d^2x1}{dt^2} + B1\frac{dx1}{dt} + B\frac{d}{dt}(x1 - x) + K1x1 + k(x1 - x) = 0$$

$$M2\frac{d^2x}{dt^2} + B2\frac{dx}{dt} + B\frac{d}{dt}(x - x1) + k(x - x1) = f(t)$$

- **Write rule for force voltage and force current analogy (3M)**
- ✓ Force voltage: M→L ; K→1/C ; B→R; velocity→I
- ✓ Force current: M→C; K→1/L; B→1/R
- **Draw electrical circuit equivalent to mechanical system (6M)**
- ✓ Write electrical equations using KVL and KCL.

2. **With its operating principle derive the transfer function of AC servo motor in control system. (13M)** BTL4

Answer : Page 48 – Lecture Notes

- **Definition of Servomotor (2M)**
- ✓ Motors are used for feedback control systems are called servomotors also called automatic control system.
- ✓ Converts electrical system into angular motion.
- ✓ 2 types: DC servomotor and AC servomotor.
- **Definition of AC Servomotor (3M)**
- ✓ Motors which runs at zero speed as its base speed is driven by error signal with AC supply called servomotor.
- ✓ Used in closed loop servo systems, high speed instrument servos, and low power applications.

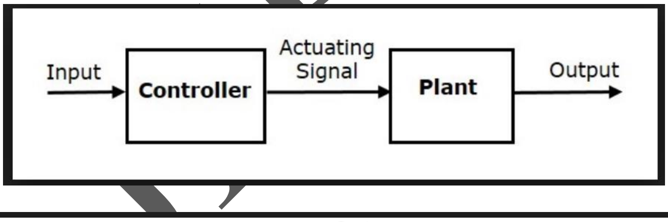
- ✓ Speed control done using armature voltage control and field control.
- ➢ **Operating principle of AC Servomotor (4M)**
- ✓ Salient features include rugged construction, Reliable in operation, Light Weight and No Slip rings.
- ➢ **Transfer function derivation (4M)**
- ✓ **$\Theta(s)/Vc2(s)=Km/s(1+st_m)$**

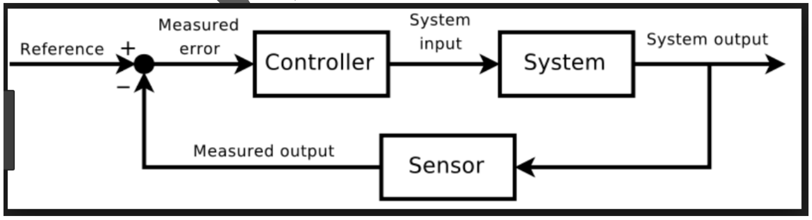
3.

Compare open and closed loop systems. (13M) (BTL4)

Answer : Page 1.29 – Nagoor Kani

- ➢ **Definition of open and closed loop systems (3M)**
- ✓ **Open loop:** any physical system does not automatically correct the variation in its output called open loop system.
- ✓ **Closed loop:** A system in which control action somehow dependent on the output.
- ✓ Output feedback to the feedback element and compared with the reference signal.
- ➢ **Block diagram of open and closed loop systems (4M)**





- ➢ **Advantages of open and closed loop systems (2M)**

Open loop:

- ✓ Simple and economical
- ✓ Easier to construct
- ✓ Less Stable

Closed loop:

- ✓ Accurate
- ✓ More stable
- ✓ Less noise affected

➢ **Disadvantages of open and closed loop systems (2M)**

Open loop

- ✓ Inaccurate
- ✓ Unreliable
- ✓ Cannot correct automatically

Closed loop:

- ✓ Complex and costly
- ✓ Oscillatory response
- ✓ Overall gain reduced

➢ **Applications of open and closed loop systems (2M)**

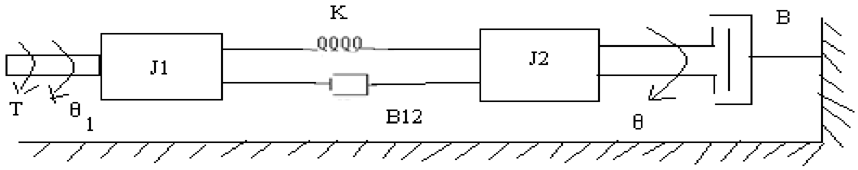
Open loop:

- ✓ Electric switch
- ✓ Automatic washing machine
- ✓ Electric toaster

Closed loop:

- ✓ Traffic light control
- ✓ Liquid level control
- ✓ Temperature level control

4. **Write the differential equations governing the mechanical rotational system as shown in the figure. Draw the both electrical analogous circuits. (13M) (Apr/May 2017)** BTL3



Answer : Page 1.46 – Nagoor Kani

- ➢ **Draw free body diagram (4M)**
- ✓ Mechanical Rotational system can be obtained using three basic elements Moment of Inertia (J), Spring (K), Damper (B).
- ✓ F = M $d^2\theta/dt^2$ for mass element
- ✓ F = B d θ /dt for dash pot element
- ✓ F = k θ for spring element
- ➢ **Write differential equations (2M)**

$$J1\frac{d^2\theta 1}{dt^2}+B1\frac{d(\theta 1-\theta 2)}{dt}+K1(\theta 1-\theta 2)=T$$

$$J2\frac{d^2\theta 2}{dt^2}+B1\frac{d(\theta 2-\theta 1)}{dt}+K1(\theta 2-\theta 1)+B2\frac{d(\theta 2-\theta 3)}{dt}=0$$

$$J3\frac{d^2\theta 3}{dt^2}+B2\frac{d(\theta 3-\theta 2)}{dt}+K2(\theta 3-\theta 2)=0$$

- ➢ **Write rule for torque voltage and torque current analogy (3M)**
- ✓ **Torque-voltage rule:**
  1. Angular Velocity v-current i
  2. Angular Displacement x-charge q
  3. Frictional coefficient F-Resistance R
  4. Mass J- Inductance L
  5. Stiffness K-Inverse of capacitance 1/C
- ✓ **Torque -current rule:**
  1. Angular Velocity v-voltage v
  2. Angular Displacement x-flux φ
  3. Frictional coefficient F conductance 1/R
  4. Mass J- capacitance C
  5. Stiffness K-Inverse of inductance 1/L
- ➢ **Draw electrical circuit equivalent to mechanical system (4M)**

5.

Differentiate DC and AC servo motors (or) With neat diagrams, explain the working of AC and DC servomotors. (13M) (Nov/Dec 2014) BTL4

Answer : Page 44,48 – Lecture Notes

- ➢ **Definition of Servomotor (3M)**
- ✓ Motors are used for feedback control systems are called servomotors, also called automatic control system.
- ✓ Converts electrical system into angular motion
- ✓ 2 types: DC servomotor and AC servomotor
- ➢ **Definition of AC Servomotor & DC Servomotor ,Block diagram of AC & DC**

Servomotor (4M)

- ✓ Motors which runs at zero speed as its base speed is driven by error signal with AC supply is called servomotor.
- ✓ Used in closed loop servo systems, high speed instrument servos, and low power applications.
- ✓ Speed control done using armature voltage control and field control.
- ➢ **Operating principle of AC & DC Servomotor (4M)**
- ✓ Salient features include rugged construction, Reliable in operation, Light Weight and No Slip rings.
- ➢ **Applications of AC & DC Servomotor (2M)**
- ✓ **DC:**

1.Large power applications

2.Robotics

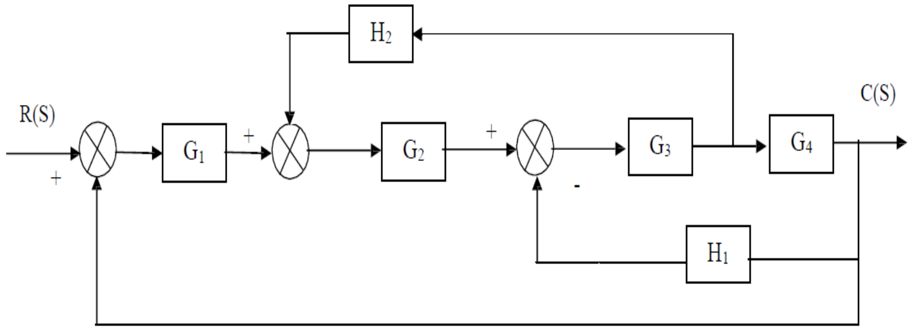
- ✓ **AC:**

1.Solar Tracking System

2.Antenna Positioning

3.Robotic Vehicle

6\. **Convert the given block diagram shown in fig. to signal flow graph and determine the closed loop transfer function C(s)/R(s).And also verify by block diagram reduction approach. (13M)** BTL4



Answer : Page 1.56 – Nagoor Kani

- ➢ **Draw signal flow graph.**

- **Give number to input, output, summing point and branching point (2M)**
- **Apply block diagram reduction rules to find transfer function (6M)**

✓ Reduce series blocks.

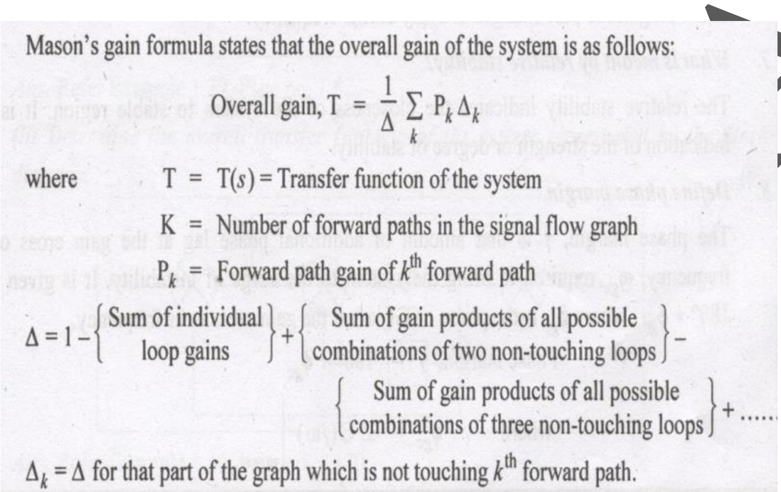
✓ Reduce parallel blocks.

✓ Reduce minor feedback loops.

✓ Shift summing point to left and take-off point to right.

✓ Splitting the summing points.

- **Apply Masons gain formula (2M)**



Mason's gain formula states that the overall gain of the system is as follows:

$$\text{Overall gain, } T = \frac{1}{\Delta}\sum_k P_k \Delta_k$$

where T = T(s) = Transfer function of the system

K = Number of forward paths in the signal flow graph

P_k = Forward path gain of k^{th} forward path

$$\Delta = 1 - \left\{\begin{matrix}\text{Sum of individual}\\ \text{loop gains}\end{matrix}\right\} + \left\{\begin{matrix}\text{Sum of gain products of all possible}\\ \text{combinations of two non-touching loops}\end{matrix}\right\} - \left\{\begin{matrix}\text{Sum of gain products of all possible}\\ \text{combinations of three non-touching loops}\end{matrix}\right\} + \ldots\ldots$$

$\Delta_k = \Delta$ for that part of the graph which is not touching k^{th} forward path.

- **Find transfer function (3M)**

C(s)/R(s)= G1G2G3G4/(1+G3G4H1+G2G3H2+G1G2G3G4)

7.

Derive the transfer function of an armature controlled DC motor (or) Obtain the mathematical model of an armature controlled DC motor. (13M) (Nov/Dec 2016) BTL3

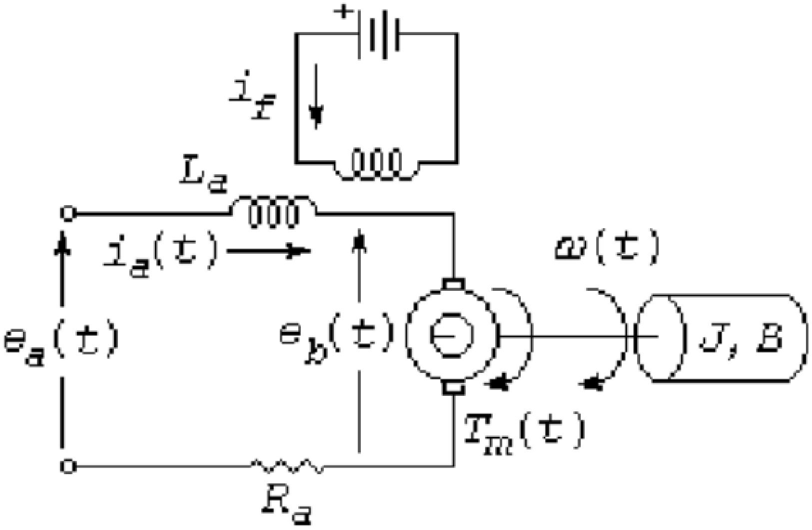
Answer : Page 1.21 – Nagoor Kani

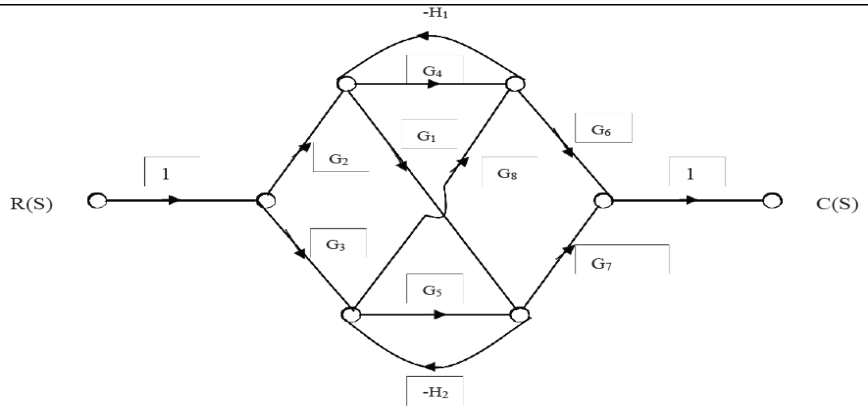
- **Explain speed control techniques (2M)**

✓ Armature control method

✓ Field control method

- **Draw equivalent circuit diagram (2M)**

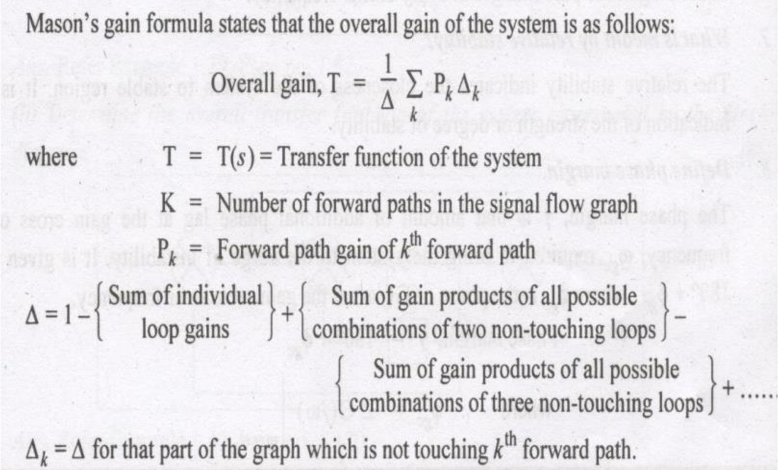
	 ➢ **Derive differential equation (4M)** $Va = i_aR_a + L_a\frac{di_a}{dt} + e_b$ $T = J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt}$ ➢ **Laplace transform (2M)** $i_a(s)R_a + L_asi_a(s) + E_b(s) = V_a(s)$ $Js^2\theta(s) + Bs\theta(s) = T(s)$ ➢ **Find transfer function (3M)** $\frac{\theta(s)}{V_a(s)} = \frac{K_m}{s\cdot\left[\left(R_a + L_a\cdot s\right)(J\cdot s + b) + K_b\cdot K_m\right]}$
8.	**Obtain the transfer function using Mason's Gain formula for the system given. (13M) (Apr/May 2017).**(BTL3)



Answer : Page 1.79 – Nagoor Kani

- **Give number to all nodes(2M)**
- **Find No.of forward paths and individual loop gain (3M)**
  - ✓ No of forward path ,K=6

    Forward path gain:
  - ✓ P1=G2G4G6
  - ✓ P2=G3G5G7
  - ✓ P3=G1G2G7
  - ✓ P4=G3G8G6
  - ✓ P5=-G1G3G7G8H1
  - ✓ P6=-G1G2G6G8H2
- **Calculate value of delta (3M)**
  - ✓ Δ=1+G4H1+G5H2+-G1G2H1H2+G4G4H1H2
- **Apply Masons gain formula (2M)**



Mason's gain formula states that the overall gain of the system is as follows:

$$\text{Overall gain, } T = \frac{1}{\Delta}\sum_{k} P_k \Delta_k$$

where T = T(s) = Transfer function of the system

K = Number of forward paths in the signal flow graph

P_k = Forward path gain of k^{th} forward path

$$\Delta = 1 - \left\{\begin{array}{c}\text{Sum of individual}\\ \text{loop gains}\end{array}\right\} + \left\{\begin{array}{c}\text{Sum of gain products of all possible}\\ \text{combinations of two non-touching loops}\end{array}\right\} - \left\{\begin{array}{c}\text{Sum of gain products of all possible}\\ \text{combinations of three non-touching loops}\end{array}\right\} + \ldots\ldots$$

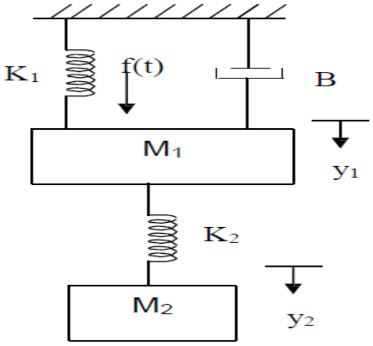
$\Delta_k = \Delta$ for that part of the graph which is not touching k^{th} forward path.

- **Find transfer function (3M)**

C(s)/R(s)= -G1G3G7G8H1-G1G2G6G8H2/(1+G4H1+G5H2-G1H8H1H2+G4G5H1H2)

9.

Write the differential equation for the electric circuit as shown in fig. hence find Y_2(s)/F(s). (13M) (Nov/Dec 2016). BTL2



Answer : Page 1.10 – Nagoor Kani

- **Draw free body diagram of mass M1 &M2 (3M)**
- **Write differential equations in terms of displacement (4M)**

$$M1\frac{d^2y1}{dt^2} + B1\frac{dy1}{dt} + K1y1 + K2(y1 - y2) = f(t)$$

$$M2\frac{d^2y2}{dt^2} + K2(y2 - y1) = 0$$

- **Laplace transform (3M)**

✓ $M1s^2y1(S)+Bsy1(s)+K1y1(s)+K2(y1(s)-y2(s))=F(s)$

- ✓ $M2\ s^2Y2(s)+K2(y2(s)-y1(s))=0$

- ➢ **Rearrange equation and find transfer function (3M)**

- ✓ $Y2(s)/F(s)=K_2/[M_1s^2+Bs+(K1+K2)][M_2s^2+K2]-k_2^2$

PART * C

1. **What are the basic elements of mechanical rotational and translational systems? Write its torque balance and force balance equations. (15M) (May/June 2016).**BTL3

Answer : Page 1.15 – Nagoor Kani

- ➢ **Elements of mechanical system (2M)**

  a)Mass(M), Dashpot(B), Spring(K)

  b) Moment of inertia (J), Dashpot(F), Spring(K)

- ➢ **Draw the free body diagram (2M)**

- ➢ **Apply Newton's second law (1M)**

- ✓ The **second law** states that acceleration of an object is dependent upon two variables, net force acting upon the object and the mass of the object.

- ➢ **Write differential equations (2M)**

- ✓ $F(t)= M\ d^2\theta/dt^2\ {}^{+}B\ d\theta/dt+k\theta$

- ✓ $T(t)= M\ d^2\theta/dt^2\ {}^{+}B\ d\theta/dt+ k\theta$

- ➢ **Force balance equation of translational system (4M)**

- ✓ $F = M\ d^2x/dt^2$ for mass element
- ✓ $F = B\ dx/dt$ for dash pot element
- ✓ $F = kx$ for spring element

- ✓ **Force-voltage rule:**
  1. Velocity v-current i
  2. Displacement x-charge q
  3. Frictional coefficient F-Resistance R
  4. Mass M- Inductance L
  5. Stiffness K-Inverse of capacitance 1/C
- ✓ **Force -current rule:**
  1. Velocity v-voltage v
  2. Displacement x-flux φ
  3. Frictional coefficient F conductance 1/R
  4. Mass M- capacitance C
  5. Stiffness K-Inverse of capacitance 1/L

- **Torque balance equation of rotational system (4M)**

1. Mechanical Rotational system can be obtained using three basic elements Moment of Inertia (J), Spring (K), Damper (B).
2. $F = M\, d^2\theta/dt^2$ for mass element
3. $F = B\, d\,\theta\,/dt$ for dash pot element
4. $F = k\,\theta$ for spring element

✓ **Torque-voltage rule:**

1. Angular Velocity v-current i
2. Angular Displacement x-charge q
3. Frictional coefficient F-Resistance R
4. Mass J- Inductance L
5. Stiffness K-Inverse of capacitance 1/C

✓ **Torque -current rule:**

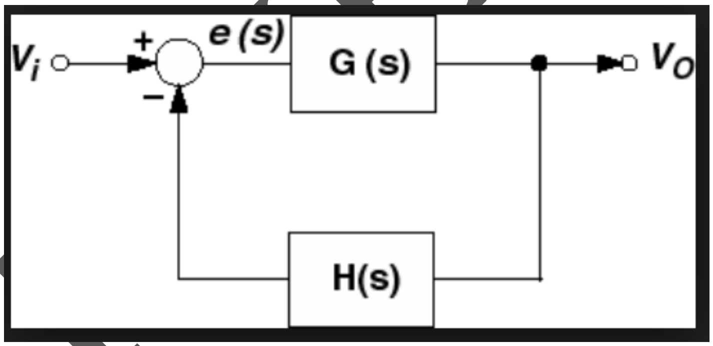
1. Angular Velocity v-voltage v
2. Angular Displacement x-flux φ
3. Frictional coefficient F conductance 1/R
4. Mass J- capacitance C
5. Stiffness K-Inverse of capacitance 1/L

2.

For a non unity negative feedback control system whose open loop transfer function is G(s) and feedback path transfer function is H(s),obtain the control ratio using Mason's gain formula. (15M) (Nov/Dec2015).BTL6

Answer : Page 1.75– Nagoor Kani

- **Draw closed loop system (2M)**



- **Choose G(s) and H(s) value (1M)**

G(s)= any value, H(s)=1

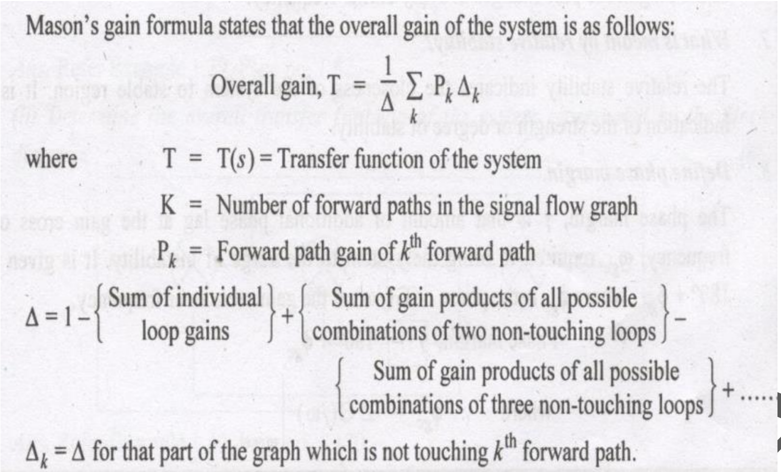
- **Convert given block diagram in to signal flow graph (2M)**
- **SFG Procedure (4M)**

✓ Find number of forward path gain

✓ Find individual loop gain

- ✓ Find non touching loop gain

- ➢ **Apply Masons gain formula (4M)**



Mason's gain formula states that the overall gain of the system is as follows:

$$\text{Overall gain, } T = \frac{1}{\Delta}\sum_{k} P_k \Delta_k$$

where $T = T(s)$ = Transfer function of the system

K = Number of forward paths in the signal flow graph

P_k = Forward path gain of k^{th} forward path

$$\Delta = 1 - \left\{\begin{matrix}\text{Sum of individual}\\ \text{loop gains}\end{matrix}\right\} + \left\{\begin{matrix}\text{Sum of gain products of all possible}\\ \text{combinations of two non-touching loops}\end{matrix}\right\} - \left\{\begin{matrix}\text{Sum of gain products of all possible}\\ \text{combinations of three non-touching loops}\end{matrix}\right\} + \ldots..$$

$\Delta_k = \Delta$ for that part of the graph which is not touching k^{th} forward path.

- ➢ **Find transfer function (2M)**

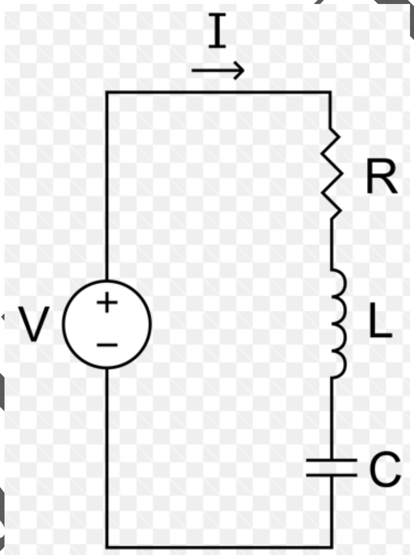
- ✓ C(s)/R(s) = Output/Input.

3.

Derive the transfer function of a RLC series circuit. (15M) (Nov/Dec 2015).BTL5

Answer : Page 1.20 – Nagoor Kani

- ➢ **Draw RLC Circuit (2M)**



- ➢ **Write KVL equations to input and output side (3M)**

Ri+ Ldi/dt + 1/C∫i.dt = Vi

1/C∫i.dt=Vo

- **Take Laplace transform of differential equations (4M)**

  Ri(s)+L s i(s) + 1/Cs i(s)= v(s)

- **Rearrange Laplace equations and find transfer function (6M)**

  Vo(s)/V(s)= 1/(1+RCS+LS^2)

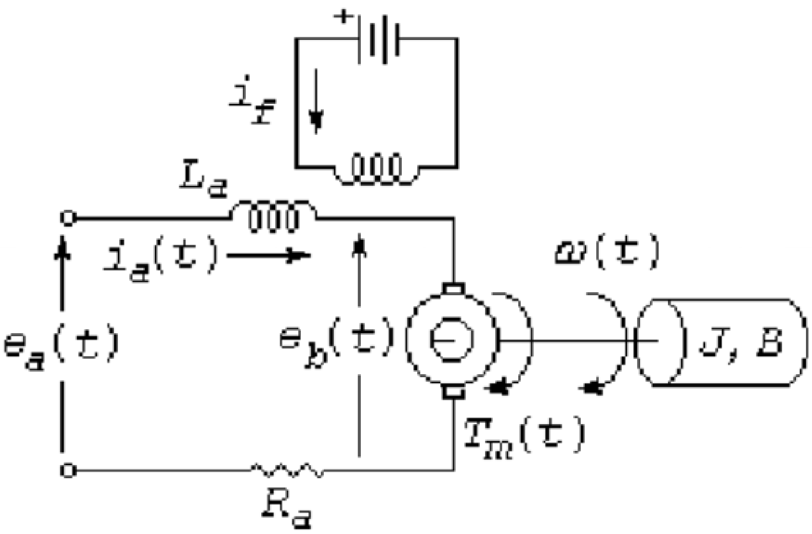
4. **With a neat diagram, derive the transfer function of a field controlled DC motor . (15M) (Nov/Dec2015).**BTL3

Answer : Page 1.24 – Nagoor Kani

- **Explain speed control techniques (2M)**

  a)Armature control b)Field control

- **Draw equivalent circuit diagram (2M)**



- **Derive differential equation (3M)**

$$Va = i_a R_a + L_a \frac{di_a}{dt} + e_b$$

$$T = J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt}$$

- **Laplace transform (3M)**

$$i_a(s)R_a + L_a s i_a(s) + E_b(s) = V_a(s)$$

$$Js^2\theta(s) + Bs\theta(s) = T(s)$$

- **Find transfer function (5M)**

	$\frac{\theta(s)}{V_f(s)} = \frac{K_m}{s\cdot(J\cdot s + b)\left(L_f\cdot s + R_f\right)}$

UNIT II TIME RESPONSE

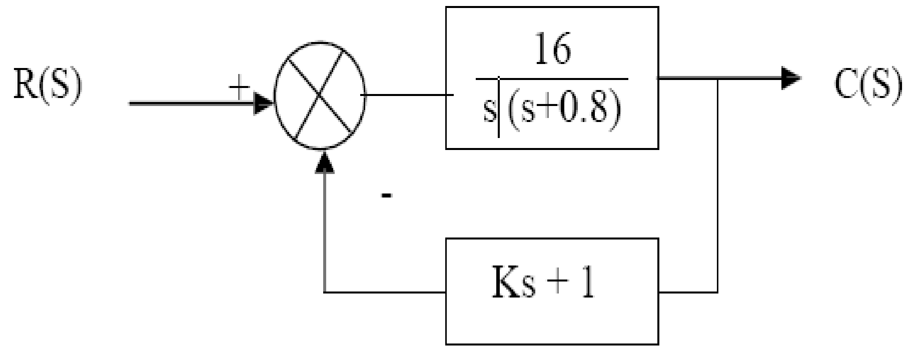
Time response – Time domain specifications – Types of test input – I and II order system response – Error coefficients – Generalized error series – Steady state error – Root locus construction- Effects of P, PI, PID modes of feedback control –Time response analysis.

PART * A

Q.No.	Questions
1.	**State the various standard test inputs used in control system.(Dec 05, May 11, 14)** BTL1 The various standard test inputs used in control system are step ramp, parabolic, impulse and sinusoidal.
2.	**Define peak overshoot. (April/May 17)** BTL1 It is defined as the ratio of the maximum peak value to final value, where maximum peak value is measured from final value.
3.	**What is steady state error? (May 04,06,07,11, Dec 11, 15)** BTL1 The difference between the desired output i.e. reference input and the actual output of the system is called steady state error which is denoted as e_{ss}.
4.	**What is rise time? (Dec 04,08, Nov 11, May 14)** BTL1 It is the time required for the response to rise from 10% to 90% of the final value for over damped systems and 0 to 100% of the final value for under damped systems. The rise time is reciprocal of the slope of the response at the instant, the response is equal to 50% of the final value.
5.	**What is settling time? (May 03, 05, 10, Dec 14)** BTL1 The settling time is defined as the time required for the response to decrease and stay within specified percentage of its final value (within tolerance band)
6.	**List out any four time-domain specification. (Dec 03,08, 15)** BTL1 The various time domain specifications are delay time, rise time, peak time, peak overshoot, settling time and steady state error.
7.	**Mention the characteristics of PI controller. (Dec 03, May 07, 13, 14)** BTL2 The PI controller has following characteristics ➢ It increases order of the system. ➢ It increases TYPE of the system. ➢ Design of K_i must be proper to maintain stability of system. So it makes system relatively less stable.

	➢ Steady state error reduces tremendously for same type of inputs.
8.	**Define transient response and steady state response of a system. (May 10)** BTL1 The output variation during the time it takes to achieve its final steady value is called transient response. Steady state response is that part of the time response which remains after complete transient response vanishes from the system output.
9.	**How a control system is classified depending on the value of damping? (May 11)** BTL2 ➢ Under damped system ($0< \zeta < 1$) ➢ Critically damped system ($\zeta = 1$) ➢ Over damped system ($\zeta > 1$) ➢ Un-damped system ($\zeta = 0$)
10.	**Why derivative controller is not used in the control system? (May 11, May 15)** BTL2 The derivative controller acts only during transient period when the error varies with time and does not produce any corrective action for a constant error as derivative of a constant error is zero. Hence the derivative controller is never used alone but always used along with some other type of controller.
11.	**What is the effect of adding a pole to a second order system? (May 04, 08)** BTL2 The second order system is generally stable. If a pole is added to it, it becomes third order due to which it becomes less stable in nature. It increases peak overshoot and settling time.
12.	**State the advantages of generalised error coefficients. (May 06)** BTL1 ➢ It gives variation of error as a function of time. ➢ It uses any input other than the standard input. ➢ As variation of error as a function of time is available, the design of the system becomes easy and optimum.
13.	**Define adaptive control system. (Dec 06)** BTL4 Adaptive control system has a property or an automatic control system having a property of automatically changing the characteristics, system parameters and / or structure of the controller during the normal operation with the aim of maintaining a given standard of performance under varying inputs and varying arbitrary, conditions of operation is called as adaptive or self-adjusting system.
14.	**What is the function of controller?** BTL2 A controller accepts error as its input and manipulates the error according to the requirement of

	the system and gives output to the plant or the process to be controlled.
15.	**What are type 0 and type 1 system? (May 2015)** BTL2 The value of N in the denominator polynomial of loop transfer function decides the type number of the system N- Number of poles at origin. If N = 0, then the system is type 0 system, If N = 1, the system is type 1 system. If N = 2, then the system is type 2 system and so on.
16.	**What is the effect of PI controller on the system performance? (Dec 14)** BTL2 The PI controller increases the order of the system by one, which results in reducing, the steady state error. But the system becomes less stable than the original system.
17.	**Define peak time. (Dec 09)** BTL1 The time at which the peak overshoot occurs in the time response of a second order system is called a peak time.
18.	**What will happen to damping factor and natural frequency of oscillations if gain K of a second order system is increased? (May 07)** BTL3 As the value of gain K increases the natural frequency of oscillations and the value of damping ratio decreases. Due to this system becomes more oscillatory in nature.
19.	**How can the maximum overshoot of a system be decreased without affecting the steady state error?** BTL3 With the use of PD i.e. proportional plus derivative controller, it can be observed that transient response and value of damping ratio increases without affecting steady state error. As damping ratio increases, the maximum overshoot decreases. So using PD controller it is possible to decrease maximum overshoot without affecting the steady state error.
20.	**What is root locus and mention its significance?** BTL1 The path taken by the roots of the open loop transfer function when the loop gain is varied from 0 to α are called root locus. The root locus technique is used for stability analysis and using root locus technique the range of values of K, for as stable system can be determined.
PART * B	
1.	**Determine the response of the system and also find time domain specifications of the given figure.(May/June 2016). (13M)** BTL3



Answer : Page 2.26 - Nagoor Kani

- **Choose G(s) and H(s) (2M)**
  - ✓ G(s)=16/s(s+0.8)
  - ✓ H(s) = Ks+1.
- **Find transfer function (1M)**
  - ✓ G(s)H(s)= G(s)/1+G(s)H(s)
  - ✓ G(s)H(s)= 16/s^2+(0.8+k)s+16.
- **Compare with standard second order expression (2M)**
  - ✓ C(s)/R(s) =ωn^2/ s^2+2 ζ ωn s+ ωn^2.
- **Find ζ and w$_n$ (2M)**
  - ✓ **w$_n$** ^{2}=16

    w$_n$ = 4 rad/sec
  - ✓ 2 ζ **w$_n$** =(0.8+K)

    K=0.2
  - ✓ Final transfer function:

    C(s)/R(s)= 16/ s^2 + 4s+16
- **Find response & time domain specifications using formulas (6M)**
  - ✓ Formula for Rise time:

$$t_r = \frac{\pi - \theta}{\omega_d}$$

Rise time = 0.64s

- ✓ Formula for Peak time:

$$t_p = \frac{\pi}{\omega_d}$$

Peak time = 0.907s

- ✓ Formula for Settling time:

$$t_s = \frac{4}{\delta\omega_n}$$

Settling time = 1.5s

- ✓ Formula for Peak overshoot:

$$\%M_p = \left(e^{-\left(\frac{\delta\pi}{\sqrt{1-\delta^2}}\right)}\right) \times 100\%$$

Peak overshoot =16.3%

2. **A unity feedback system has $10/s^2(s+2)$.Find the steady state error and generalized error coefficients for $r(t)=6t^4+5t^3+4t^2+2t+3$.((13M) May/June 2016).** BTL3

Answer : Page 2.48 - Nagoor Kani

- ➢ **Choose G(s) and H(s) (1M)**
- ✓ $G(s)=10/s^2(s+2)$
- ✓ $H(s)=1$
- ➢ **Find transfer function (2M)**

$G(s)H(s)= G(s)/1+G(s)H(s)$

- ➢ **Apply r(t) in S domain (4M)**
- ✓ $E(s) = R(s)/ 1+G(s) H(s)$.
- ✓ $R(s) =3/s+ 2/s^2 + 4/s^3 + 5/s^4 + 6/s^5$.
- ✓ $G(s)=10/s^2(s+2)$
- ➢ **Find e_{ss} using final value theorem in S domain (4M)**

$$e(\infty) = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{sR(s)}{1+G(s)}$$

- ➢ **Find generalised error coefficients (2M)**

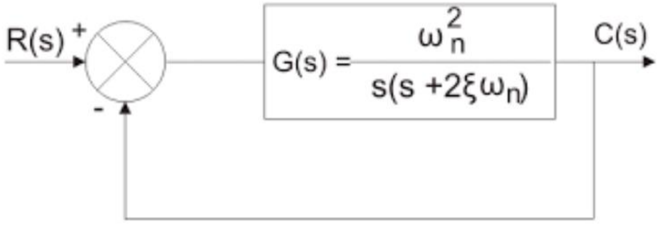
	✓ Co = 1/1+Kp ✓ C1 = 1/Kv ✓ C2 = 1/Ka
3.	**Derive the time domain specifications of a second order system.(13M)(May/June 2016)** BTL1 **Answer: Page 2.17 - NagoorKani** ➢ **Rise time definition and its formula (3M)** It is the time required for response to rise from 0% to 100% of its final value. This is applicable for under-damped systems. $t_r = \frac{\pi - \theta}{\omega_d}$ ➢ **Peak time definition and its formula (3M)** It is the time required for response to reach the peak value for first time. It is denoted by tp. At t=tp, the first derivate of the response is zero. $t_p = \frac{\pi}{\omega_d}$ ➢ **Settling time definition and its formula (3M)** It is the time required for response to reach steady state and stay within specified tolerance bands around the final value. The settling time is denoted by ts. $t_s = \frac{4}{\delta\omega_n}$ ➢ **Maximum overshoot definition and its formula (4M)** Peak overshoot Mp is defined as the deviation of the response at peak time from final value of response. It is also called the maximum overshoot. $\%M_p = \left(e^{-\left(\frac{\delta\pi}{\sqrt{1-\delta^2}}\right)}\right) \times 100\%$
4.	**For a unity feedback control system, the open loop transfer function is given by G(s)=10(s+2)/s^2(s+1). Find the position ,velocity, and acceleration error coefficients and also find the steady state error when the input is R(s)=3/s-2/s^2+1/3s^3. (13M) (May/June**

	2016). BTL3 **Answer: Page 2.41 - Nagoor kani** ➢ **Choose G(s) and H(s) & Find transfer function** ➢ **Find static error constants (4M)** ✓ Kp=α ✓ Kv= α ✓ Ka=20 ➢ **Apply r(t) in S domain to the system(3M)** ✓ E(s) = R(s)/ 1+G(s) H(s). ✓ R(s) =3/s-2/s^2+1/3s^3 ✓ G(s)=10(s+2) /s^2(s+1) ➢ **Find e_{ss} using final value theorem in S domain (4M)** $e(\infty) = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{sR(s)}{1+G(s)}$ $e_{ss =}$ 1/60 ➢ **Find generalised error coefficients (2M)** ✓ Co = 0 ✓ C1 = 0 ✓ C2 = 1/10
5.	**With a neat diagram explain the effect of PD controller in detail. (13M) (May/June 2016)** BTL5 **Answer: Page 2.62 - Nagoor Kani** ➢ **Transfer function of P & D Controller (3M)** ✓ U(s)/E(s) = Kp (1+Td S) ➢ **Block diagram of PD Controller (3M)** ➢ **Compare with standard second order expression (3M)** ✓ Loop transfer function= Gc(s)G(s) / 1+ Gc(s)G(s)H(s)

	$= Kp\ (1+Td\ s)*\ \{\omega n^2/ s^2+2\zeta\omega n\ s+ \omega n^{2\cdot}\}$ $= \omega n^2 (Kp+ Kd\ s) / (s^2+ (2\zeta\omega n + Kd\omega n^2)s +Kp\ \omega n^2)$ ➢ **Justify results(4M)** ✓ Addition of zero increases peak overshoot and reduces rise time. ✓ Increased damping reduces peak overshoot.
6.	**Write explanatory notes on PI and PD controllers. (13M) (May/June 2016)** BTL5 **Answer: Page 2.54 & 2.56 - Nagoor Kani** ➢ **Transfer function of PI & PD Controller (3M)** ✓ U(s)/E(s) = Kp (1+Td S) ✓ U(s)/E(s) = Kp (1+TiS)/TiS ➢ **Block diagram of PD Controller (3M)** ➢ **Compare with standard second order expression (3M)** ✓ Loop transfer function PD= Gc(s)G(s) / 1+ Gc(s)G(s)H(s) $= Kp\ (1+Td\ s)*\ \{\omega n^2/ s^2+2\zeta\omega n\ s+ \omega n^{2\cdot}\}$ $= \omega n^2 (Kp+ Kd\ s) / (s^2+ (2\zeta\omega n + Kd\omega n^2)s +Kp\ \omega n^2)$ ✓ Loop transfer function PI = Gc(s)G(s) / 1+ Gc(s)G(s)H(s) $= Kp\ (1+Ti\ s / Ti\ s)*\ \{\omega n^2/ s^2+2\zeta\omega n\ s+ \omega n^{2\cdot}\}$ $= Ki\omega n^2(10+ Ti\ s) / (s^3+ (2\zeta\omega n s^2 + Kp\omega n^2\ s +Ki\omega n^2)$ ➢ **Justify results (4M)** ✓ **PD controller:** a) Addition of zero increases peak overshoot and reduces rise time. b) Increased damping reduces peak overshoot. ✓ **PI controller:** a) Increase in order results in less stability. b) Increase in type reduces steady state error.
7.	**Derive the expressions for the unit step response of a second order of the underdamped and un damped systems. (13M) (Nov/Dec 2015).** BTL1

Answer: Page 2.10& 2.11 - Nagoor Kani

- **Draw block diagram of second order system (2M)**



- **Find transfer function (2M)**
  - ✓ G(s)H(s)= G(s)/1+G(s)H(s)
  - ✓ $G(s) = \omega n^2 / s^2+2\zeta\omega n\ s+ \omega n^{2.}$
- **Apply input signal (3M)**
  - ✓ R(s)= 1/s, ζ=0 for undamped case and ζ<1 for underdamped case.
- **Use partial fraction method find response of system (6M)**

$$y(t) = 1 - \frac{1}{\sqrt{1-\xi^2}} e^{-\zeta\omega_n t} \sin\left(\omega_n \sqrt{1-\xi^2}\, t + \theta\right)$$

8\. **The open loop transfer function of a unity feedback system is given by G(s)=1/s(1+s).The input to the system is described by r(t)=4+6t.Find the generalized error coefficients and steady state error. (13M) (Nov/Dec 2015).** BTL3

Answer: Page 2.48 - Nagoor Kani

- **Choose G(s) and H(s) & Find transfer function (2M)**
  - ✓ $R(s) = 4/s+6/t^2$
  - ✓ G(s)=1/s(s+1)
  - ✓ H(s)=1
- **Apply r(t) to find e_{ss} using initial value theorem or final value theorem (6M)**

$$e(\infty) = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{sR(s)}{1+G(s)}$$

- **Find C0,C1,C2 from static error constants (5M)**
  - ✓ C0=1/1+kp

	✓ C1=1/kv ✓ C3=1/ka
9.	**Explain the rules to construct root locus of a system. (13M) (Nov/Dec 2015).** BTL1 **Answer: Page 4.64 - Nagoor kani** ➢ **Find poles and zeros (2M)** ➢ **Identify root locus path (2M)** ➢ **Find centroid and angle of asymptotes (2M)** ➢ **Find breakaway points (2M)** ➢ **Find angle of arrival and angle of departure (2M)** ➢ **Find intersection of real axis with imaginary axis (3M)**
10.	**The open loop transfer function of a unity feedback system is given by G(s)=40/(s(0.2s+1)).Determine the steady state error using error series approach for the input r(t)=3t+4t^2.).(May/June 2016). (13M)** BTL3 **Answer: Page 2.45 - Nagoor kani** ➢ **Choose G(s) and H(s) & Find transfer function (4M)** ✓ G(s)=40/s(0.2s+1) ✓ R(s)=3/s^2+4/s^4 ✓ H(s)=1 ➢ **Apply r(t) to find e_{ss} using initial value theorem or final value theorem (6M)** $e(\infty) = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{sR(s)}{1+G(s)}$ ➢ **Find C0,C1,C2 from static error constants (3M)** ✓ C0=1/1+kp ✓ C1=1/kv ✓ C3=1/ka
11.	**A unity feedback control system has the open loop transfer function G(s)=K/(s+A)(s+2).Find the values of K and A, so that the damping ratio is 0.707 and the peak time for unit step response is 1.8s. (13M) (Nov/Dec 2015).** BTL2

	Answer: Page.2.26 - Nagoor kani ➢ **Choose G(s) and H(s) & Find transfer function (2M)** ✓ G(s)= K/(s+A)(s+2) ✓ ζ=0.707 ✓ Tp=1.8 ➢ **Compare with standard expression (2M)** $G(s) =\omega n^2/ s^2+2\zeta\omega n\ s+ \omega n^2=$ **K/(s+A)(s+2)** ➢ **Find Wn, also find K,A by using peak time (9M)** ✓ 2ζωn=(A+2) ✓ Tp=1.8 π/wn(sqrt(1-ζ^2))=1.8 (calculate Wn) ✓ Substitute the value of ζ and find value of A.
12.	**Obtain the impulse and step responses of the following unity feedback control system with open loop transfer function. G(s)=6/(s(s+5)). (13M) Nov/Dec 2015).** BTL2 **Answer: Page 2.81--Nagoorkani** ➢ **Choose G(s) and H(s) & Find transfer function (2M)** ✓ C(s)/R(s)=G(s)/1+G(s) ✓ C(s)=R(s)* 6/s(s+5) ✓ Step response R(s)=1/s C(s)= 1/s * 6/s(s+5) ✓ Impulse response R(s)=1 C(s)= 1 * (6/s(s+5)) ➢ **Apply input signal R(s), Find response of system (5M)** The time domain response c(t) is obtained by taking inverse Laplace transform of C(s). ➢ **Find derivative of response of system is response of impulse system (6M)** The time domain response c(t) is obtained by taking inverse Laplace transform of C(s).
13.	**(i)Develop an Expression to find steady state error of closed Loop system. (6M)** BTL4

Answer: Page.2.48 - Nagoor kani

➢ **Choose G(s) and H(s) & Find transfer function (3M)**

✓ E(s)= R(s)/[1+G(s)H(s)]

✓ e(t)= LT^{-1}(E(s))

G(s)=transfer function

H(s)= feedback

➢ **Apply r(t) to find e_{ss} using initial value theorem or final value theorem (3M)**

✓ Ess= t→∞ LT (e(t))

$$e(\infty) = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{sR(s)}{1+G(s)}$$

(ii) A unity feedback system has the forward transfer function G(s)=Ks/(s+1)^2. For the input r (t) = 1 + 5t, formulate the minimum value of K so that the steady state error is < 0.1.(Use final value theorem). (7M) BTL4

Answer: Page 2.48 - Nagoor kani

➢ **Choose G(s) and H(s) & Find transfer function (4M)**

✓ G(s)=Ks/(s+1)^2.

✓ H(s)=1

✓ R(s)=1/s+5/s^2

➢ **Apply r(t) to find e_{ss} using final value theorem (3M)**

$$e(\infty) = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{sR(s)}{1+G(s)}$$

PART * C

1\. **Explain the effect of P,PI and PID controllers on the system performances. (15M) (Nov/Dec 2015).** BTL5

Answer: Page 2.61-Nagoor kani

➢ **Transfer function of P, I & D Controller (5M)**

➢ **Compare with standard second order expression (2M)**

✓ **PD controller:**

$U(s)/E(s) = Kp\ (1+Td\ S)$

Loop transfer function = $Gc(s)G(s) / 1+ Gc(s)G(s)H(s)$

$= Kp\ (1+Td\ s)^*\ \{\omega n^2/ s^2+2\varepsilon\ \omega n\ s+ \omega n^{2.}\}$

$= \omega n^2\ (Kp+ Kd\ s) / (s^2+ (2\varepsilon\ \omega n + Kd\omega n^2\ )s +Kp\ \omega n^2\ )$

- ✓ **PI controller:**

$U(s)/E(s) = Kp\ (1+TiS)/TiS$

Loop transfer function PI= $Gc(s)G(s) / 1+ Gc(s)G(s)H(s)$

$= Kp\ (1+Ti\ s / Ti\ s)^*\ \{\omega n^2/ s^2+2\varepsilon\ \omega n\ s+ \omega n^{2.}\}$

$= Ki\omega n^2(10+ Ti\ s) / (s^3+ (2\varepsilon\ \omega ns^2 + Kp\omega n^2\ s +Ki\omega n^2\ )$

- ✓ **PID controller:**

$U(s)/E(s) = Kp(1+ 1/Tis +Tds)$

Loop transfer function PID = $Gc(s)G(S)/1+ Gc(s)G(s)H(s)$

$= Kp(1+ 1/Tis +Tds)\ ^*\ \{\omega n^2/ s^2+2\varepsilon\ \omega n\ s+ \omega n^{2.}\}$

- **Block diagram of P,PI, PID Controller (5M)**
- **Justify the results (3M)**

PD controller:

1. Addition of zero Increases peak overshoot and reduces rise time.
2. Increased damping, reduces peak overshoot.

PI controller:

1. Increase in order results in less stability
2. Increase in type reduces steady state error

PID controller:

1. Proportional controller stabilizes gain but introduces steady state error.
2. Integral controller eliminates error.
3. Derivative controller reduce rate of change of error.

2. **A unity feedback system has the forward transfer function $G(s)=K1(2s+1)/s(5s+1)(1+s)^2$.The input r(t)=1+6t is applied to the system. Determine the minimum value of K1,if the steady state error is to be less than 0.1. (15M) (Apr/May 2017).**

	BTL3 **Answer: Page 2.48-Nagoor kani** ➢ **Choose G(s) and H(s) & Find transfer function (2M)** ✓ $G(s) = K1\ (2s+1)/s\ (5s+1)\ (1+s)^2$ ✓ $R(s)=1/s+6/s^2$ ➢ **Apply r(t) to find e_{ss} using initial value theorem or final value theorem (6M)** ✓ **Ess=0.1** $e(\infty) = \lim_{s\to 0} sE(s) = \lim_{s\to 0} \frac{sR(s)}{1+G(s)}$ ➢ **Find C0, C1, and C2 from static error constants (5M)** ✓ C0=1/1+kp ✓ C1=1/kv ✓ C3=1/ka ➢ **Find value of K (2M)** ✓ K should be greater than 60.
3.	**Sketch the root locus of the system having G(s)=K(s+3)/s(s+1)(s+2)(s+4). (15M) (Apr/May 2017).** BTL6 **Answer: Page 4.72 -Nagoor kani** ➢ **Find poles and zeros (2M)** ➢ **Identify root locus path (2M)** ➢ **Find centroid and angle of asymptotes (3M)** ➢ **Find breakaway points (3M)** ➢ **Find intersection of real axis with imaginary axis (3M)** ➢ **Find the value of K (2M)**
4.	**A unity feedback control system has an open loop transfer function G(S)= K / S (S^2+4S+13).Sketch the root locus. (15M)** BTL6 **Answer: Page 4.79 -Nagoor kani** ➢ **Find poles and zeros & Identify root locus path (2M)**

- **Find centroid and angle of asymptotes (3M)**
- **Find breakaway points (3M)**
- **Find angle of arrival and angle of departure (3M)**
- **Find intersection of real axis with imaginary axis (2M)**
- **Find the value of K (2M)**

5.

Sketch the root locus of the system whose open loop transfer function is G(S)= K / S (S+2)(S+4).Find the value of K so that the damping ratio of the closed loop system is 0.5. (15M) BTL6

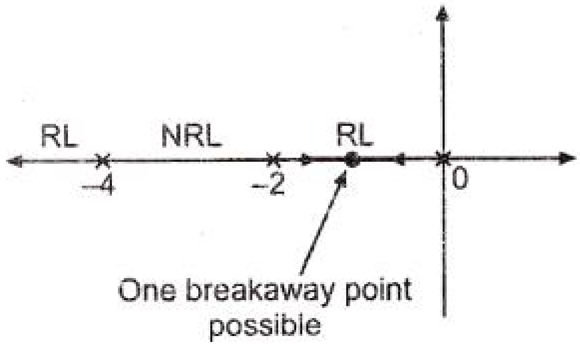
Answer: Page 4.72 -Nagoor kani

- **Find poles and zeros & Identify root locus path (4M)**

✓ Poles = 0, -4, -2. Therefore P=3.

✓ Zeros = there are no zeros. Z=0. (P-Z=3) branches terminate at infinity.

✓ Root Locus existence region and NRL denotes the non-existence region of root locus.



✓ These sections of real axis identified as a part of root locus as to right sum of poles and zeros is odd for those sections.

- **Find centroid and angle of asymptotes (3M)**

✓ Asymptote touches real axis at a point called centroid.

✓ Branches will approach infinity along these lines which are asymptotes.

$$\sigma = \frac{\sum \text{R.P. of poles} - \sum \text{R.P. of zeros}}{P - Z} = \frac{0-2-4}{3} = -2$$

- ✓ A line to which root locus touches at infinity is called asymptotes.
- ✓ Number of asymptotes = P-Z = 3. Therefore 3 asymptotes are approaching to infinity.

$$\theta = \frac{(2q+1)180^\circ}{P-Z}, \qquad q = 0, 1, 2$$

$$\theta_1 = \frac{180^\circ}{3} = 60^\circ, \quad \theta_2 = \frac{(2+1)180^\circ}{3} = 180^\circ, \quad \theta_3 = \frac{(2\times 2+1)180^\circ}{3} = 300^\circ$$

- ➢ **Find breakaway points (3M)**

$$1 + G(s)\,H(s) = 0$$

$$1 + \frac{K}{s(s+2)(s+4)} = 0$$

$$s^3 + 6s^2 + 8s + K = 0$$

$$K = -s^3 - 6s^2 - 8s$$

$$\frac{dK}{ds} = -3s^2 - 12s - 8 = 0$$

$$3s^2 + 12s + 8 = 0$$

$$\text{Roots i.e. breakaway points} = \frac{-12 \pm \sqrt{144 - 4\times 3\times 8}}{2\times 3} = -0.845, -3.15$$

- ✓ As there is no root locus between -2 to -4, -3.15 can not be a breakaway point.
- ✓ It also can be confirmed by calculating 'K' for s = -3.15.
- ✓ It will be negative that confirms s = -3.15 is not a breakaway point.
- ✓ For s = -3.15, K = -3.079 (Substituting in equation for K).
- ✓ But as there has to be breakaway point between'0'and '-2', s = – 0.845 is a valid breakaway point.
- ✓ For s = -0.845 K = +3.079. As K is positive s = – 0.845 is valid breakaway point.

- **Find intersection of real axis with imaginary axis (3M)**

$$\begin{array}{l|cc} s^3 & 1 & 8 \\ s^2 & 6 & K \\ s^1 & \dfrac{48-K}{6} & 0 \\ s^0 & K & \end{array}$$

$$\begin{aligned} K_{marginal} &= 48 \text{ which makes row of } s^1 \text{ as row of zeros.} \\ A(s) &= 6\,s^2 + K = 0 \\ K_{mar} &= 48 \\ 6\,s^2 + 48 &= 0 \\ s^2 &= -\,8 \\ s &= \pm\ j\ \sqrt{8}\ =\ \pm\ j\,2.828 \end{aligned}$$

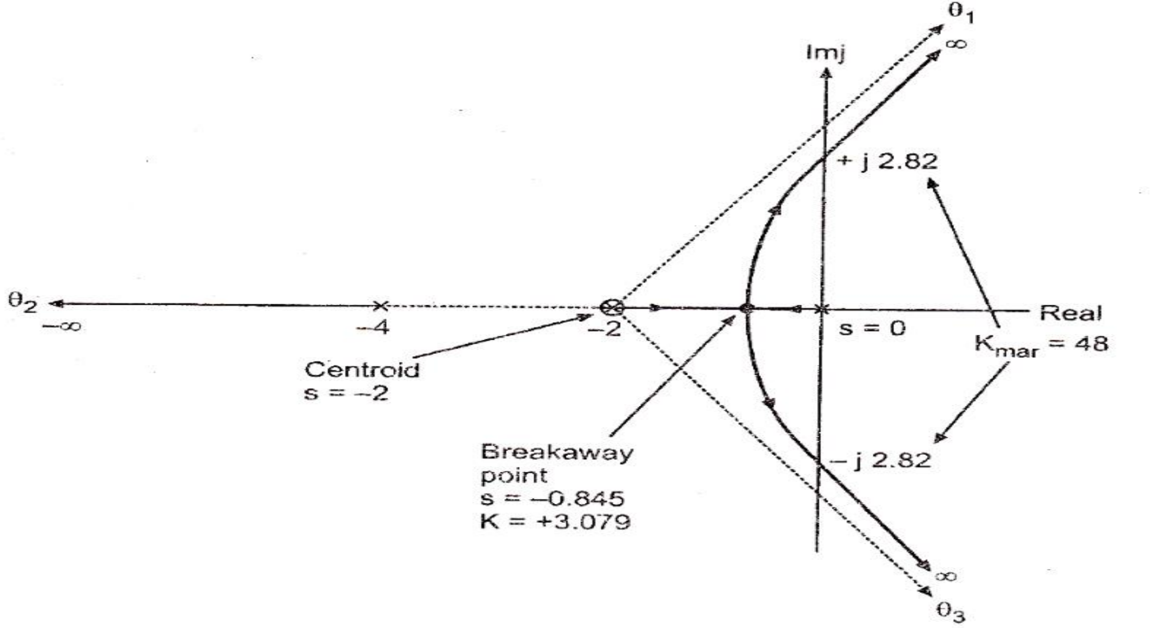
- ✓ Characteristic equation

  $s^3+6s^2+8s+K = 0$

- ✓ Intersection of root locus with imaginary axis is at ±j2.828 and corresponding value of K(marginal) = 48.

- **Root locus diagram and stability (2M)**

- ✓ For 0 < K < 48, all roots are in left half of s-plane hence system is absolutely stable.



6. **A unity feedback control system has an open loop transfer function G(S)= K (S+9) / S**

	(S^2+4S+11).Sketch the root locus. (15M) BTL6 **Answer: Page 4.75 -Nagoor kani** ➢ **Find poles and zeros &Identify root locus path (2M)** ➢ **Find centroid and angle of asymptotes (3M)** ➢ **Find breakaway points (3M)** ➢ **Find angle of arrival and angle of departure (2M)** ➢ **Find intersection of real axis with imaginary axis (3M)** ➢ **Find the value of K (2M)**

UNIT III FREQUENCY RESPONSE

Closed loop frequency response-Performance specification in frequency domain-Frequency response of standard second order system- Bode Plot - Polar Plot- Nyquist plots-Design of compensators using Bode plots-Cascade lead compensation-Cascade lag compensation-Cascade lag-lead compensation.

PART * A

Q.No.	Questions
1.	**Define gain Margin. (May 03,11,13, Dec 06,08,09,11,12,14)** BTL1 The gain margin (G.M.) is defined as the margin in gain allowable by which gain can be increased till system reaches on the verge of instability. Mathematically it can be defined as reciprocal of the magnitude of the G(jω)H(jω) measured at phase crossover frequency.
2.	**What is meant by frequency response? (April/May 17)** BTL1 The magnitude and phase angle of sinusoidal transfer function of a system are real function of frequency ω, and so they are called frequency response.
3.	**Define phase margin. (Dec 03,06,08,09,10,11,12, May 03,11,12,13)** BTL1 The amount of additional phase lags which can be introduced in the system till the system reaches on the verge of instability is called phase margin.
4.	**State any four frequency domain specification. (Nov 08,10,15 May 07,11)** BTL1 ➢ Resonant Peak ➢ Resonant frequency ➢ Cutoff region ➢ Phase Margin ➢ Gain Margin ➢ Phase cross over frequency ➢ Gain cross over frequency
5.	**What are the advantages of Bode plot? (May 06, Dec 09,10)** BTL2 ➢ It shows both low and high frequency characteristics of transfer function in single diagram. ➢ The plots can be easily constructed using some valid approximations. ➢ Relative stability of system can be studied by calculating G.M. and P.M. from the ode plot. ➢ The various other frequency domain specifications like cut-off frequency ,

	bandwidth etc. can be determined. ➢ Data for constructing complicated polar and Nyquist plots can be easily obtained from Bode plot. ➢ Transfer function of system can be obtained from the bode plot.
6.	**What is gain crossover frequency and phase crossover frequency? (Dec 10, May 06,11, 14)** BTL1 ➢ Gain crossover frequency (ω_{gc}): The frequency at which magnitude of G(jω)H(jω) is unity is called gain crossover frequency. ➢ Phase crossover frequency (ω_{pc}): The frequency at which phase angle of G(jω)H(jω) is -180 deg. is called phase crossover frequency**.**
7.	**What is meant by corner frequency in frequency response analysis? (May 05)** BTL2 A frequency up to which the magnitude contribution of a factor is negligible and can be neglected is called its corner frequency. It is the frequency at which low frequency and high frequency asymptotes intersect each other. At the corner frequency, a change in the slope of a magnitude plot occurs. Frequency range and the number of points are chosen automatically.
8.	**What is the use of Nichol's chart in control system? (Dec 14, May 15)** BTL2 ➢ Nichol's chart used to find closed loop frequency response from open loop frequency response. ➢ The frequency domain specifications can be determined from Nichols chart. ➢ The gain of the system can be adjusted to satisfy the given specifications.
9.	**Define BIBO stability. (Dec 14)** BTL1 A linear relaxed system is said to have BIBO stability if every bounded (finite) input results in a bounded (finite) output.
10.	**What are the characteristics of phase lead network? (May 15)** BTL2 ➢ Increases system bandwidth which usually correlates to reduce rise and settling times and a susceptibility to high frequency noise. ➢ The phase of the forward path transfer function in the vicinity of the zero gain crossover frequency. This increases the phase margin of the closed loop system and hence the relative stability.
11.	**What is the basis for the selection of a particular compensator for a system? (May 15)** BTL2 When the system is to be redesigned so as to meet the required specifications, it is necessary to alter the system by adding an external device to it. The system must provide,

	➢ Attenuation in the high frequency range to give a system sufficient phase margin. ➢ Large bandwidth, short rise time and less settling time.
12.	**What are M & N circles?** BTL1 ➢ The magnitude of closed loop transfer function with unity feedback can be shown to be for every value of M. These circles are called M circles . ➢ If the phase of closed loop transfer function with unity feedback is α, then tan α will be in the form of circles for every value of α; these circles are called N circles.
13.	**How the resonant peak (Mr), resonant frequency (wr), and band width are determined from Nichols chart?** BTL2 The resonant peak is given by the value of µ. Contour which is tangent to G (jw) locus. The resonant frequency is given by the frequency of G(jw) at the tangent point. The bandwidth is given by frequency corresponding to the intersection point of G(jw) and –3dB M-contour.
14.	**What is meant by Cut off frequency**? BTL1 it is denoted by ω_b. the frequency at which the magnitude of the closed loop response is 3 dB down from its zero frequency value is called cut-off frequency.
15.	**What is meant by resonant peak?** BTL1 Resonant peak (M_r): It is the maximum value of magnitude of the closed loop frequency response.
16.	**What is meant by resonant frequency?** BTL1 Resonant frequency (ω_r): The frequency at which resonant peak Mr occurs in closed loop frequency response is called resonant frequency.
	PART * B
1.	**Define all frequency domain specifications of a second order control system after plotting the response. (13M) (Apr/May 2017).** BTL1 **Answer: Page 3.2-Nagoor kani** ➢ **Definition (5M) and Derivations of frequency domain frequency specifications: (8M)** ✓ **Resonant peak:** It is the peak (maximum) value of the magnitude of *T*(*jω*)T(jω). It is denoted by *Mr*. $M_r = \frac{1}{\sqrt{(1-u_r^2)^2+(2\delta u_r)^2}}$ ✓ **Resonant Frequency:** It is the frequency at which the magnitude of the frequency response has peak value for the first time. It is denoted by *ωr*.

$$M_r = \frac{1}{2\delta\sqrt{1-\delta^2}}$$

- ✓ **Cut off rate:**

  The slope of the log magnitude curve near the cut off frequency is called cut off rate.

- ✓ **Band width:**

  The bandwidth is the range of frequencies in which the gain of the system is more than -3dB.the frequency at which the gain is -3dB is called cut off frequency.

  $$wb = wn[1-2\varepsilon^2+\sqrt{2-}\,4\varepsilon^2+4\varepsilon^4]^{1/2}$$

- ✓ **Gain margin:**

  1. The values of gain to be added to the system in order to bring the system to the verge of instability.
  2. $Kg= 1/|G(jw)|_{wpc}$
  3. Kg in dB= 20 log Kg

- ✓ **Phase margin:**

  1. The additional phase lag to be added at the gain cross over frequency in order to bring my system to the verge of instability.
  2. $\mu=180^0+\phi_{gc}$

2.

Sketch the polar plot for a system whose open loop transfer function is 4/(s+2)(s+4).Find gain margin and phase margin. (13M) (Apr/May 2017).BTL3

Answer: Page.3.54- Nagoor kani

- ➢ **Convert G(s) into time constant form (3M)**
- ✓ G(s)=0.5/ (0.5s+1)(0.25s+1)
- ➢ **S=jw (2M)**
- ✓ G(jw)=0.5/(0.5jw+1)(0.25jw+1)
- ➢ **Find magnitude and phase angle (2M)**
- ✓ Magnitude = |G(jw)|

  $= 0.5/\text{sqrt}[(1+0.25w^2)(1+0.625w^{2)}]$
- ✓ Phase angle = angle of G(jw)

  $=-\tan^{-1}(0.5w)-\tan^{-1}(0.25w)$

- **Draw polar plot (4M)**
- **Find PM & GM (2M)**

✓ **Gain margin:**

The values of gain to be added to the system in order to bring the system to the verge of instability.

1.$Kg= 1/|G(jw)|_{wpc}$

2. Kg in dB= 20 log Kg

✓ **Phase margin:**

The additional phase lag to be added at the gain cross over frequency in order to bring system to the verge of instability.

1. $\mu=180^0+\phi_{gc}$

3.

Consider a unity feedback open loop transfer function G(s) =100/s (1+0.1s) (1+0.2s).Draw the bode plot and find gain margin and stability of the system. (13M) (Nov/Dec 2016). BTL3

Answer: Page 3.30-NagoorKani

- **Convert G(s) into time constant form (3M)**
  - ✓ 100/s(1+0.1s)(1+0.2s)
- **S=jw (2M)**
  - ✓ G(jw)= 100/jw(1+0.1jw)(1+0.2jw)
- **Find magnitude and phase angle (2M)**
  - ✓ Magnitude = |G(jw)|
  - ✓ Phase angle = angle of G(jw)

$$= -90-\tan^{-1}(0.1w)-\tan^{-1}(0.2w)$$

- **Draw bode plot (4M)**
- **Find PM & GM (2M)**

✓ **Gain margin:**

The values of gain to be added to the system in order to bring the system to the verge of instability.

$Kg= 1/|G(jw)|_{wpc}$

Kg in dB= 20 log Kg

✓ **Phase margin:**

	The additional phase lag to be added at the gain cross over frequency in order to bring system to the verge of instability. $\mu=180^0+\phi_{gc}$
4.	**List any four frequency domain specifications. (13M) (May/June 2016).** BTL1 **Answer: Page 3.4-NagoorKani** ➢ **Definition (5M) and Derivations of frequency domain frequency specifications: (8M)** ✓ **Resonant peak:** It is the peak (maximum) value of the magnitude of $T(j\omega)$T(jω). It is denoted by *Mr*. $M_r = \frac{1}{\sqrt{(1-u_r^2)^2+(2\delta u_r)^2}}$ ✓ **Resonant Frequency:** It is the frequency at which the magnitude of the frequency response has peak value for the first time. It is denoted by *ωr*. $M_r = \frac{1}{2\delta\sqrt{1-\delta^2}}$ ✓ **Cut off rate:** The slope of the log magnitude curve near the cut off frequency is called cut off rate . ✓ **Band width:** The bandwidth is the range of frequencies in which the gain of the system is more than -3dB.the frequency at which the gain is -3dB is called cut off frequency. $wb = wn[1-2\varepsilon^2+\sqrt{2-}\,4\varepsilon^2+4\varepsilon^4]^{1/2}$
5.	**Draw the bode magnitude and phase plot for the unity feedback system with G(s) =40/s (1+0.1s) and hence determine phase margin and gain margin. (13M) (May/June 2016).** BTL3 **Answer: Page 3.32-Nagoor Kani** ➢ **Convert G(s) into time constant form (3M)** ✓ 40/s(1+0.1s) ➢ **S=jw (2M)** ✓ G(jw)= 40/jw(1+0.1jw) ➢ **Find magnitude and phase angle (2M)**

	✓ Magnitude = $\lvert G(jw)\rvert$ ✓ Phase angle = angle of G(jw) $= -90-\tan^{-1}(0.1w)$ ➢ **Draw bode plot (4M)** ➢ **Find PM & GM (2M)** ✓ **Gain margin:** The values of gain to be added to the system in order to bring the system to the verge of instability. $Kg= 1/\lvert G(jw)\rvert_{wpc}$ Kg in dB= 20 log Kg ✓ **Phase margin:** The additional phase lag to be added at the gain cross over frequency in order to bring my system to the verge of instability. $\mu=180^0+\phi_{gc}$
6.	**Sketch the bode plot for the following transfer function and determine the value of K for the gain cross over frequency of 5 rad/sec $G(s) = Ks^2/(1+0.2s)(1+0.02s)$. (13M) (Apr/May 2017).** BTL3 **Answer:Page3.21-Nagoor Kani** ➢ **Convert G(s) into time constant form (3M)** ✓ $Ks^2/s(1+0.2s)(1+0.02s)$ ➢ **S=jw (2M)** ✓ $G(jw)= K(jw)^2/(1+0.2jw)(1+0.02jw)$ ➢ **Find magnitude and phase angle (2M)** ✓ Magnitude = $\lvert G(jw)\rvert$ ✓ Phase angle = angle of G(jw) $= 180-\tan^{-1}(0.2w)-\tan^{-1}(0.02w)$ ➢ **Draw bode plot (3M)** ➢ **Find PM & GM (2M)** ✓ **Gain margin:** The values of gain to be added to the system in order to bring the system to the

	verge of instability. Kg= 1/$\vert G(jw)\vert_{wpc}$ Kg in dB= 20 log Kg ✓ **Phase margin:** The additional phase lag to be added at the gain cross over frequency in order to bring my system to the verge of instability. $\mu=180^0+\phi_{gc}$ ➢ **Find the value of K (1M)**
7.	**Sketch the polar plot for the following transfer function and determine the gain and phase margin. G(s)=1/s(s+1)(1+2s). (13M) (Apr/May 2017)** BTL3 **Answer: Page3.42-Nagoor kani** ➢ **Convert G(s) into time constant form (3M)** ✓ G(s)=1/ s(s+1)(2s+1) ➢ **S=jw (2M)** ✓ G(jw)=1/jw(jw+1)(2jw+1) ➢ **Find magnitude and phase angle (2M)** ✓ Magnitude = $\vert G(jw)\vert$ $= 1/sqrt[(1+w^2)(1+4w^{2)}]$ ✓ Phase angle = angle of G(jw) $=-90-\tan^{-1}(w)-\tan^{-1}(2w)$ ➢ **Draw polar plot (4M)** ➢ **Find PM & GM (2M)** ✓ **Gain margin:** The values of gain to be added to the system in order to bring the system to the verge of instability. Kg= 1/$\vert G(jw)\vert_{wpc}$ Kg in dB= 20 log Kg ✓ **Phase margin:** The additional phase lag to be added at the gain cross over frequency in order to bring my system to the verge of instability.

$\mu = 180^0 + \phi_{gc}$

8.

Obtain the relationship between any three frequency domain specifications in terms of time domain specifications. (13M) (Nov/Dec 2016). BTL4

Answer:Page.3.7-Nagoor Kani

- **Calculate time domain specifications such as maximum overshoot, natural frequency, damping ratio (4M)**
  - ✓ **Rise time definition**

The time required for the response to rise from 0% to 100% of its final value. This is applicable for the under-damped systems.

$$t_r = \frac{\pi - \theta}{\omega_d}$$

- ✓ **Peak time definition**

The time required for the response to reach the peak value for the first time. It is denoted by tp. At t=tp, the first derivate of the response is zero.

$$t_p = \frac{\pi}{\omega_d}$$

- ✓ **Settling time definition and its formula**

The time required for the response to reach the steady state and stay within the specified tolerance bands around the final value. The settling time is denoted by ts.

$$t_s = \frac{4}{\delta\omega_n}$$

- ✓ **Maximum overshoot definition and its formula**

Peak overshoot Mp is defined as the deviation of the response at peak time from the final value of response. It is also called the maximum overshoot

$$\%M_p = \left(e^{-\left(\frac{\delta\pi}{\sqrt{1-\delta^2}}\right)}\right) \times 100\%$$

- **Calculate frequency domain specifications such as resonant peak, damping ratio, resonant frequency (4M)**
  - ✓ **Resonant peak:**

	It is the peak (maximum) value of the magnitude of *T*(*jω*)T(jω). It is denoted by *Mr*. $M_r = \frac{1}{\sqrt{(1-u_r^2)^2+(2\delta u_r)^2}}$ ✓ **Resonant Frequency:** It is the frequency at which the magnitude of the frequency response has peak value for the first time. It is denoted by *ωr*. $M_r = \frac{1}{2\delta\sqrt{1-\delta^2}}$ ✓ **Cut off rate:** The slope of the log magnitude curve near the cut off frequency is called cut off rate. ✓ **Band width:** The bandwidth is the range of frequencies in which the gain of the system is more than -3dB.the frequency at which the gain is -3dB is called cut off frequency. $wb = wn[1-2\varepsilon^2+\sqrt{2}-4\varepsilon^2+4\varepsilon^4]^{1/2}$ ✓ **Gain margin:** The values of gain to be added to the system in order to bring the system to the verge of instability. 1. Kg= $1/\lvert G(jw)\rvert_{wpc}$ 2. Kg in dB= 20 log Kg ✓ **Phase margin:** The additional phase lag to be added at the gain cross over frequency in order to bring my system to the verge of instability. $\mu=180^0+\phi_{gc}$ ϕ_{gc}= angle(G(jw) ➢ **By using various values of damping ratio compare the results (5M)**
9.	**The closed loop transfer function of a system C(s)/R(s)=81/s^2+7s+81 calculate the values of resonant frequency ,resonant peak and band width. (13M) (Nov/Dec 2015).** BTL3 **Answer:Page.3.8-Nagoor Kani** ➢ **Resonant peak (4M)** It is the peak (maximum) value of the magnitude of *T*(*jω*).It is denoted by *Mr*.

$$M_r = \frac{1}{2\delta\sqrt{1-\delta^2}}$$

- **Resonant Frequency (4M)**
  It is the frequency at which the magnitude of the frequency response has peak value for the first time. It is denoted by *ωr*
  $wr = wn * sqrt(1-2^2)$

- **Band Width (5M)**

  The bandwidth is the range of frequencies in which the gain of the system is more than -3dB.the frequency at which the gain is -3dB is called cut off frequency.

$$wb = wn[1-2\varepsilon^2+\sqrt{2-4\varepsilon^2+4\varepsilon^4}]^{1/2}$$

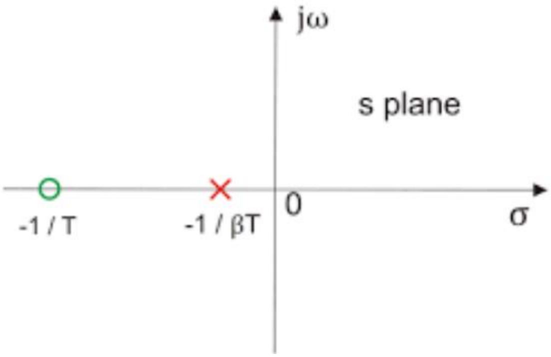
10.

Draw the frequency response of lag compensator with necessary expressions. (13M) BTL 3

Answer:Page5.5-Nagoor Kani

- **G(s), s can be replaced by jw (4M)**

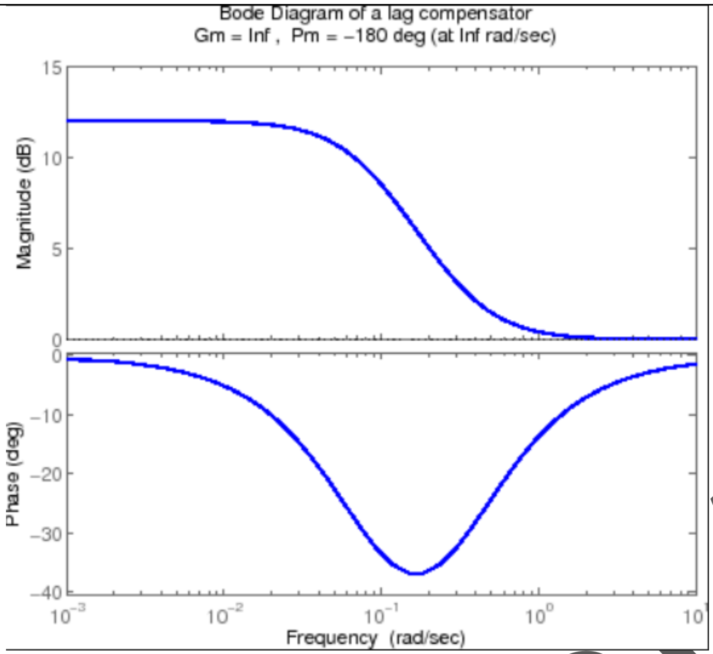
1. $Gc(s) = \frac{(s+1/T)}{(s+\frac{1}{\beta T})}$
2. $Gc(s) = \frac{(jw+1/T)}{(jw+\frac{1}{\beta T})}$



- **Find magnitude and Phase angle.(4M)**

$$Gc(jw) = \frac{1+jwT}{1+jw\beta T} = \frac{\sqrt{1+(wT)^2} < tan^{-1}wT}{\sqrt{1+(w\beta T)^2} < tan^{-1}w\beta T}$$

- **Draw the graph between frequency versus phase angle & magnitude (5M)**



PART * C

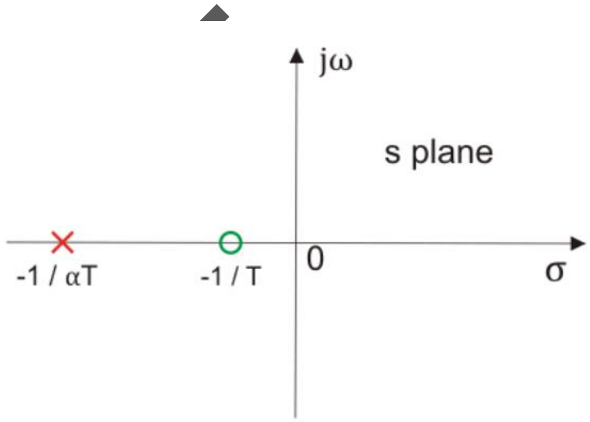
1.

Draw the frequency response of lead compensator with necessary expressions. (15M) BTL4

Answer: Page.5.28-Nagoor Kani

- **G(s), s can be replaced by jw (4M)**

1. $Gc(s) = \frac{(s+1/T)}{(s+\frac{1}{\alpha T})}$
2. $Gc(s) = \frac{(jw+1/T)}{(jw+\frac{1}{\alpha T})}$



- **Find magnitude and Phase angle (5M)**

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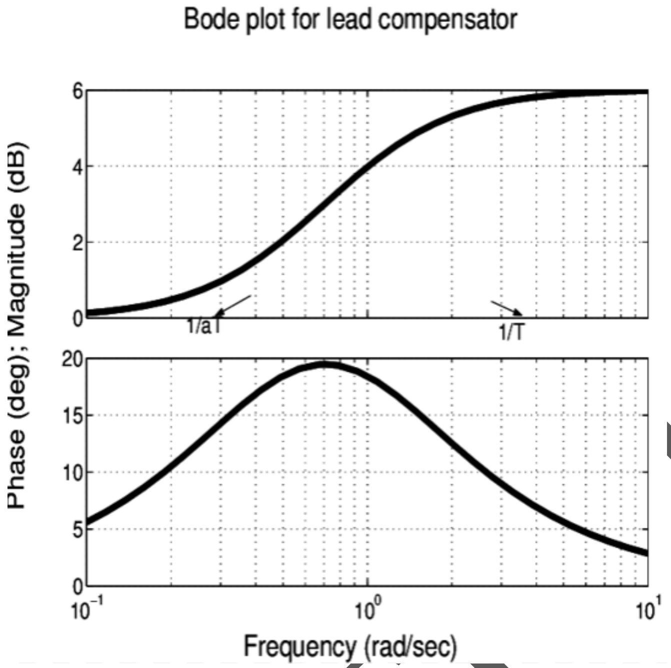
$$Gc(jw) = \frac{1 + jwT}{1 + jw\alpha T} = \frac{\sqrt{1 + (wT)^2} < tan^{-1}wT}{\sqrt{1 + (w\alpha T)^2} < tan^{-1}w\alpha T}$$

- **Draw the graph between frequency versus phase angle & magnitude (6M)**



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Draw the frequency response of lead lag compensator with necessary expressions. (15M) BTL4

Answer: Page 5.28 – NagoorKani

- **G(s), s can be replaced by jw (4M)**

1. $Gc(s) = \frac{(s+1/T1)}{(s+\frac{1}{\beta T1})} \frac{(s+1/T2)}{(s+\frac{1}{\alpha T2})}$
2. $GGc(s) = \frac{(jw+1/T1)}{(jw+\frac{1}{\beta T1})} \frac{(jw+1/T2)}{(jw+\frac{1}{\alpha T2})}$

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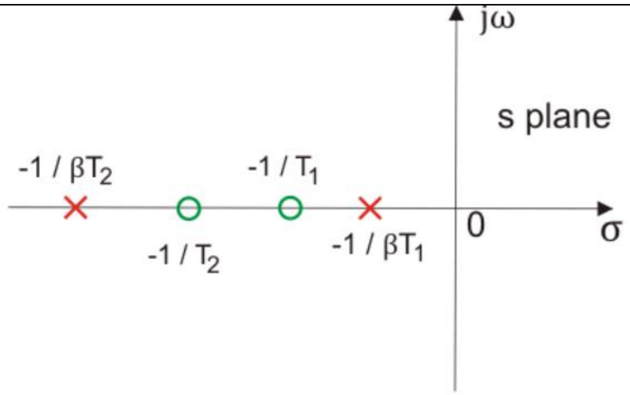
</table>

	 ➢ **Find magnitude and Phase angle (6M)** $Gc(jw) = \frac{1+jwT1}{1+jw\beta T1}\frac{1+jwT2}{1+jw\alpha T2} = \frac{\sqrt{1+(wT1)^2} < tan^{-1}wT1 \sqrt{1+(wT2)^2} < tan^{-1}wT2}{\sqrt{1+(w\beta T1)^2} < tan^{-1}w\beta T1\sqrt{1+(w\alpha T2)^2} < tan^{-1}w\alpha T2}$ ➢ **Draw the graph between frequency versus phase angle (3M)** ➢ **Draw the graph between frequency versus magnitude (2M)**
3.	**Explain in detail about M and N circles. (15M)** BTL3 **Answer: Page.3.65 -Nagoor Kani** ➢ **M Circles (8M)** ✓ **Derivation (4M)** ✓ **Diagram (4M)** ➢ **N Circles (7M)** ✓ **Derivation (4M)** ✓ **Diagram (3M)**

UNIT IV STABILITY AND COMPENSATOR DESIGN

Characteristics equation – Routh Hurwitz criterion – Nyquist stability criterion- Performance criteria – Lag, lead and lag-lead networks – Lag/Lead compensator design using bode plots.

PART * A

Q.No.	Questions
1.	**What is characteristic equation? (APRIL/MAY 17)** BTL1 The denominator polynomial of C(s) / R(s) is the characteristics equation of the system.
2.	**Define stability**.BTL1 A linear relaxed system is said to have BIBIO stability if every bounded input results in abounded output.
3.	**What will be the nature of impulse response when the roots of characteristic equation are lying on imaginary axis?** BTL2 If the root of characteristic equation lies on imaginary axis the nature of impulse response is oscillatory.
4.	**What is the relationship between Stability and coefficient of characteristic polynomial?** BTL3 If the coefficient of characteristic polynomial are negative or zero, then some of the roots lie on the negative half of the S-plane. Hence the system is unstable. If the coefficients of the characteristic polynomial are positive and if no coefficient is zero then there is a possibility of the system to be stable provided all the roots are lying on the left half of the S-plane
5.	**What is Routh stability criterion?** BTL2 Routh criterion states that the necessary and sufficient condition for stability is that all of the elements in the first column of the routh array is positive. If this condition is not met, the system is unstable and the number of sign changes in the elements of the first column of Routh array corresponds to the number of roots of characteristic equation in the right half of the S-plane.
6.	**What is limitedly stable system?** BTL2 For a bounded input signal if the output has constant amplitude oscillations, then the system may be stable or unstable under some limited constraints such a system is called limitedly stable system.
7.	**In Routh array what conclusion you can make when there is a row of all zeros?** BTL2 All zero rows in the Routh array indicate the existence of an even polynomial as a factor of the given characteristic equation. The even polynomial may have roots on imaginary axis
8.	**What is a principle of argument?** BTL2

	The principles of arguments state that, Let F(S) are analytic function and if an arbitrary closed contour in a clockwise direction is chosen in the S-plane so that F(S) is analytic at every point of the contour. Then the corresponding F(S) plane contour mapped in the F(S) plane will encircle the origin N times in the anti-clockwise direction, where N is the difference between number of poles and zeros of F(S) that are encircled by the chosen closed contour in the S plane.
9.	**How the roots of characteristic are related to stability?** BTL1 If the root of characteristic equation has positive real part then the impulse response of the system is not bounded. Hence the system will be unstable. If the root has negative real parts then the impulse response is bounded. Hence the system will be stable.
10.	**What is the necessary condition for stability?** BTL1 The necessary condition for stability is that all the coefficients of the characteristic polynomial be positive. The necessary and sufficient condition for stability is that all of the elements in the first column of the Routh array should be positive.
11.	**What are the requirements for BIBO Stability?** BTL2 The requirements of the BIBO stability is that the absolute integral of the impulse response of the system should take only the finite value.
12.	**What is auxiliary polynomial?** BTL2 In the construction of Routh array a row of all zero indicates the existence of an even polynomial as a factor of given characteristic equation. In an even polynomial the exponents of S are even integers or zero only. This even polynomial factor is called auxiliary polynomial. The coefficients of auxiliary polynomial are given by the elements of the row just above the row of all zeros.
13.	**Why compensation is required in feedback control systems?** BTL4 In feedback control systems compensation is required in the following situations: ➢ When the system is absolutely unstable, then compensation is required to stabilize the system and also to meet the desired performance. ➢ When the system is stable, compensation is provided to obtain desired performance.
14.	**When lag, lead, lag-lead compensation is employed?** BTL4 ➢ Lag compensation is employed for a stable system for improvement in steady state performance. ➢ Lead compensation is employed for stable/unstable system for improvement in transient state performance. ➢ Lag-lead compensation is employed for stable/unstable system for improvement in both steady state and transient state performance.

15.	**Discuss the effect of adding a pole to open loop transfer function of a system.** BTL2 The addition of pole to open loop transfer function of a system will reduce the steady state error. The closer the pole to origin lesser will be the steady state error. Thus the steady state performance of the system is improved. Also the addition of pole will increase the order of the system, which in turn makes the system less stable than the original system.
16.	**Discuss the effect of adding a zero to open loop transfer function of a system.** BTL2 The addition of zero to open loop transfer function of a system will improve the transient response. The addition of zero reduces the rise time. If the zero is introduced close to origin the peak overshoot will be large. If the zero is introduced far away from the origin in the left half of s plane then the effect of zero on the transient response will be negligible.
17.	**What are the characteristics of lag compensator?** BTL2 The lag compensator improves the steady state performance, reduces the bandwidth and increases the rise time(which results in slower transient response). If the pole introduced by the compensator is not cancelled by a zero in the system then the lag compensator increases the order of the system by one.
18.	**What are the characteristics of lead compensator?** BTL2 The lead compensation increases the bandwidth and improves the speed of response .It also reduces the peak overshoot. If the pole introduced by the compensator is not cancelled by a zero in the system, then lead compensation increases the order of the system by one. When the given system is stable/unstable and improvement in transient state response then lead compensation is employed.
19.	**What are the transfer function of lag, lead and lag-lead compensator?** BTL2 $Gc(s)=(s+1/T)/(s+1/T\beta)$ $Gc(s)=(s+1/T)/(s+1/T\alpha)$ $Gc(s)=(s+1/T_1)(s+1/T_2)/(s+1/T_1\beta)(s+1/ T_2\alpha)$
20.	**What is meant by lead-lag compensator? (APRIL/MAY 17)** BTL2 The lead-lag compensation is a design procedure in which a lead-lag compensator is introduced in the system so as to meet the desired specifications.
21.	**Define Nyquist stability criterion. (May 17, 13, Dec 15)** BTL1 If the nyquist plot of the open loop transfer function G(s) H(s) corresponding to the nyquist contour in the s-plane encircles the critical point -1+j0 in the counter clockwise direction as many times as the number of right half s-plane poles of G(s)H(s), the closed loop system is stable.

PART * B

1\. **Draw the Nyquist plot for the system whose open loop transfer function is G(S)H(S) =K/S (S+2) (S+10).Determine the range of K for which closed loop system is stable. (13M)** BTL3
Answer: Page 4.35- NagoorKani

- **Convert G(s) into time constant form (2M)**
- ✓ $G(s)H(s)= 0.05K/s(0.5s+1)(0.1s+1)$
- **Select contour regions (3M)**
- ✓ System has one pole at origin.
- ✓ Select S-plane enclosing entire right half except the origin.
- **Apply four sections and draw the F(s) contour (4M)**
- ✓ Four sections C1,C2,C3 and C4.
- **Finally draw all contour regions in single nyquist plot (4M)**
- ✓ **Stability**

  $-0.00417k = -1$

  $K=240$

  This contour passes through the point -1+j0.
- ✓ **K<240**

  The closed loop system is stable.
- ✓ **K>240**

  The closed loop system is unstable.

2\. **Construct Nyquist plot for a feedback control system whose open loop transfer function is given by G(S)H(S) =$K(1+s)^2/ s^3$.Comment on the stability of open loop and closed loop transfer function. (13M)** BTL3

Answer: Page 4.38-Nagoor kani

- **Convert G(s) into time constant form (2M)**
- ✓ $G(s)H(s)= K(1+s)^2/ s^3$
- ✓ $G(jw)H(jw)= K(1+jw)^2/(jw)^3$
- **Select contour regions (3M)**
- ✓ System has three poles at origin.

	✓ Select S-plane enclosing entire right half except the origin. ➢ **Apply four sections and draw the F(s) contour (4M)** ✓ Four sections C1,C2,C3 and C4. ➢ **Finally draw all contour regions in single Nyquist plot (4M)** ✓ **Stability** -2k = -1 K=0.5 This contour passes through the point -1+j0. ✓ **K<0.5** The closed loop system is Unstable. ✓ **K>0.5** The closed loop system is stable**.**
3.	**Sketch the Nyquist plot for a system with the open loop transfer function G(S)H(S) =(1+4S) /s^2 (1+S) (2S+1).Determine the stability of the system. (13M)** BTL3 **Answer:Page4.42-Nagoor Kani** ➢ **Convert G(s) into time constant form (2M)** ✓ G(s)H(s)= (1+4S) /s^2 (1+S) (2S+1) ✓ G(jw)H(jw)= (1+4jw)/jw^2(1+jw)(2jw+1) ➢ **Select contour regions (3M)** ✓ System has two poles at origin. ✓ Select S-plane enclosing entire right half except the origin. ➢ **Apply four sections and draw the F(s) contour (4M)** ✓ Four sections C1,C2,C3 and C4. ➢ **Finally draw all contour regions in single Nyquist plot (4M)** ✓ Closed loop system is unstable. ✓ Two poles of closed loop system are lying on the right half of s plane.
4.	**Construct Routh array and determine the stability of the system represented by the characteristics equation $S^5+S^4+2S^3+2S^2+3S+5=0$.Comment on the location of the roots of**

	characteristic equation. **(13M)** BTL2 **Answer: Page 4.14-Nagoor kani** ➢ **Form routh array from Characteristic equation (5M)** ➢ **Check first column of routh array (5M)** ✓ If it is positive, system is stable. ✓ If it is not positive, system is unstable. ➢ **Sign changes in first column (3M)** ✓ All are negative→all roots on left half of s plane. ✓ Sign changes→ corresponds to roots in right half of s plane.
5.	**Construct Routh array and determine the stability of the system represented by the characteristics equation $S^7+9S^6+24S^4+24S^3+24S^2+23S+15=0$comment on the location of the roots of characteristic equation. (13M)** BTL2 **Answer: Page 4.16-Nagoor kani** ➢ **Form Routh array from Characteristic equation (5M)** ➢ **Check the first column of the Routh array (5M)** ✓ If it is positive, system is stable. ✓ If it is not positive, system is unstable. ➢ **Sign changes in first column (3M)** ✓ All are negative→all roots on left half of s plane. ✓ Sign changes→ corresponds to roots in right half of s plane.
6.	**Design suitable lead compensator for a system unity feedback and having open loop transfer function G(S)= K/ S(S+4) (S+7) to meet the specifications.(i)%peak overshoot=12.63% , (ii) Wn=8 rad/sec, velocity error constant Kv>2.5. (13M)** BTL6 **Answer: Refer Page No.5.46** ➢ Find the value of K using velocity error constant **(1M)** ➢ Convert G(s) into time constant form & S=jw **(2M)** ➢ Find magnitude, phase angle & draw bode plot **(3M)**

	➢ Find PM & GM. If the PM is not matched with the given specifications, lead compensator is employed **(2M)** ➢ Using design procedure of lead compensator find compensator transfer function**.(3M)** ➢ Find overall transfer function. From the overall transfer function find PM. It will be matched with given specifications.**(2M)**
7.	**Construct Routh array and determine the stability of the system represented by the characteristics equation $S^4+8S^3+18S^2+16S+5=0$.Comment on the location of the roots of characteristic equation. (13M)** BTL2 **Answer: Page 4.13-Nagoor Kani** ➢ **Form Routh array from Characteristic equation (5M)** ➢ **Check the first column of the Routh array (5M)** ✓ If it is positive, system is stable. ✓ If it is not positive, system is unstable. ➢ **Sign changes in first column (3M)** ✓ All are negative→all roots on left half of s plane. ✓ Sign changes→ corresponds to roots in right half of s plane.
8.	**Construct Routh array and determine the stability of the system represented by the characteristics equation $S^6+2S^5+8S^4+12S^3+20S^2+16S+16=0$.Comment on the location of the roots of characteristic equation. (13M)** BTL2 **Answer: Page 4.13 -Nagoor Kani** ➢ **Form Routh array from Characteristic equation (5M)** ➢ **Check the first column of the Routh array (5M)** ✓ If it is positive, system is stable. ✓ If it is not positive, system is unstable. ➢ **Sign changes in first column (3M)** ✓ All are negative→all roots on left half of s plane. ✓ Sign changes→ corresponds to roots in right half of s plane.
9.	**Construct Routh array and determine the stability of the system represented by the**

characteristics equation $S^6+S^5+3S^4+3S^3+3S^2+2S+1=0$.Comment on the location of the roots of characteristic equation. (13M) BTL2

Answer: Page 4.20 -Nagoor Kani

- **Form Routh array from Characteristic equation (5M)**
- **Check the first column of the Routh array (5M)**
  - ✓ If it is positive, system is stable.
  - ✓ If it is not positive, system is unstable.
- **Sign changes in first column (3M)**
  - ✓ All are negative→all roots on left half of s plane.
  - ✓ Sign changes→ corresponds to roots in right half of s plane.

PART * C

1. **A unity feed back system has an open loop transfer function G(S)= K/ S(S+4) (S+80). Design a suitable phase lag compensators to achieve following specifications Kv= 30 and Phase margin 33 deg with usual notation. (15M)** BTL6

Answer: Page 4.13 -Nagoor Kani

Answer: Page 5.14 -Nagoor Kani

- Find the value of K using velocity error constant **(1M)**
- Convert G(s) into time constant form & S=jw **(2M)**
- Find magnitude, phase angle & draw bode plot **(3M)**
- Find PM & GM. If the PM is not matched with the given specifications, lag compensator is employed **(2M)**
- Using design procedure of lag compensator find compensator transfer function **(5M)**
- Find overall transfer function. From the overall transfer function find PM. It will be matched with given specifications **(2M)**

2. **Consider the unity feed back system whose OLTF is G(s) = K / s (s+3)(s+6). Design a lag-lead compensator to meet the following specifications. (i) Velocity error constant, Kv = 80, (ii) P.M 35º . (15M)** BTL6

	Answer: Page 5.55 -Nagoor Kani ➢ Find the value of K using velocity error constant **(1M)** ➢ Convert G(s) into time constant form & S=jw **(2M)** ➢ Find magnitude, phase angle & draw bode plot **(3M)** ➢ Find PM & GM. If the PM is not matched with the given specifications, lag lead compensator is employed **(2M)** ➢ Using design procedure of lag lead compensator find compensator transfer function **(4M)** ➢ Find overall transfer function. From the overall transfer function find PM. It will be matched with given specifications **(3M)**
3.	**Determine the range of K for stability of unity feedback system whose open loop transfer function is G(s) =K/s(s+1) (s+2). (15M)** BTL2 **Answer: Page 4.22-Nagoor Kani** ➢ **Form Routh array from Characteristic equation (5M)** ➢ **Check the first column of the Routh array (5M)** ✓ If it is positive, system is stable. ✓ If it is not positive, system is unstable. ➢ **Sign changes in first column (3M)** ✓ All are negative→all roots on left half of s plane. ✓ Sign changes→ corresponds to roots in right half of s plane. ➢ **K value (2M)**
4.	**The open loop transfer function of a unity feedback control system is given by G(s)=K/(s+2)(s+4)(s2+6s+25).By applying the Routh criterion ,discuss the stability of the closed loop system as a function of K. Determine the value of K which will cause sustained oscillations in the closed loop system. What are the corresponding oscillating frequencies? (15M)** BTL2 **Answer: Page 4.23-Nagoor Kani** ➢ **Form Routh array from Characteristic equation (5M)**

	➢ **Check the first column of the Routh array (5M)** ✓ If it is positive, system is stable. ✓ If it is not positive, system is unstable. ➢ **Sign changes in first column (3M)** ✓ All are negative→all roots on left half of s plane. ✓ Sign changes→ corresponds to roots in right half of s plane. ➢ **K value (2M)** ✓ K value is in the range of 0<K<666.25.
5.	**A unity feedback system has an OLTF G(s) = K / s(s+0.5). Design a Lead-Lag compensator is to meet the following specifications. ζ= 0.5,Wn=5 rad/sec, velocity error constant, Kv = 80. (15M)** BTL6 **Answer: Page 5.61 -Nagoor Kani** ➢ Find the value of K using velocity error constant **(1M)** ➢ Convert G(s) into time constant form & S=jw **(2M)** ➢ Find magnitude, phase angle & draw bode plot **(3M)** ➢ Find PM & GM. If the PM is not matched with the given specifications, lag lead compensator is employed **(2M)** ➢ Using design procedure of lag lead compensator find compensator transfer function **(4M)** ➢ Find overall transfer function. From the overall transfer function find PM. It will be matched with given specifications **(3M)**

UNIT V STATE VARIABLE ANALYSIS

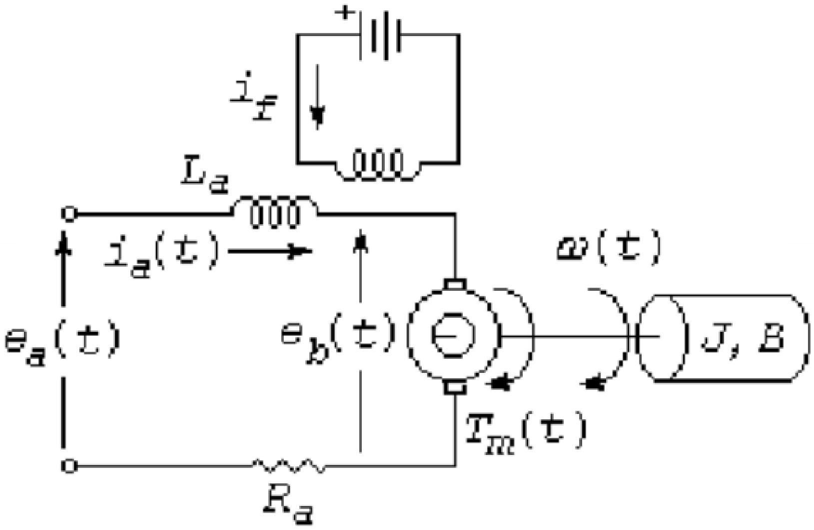
Concept of state variables – State models for linear and time invariant Systems – Solution of state and output equation in controllable canonical form – Concepts of controllability and observability – Effect of state feedback.

PART * A

Q.No.	Questions
1.	**What are the advantages of state space analysis?** BTL2 It can be applied to non-linear as well as time varying systems. Any type of input can be considered for designing the system. It can be conveniently applied to multiple input multiple output systems. The state variables selected need not necessarily be the physical quantities of the system.
2.	**What are phase variables?** BTL1 The phase variables are defined as the state variables which are obtained from one of the system variables and its derivatives.
3.	**Define state variable.** BTL1 The state of a dynamical system is a minimal set of variables(known as state variables) such that the knowledge of these variables at t-t0 together with the knowledge of the inputs for t > t0 , completely determines the behavior of the system for t > t0.
4.	**Write the general form of state variable matrix.** BTL1 The most general state-space representation of a linear system with m inputs, p outputs and n state variables is written in the following form: $\dot{X}$= AX + BU Y = CX + DU Where = state vector of order n X_1 U = input vector of order n X_1. A=System matrix of order n X_n. B=Input matrix of order n X_m C =output matrix of order p X_n D = transmission matrix of order p X_m.
5.	**What is the necessary condition to be satisfied for design using state feedback?** BTL2 The state feedback design requires arbitrary pole placements to achieve the desire performance. The necessary and sufficient condition to be satisfied for arbitrary pole placement is that the system is completely state controllable.
6.	**What is controllability?** BTL1 A system is said to be completely state controllable if it is possible to transfer the system state from any initial state X(t0) at any other desired state X(t), in specified finite time by a control vector U(t).
7.	**What is observability?** BTL1 A system is said to be completely observable if every state X(t) can be completely identified by measurements of the output Y(t) over a finite time interval.
8.	**What is similarity transformation?** BTL2 The process of transforming a square matrix A to another similar matrix B by a transformation P- 1AP = B is called similarity transformation. The matrix P is called transformation matrix.

9.	**What is meant by diagonalization?** BTL2 The process of converting the system matrix A into a diagonal matrix by a similarity transformation using the modal matrix M is called diagonalization.
10.	**What is modal matrix?** BTL2 The modal matrix is a matrix used to diagonalize the system matrix. It is also called diagonalization matrix. If A = system matrix M = Modal matrix And M^{-1}=inverse of modal matrix Then $M^{-1}AM$ will be a diagonalized system matrix
11.	**How modal matrix is determined?** BTL2 The modal matrix M can be formed from eigenvectors. Let m1, m2, m3 …. mn be the eigen vectors of the nth order system. Now the modal matrix M is obtained by arranging all the eigenvectors column wise as shown below. Modal matrix , M = [m1, m2, m3 …. mn].
12.	**What is the need for controllability test?** BTL2 The controllability test is necessary to find the usefulness of a state variable. If the state variables are controllable then by controlling (i.e. varying) the state variables the desired outputs of the system are achieved.
13.	**What is the need for observability test?** BTL2 The observability test is necessary to find whether the state variables are measurable or not. If the state variables are measurable then the state of the system can be determined by practical measurements of the state variables.
14.	**State the condition for controllability by Gilbert's method.** BTL2 **Case (i) when the eigen values are distinct:** Consider the canonical form of state model shown below which is obtained by using the transformation X=MZ. $\dot{X}= \Lambda Z + U$ $Y=Z + DU$ Where, $\Lambda = M^{-1}AM$, $= CM$, $= M^{-1}B$ and M = Modal matrix. In this case the necessary and sufficient condition for complete controllability is that, the matrix must have no row with all zeros. If any row of the matrix is zero then the corresponding state variable is uncontrollable. **Case (ii) when eigen values have multiplicity:** In this case the state modal can be converted to Jordan canonical form shown below : $Z= JZ + U$ $Y=Z + DU$ Where, $J = M^{-1}AM$ In this case the system is completely controllable, if the elements of any row of that correspond to the last row of each Jordan block are not all zero.
15.	**State the condition for observability by Gilbert's method**. BTL2 Consider the transformed canonical or Jordan canonical form of the state model shown below: which is obtained by using the transformation, X =MZ $Z= \Lambda Z + U$

	$Y=Z + DU$ (Or) $Z= JZ + U$ $Y=Z + DU$ where =CM and M=modal matrix. The necessary and sufficient condition for complete observability is that none of the columns of the matrix be zero. If any of the column has all zeros then the corresponding state variable is not observable.
16.	**State the duality between controllability and observability.** BTL2 The concept of controllability and observability are dual concepts and it is proposed by kalman as principle of duality. The principle of duality states that a system is completely state controllable if and only if its dual system is completely state controllable if and only if its dual system is completely observable or vice versa.
17.	**What is need for state observer?** BTL2 In certain systems the state variables may not be available for measurement and feedback. In such situations we need to estimate the un measurable state variables from the knowledge of input and output. Hence a state observer is employed which estimates the state variables from the input and output of the system. The estimated state variable can be used for feedback to design the system by pole placement.
18.	**How will you find the transformation matrix, Po to transform the state model to observable phase variable form?** BTL2 ➢ Compute the composite matrix for observability,Q_0. ➢ Determine the characteristic equation of the system $\|\lambda I -A \|=0$. ➢ Using the coefficients a1,a2,….an-1 of characteristic equation form a matrix, W. ➢ Now the transformation matrix, P_0 is given by $P_0=W\ Q_0T$.
19.	**Write the observable phase variable form of state model.** BTL1 The observable phase variable form of state model is given by the following equations $Z= A_0Z + B_0u$. $Y =C_0Z + Du$ Where, $A_0 =$, $B_0 =$ and $C_0 = [\ 0\ 0\ …..\ 0\ 1\ ]$.
	PART * B
1.	**Determine the state model of armature controlled DC motor. (13M)** BTL1 **Answer : Page 6.16 - Nagoor Kani** ➢ **Draw the electrical circuit (3M)**

	 ➢ **Write differential equations in terms of displacement (3M)** $$Va = i_aR_a + L_a\frac{di_a}{dt} + e_b$$ $$T = J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt}$$ ➢ **Apply the state variables to differential equation (2M)** ➢ **Rearrange the equation and derive state model (2M)** ➢ **Draw the block diagram for state equation and output equation (3M)**
2.	**Construct the state model for a system characterized by the differential equation $d^3y/dt^3+6d^2y/dt^2+11dy/dt+6y+u=0$. Give the block diagram representation of the state model. (13M)** BTL3 **Answer : Page 6.26 - Nagoor Kani** ➢ **Convert differential equations in to dot variables (2M)** ➢ **Apply the state variables to dot variables (2M)** ➢ **Rearrange the equation and derive state model (3M)** ➢ **Draw the block diagram for state equation and output equation (6M)**
3.	**Obtain the state model of the system whose open loop transfer function is given as, $Y(s)/U(s)=10/s^3+4s^2+2s+1$. (13M)** BTL3 **Answer : Page 6.29 - Nagoor Kani**

	➢ **Use inspection, cascade, signal flow graph method (1M)** ➢ **Take inverse Laplace transform & Convert differential equations in to dot variables (2M)** ➢ **Apply the state variables to dot variables (2M)** ➢ **Rearrange the equation and derive state model (3M)** ➢ **Draw the block diagram for state equation and output equation (5M)**
4.	**A feedback system has a closed loop transfer function Y(s)/U(s)=10(s+4)/s(s+1)(s+3),construct block diagram representation of the each state model. (13M)** BTL3 **Answer : Page 6.33 - Nagoor Kani** ➢ **Use inspection, cascade, signal flow graph method (1M)** ➢ **Take inverse Laplace transform & Convert differential equations in to dot variables (2M)** ➢ **Apply the state variables to dot variables (2M)** ➢ **Rearrange the equation and derive state model (3M)** ➢ **Draw the block diagram for state equation and output equation (5M)**
5.	**Determine the canonical state model of the system ,whose transfer function is T(s)= 2(s+5)/(s+1)(s+3)(s+4). (13M)** BTL4 **Answer : Page 6.36 - Nagoor Kani** ➢ **Use inspection, cascade, signal flow graph method (1M)** ➢ **Take inverse Laplace transform & Convert differential equations in to dot variables (2M)** ➢ **Apply the state variables to dot variables (2M)** ➢ **Rearrange the equation and derive state model (3M)** ➢ **Draw the block diagram for state equation and output equation (5M)**
6.	**Compute state transition matrix A= 0 -1.** **-2 -3 (13M)** BTL3 **Answer : Page 6.42 - Nagoor Kani** ➢ **Find eigen values by using |SI -A |=0 (4M)**

- **Find inverse matrix of |SI -A | (4M)**
- **Use partial fraction method to find A,B,C (2M)**
- **Find inverse Laplace of φ(s) to get φ(t) (3M)**

7. **Consider the state model given below, verify the system is observable and controllable.(Apr/May 2015) (13M)** BTL4

$$x = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -5 & -1 \end{bmatrix} X + \begin{bmatrix} 0 \\ 5 \\ -24 \end{bmatrix} u;\ y = [1\ 0\ 0]x + [0]u;$$

Answer : Page 6.61 - Nagoor Kani

- **From the state model identify A,B,C Matrix (2M)**
- **Use Gillberts method or Kalmans method (2M)**
- **In Gillberts method Find Ḃ and C. The value of Ḃ does not contain zero value then the system is completely controllable. The value of C does not contain zero value then the system is completely observable.(5M)**

Case (i) when the eigen values are distinct:

Consider the canonical form of state model shown below which is obtained by using the transformation X=MZ.

Ẋ= ΛZ + U

Y=Z + DU

Where, $\Lambda = M^{-1}AM$; = CM , = $M^{-1}B$ and M = Modal matrix.

In this case the necessary and sufficient condition for complete controllability is that, the matrix must have no row with all zeros. If any row of the matrix is zero then the corresponding state variable is uncontrollable.

Case (ii) when eigen values have multiplicity:

In this case the state modal can be converted to Jordan canonical form shown below :

Z= JZ + U

Y=Z + DU Where, $J = M^{-1}AM$

In this case the system is completely controllable, if the elements of any row of that correspond to the last row of each Jordan block are not all zero.

- **In Kalmans method Find Qo and Qc. The value of Qo does not contain zero value then the system is completely controllable. The value of Qo does not contain zero value then the system is completely observable.(4M)**

8. **Test the controllability and observability by using any one method of the given state space representation model.(Apr/May 2015). (13M)** BTL4

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{bmatrix}=\begin{bmatrix}0 & 0 & 1\\ -2 & -3 & 0\\ 0 & 2 & -3\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}+\begin{bmatrix}0\\ 2\\ 0\end{bmatrix}u\,;\ y=[1\,0\,0]\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}$$

Answer : Page 5.78 - Nagoor Kani

- **From the state model identify A,B,C Matrix (2M)**
- **Use Gillberts method or Kalmans method (2M)**
- **In Gillberts method Find Ḃ and C. The value of Ḃ does not contain zero value then the system is completely controllable. The value of C does not contain zero value then the system is completely observable.(5M)**

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Consider the canonical form of state model shown below which is obtained by using the transformation X=MZ.
Ẋ= ΛZ + U
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Where, Λ = M^{-1}AM; = CM , = M^{-1}B and M = Modal matrix.
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Z= JZ + U
Y=Z + DU Where, J = M^{-1}AM

In this case the system is completely controllable, if the elements of any row of that correspond to the last row of each Jordan block are not all zero.

- **In Kalmans method Find Qo and Qc. The value of Qo does not contain zero value then the system is completely controllable. The value of Qo does not contain zero value then the system is completely observable.(4M)**

Consider the following differential equation ,obtain the state model in diagonal form. (13M) (nov/dec 2015) BTL3

$$\dddot{y} + 6\ddot{y} + 11\dot{y} + 6y = 6u$$

9. **Answer : Page 5.34 - Nagoor Kani**

- **Apply the state variables to dot variables (4M)**
- **Rearrange the equation and derive state model (4M)**
- **Draw the block diagram for state equation and output equation(5M)**

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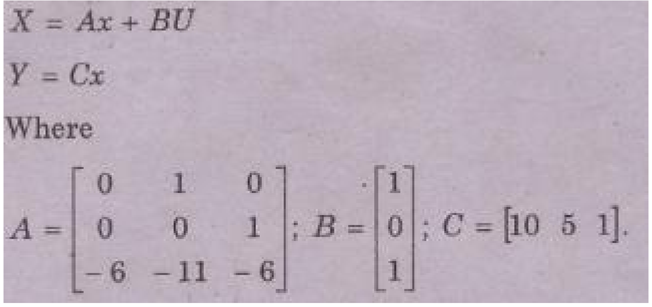
Consider the system defined by



$X = Ax + BU$

$Y = Cx$

Where

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}; B = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix}; C = [10 \ \ 5 \ \ 1].$$

Check controllability and observability. (13M) (nov/dec 2015) BTL3

Answer : Page 5.80 - Nagoor Kani

- **From the state model identify A,B,C Matrix (2M)**
- **Use Gillberts method or Kalmans method (2M)**
- **In Gillberts method Find $\dot{B}$ and C. The value of $\dot{B}$ does not contain zero value then the system is completely controllable. The value of C does not contain zero value then the system is completely observable.(5M)**

Case (i) when the eigen values are distinct:
Consider the canonical form of state model shown below which is obtained by using the transformation X=MZ.
$\dot{X}= \Lambda Z + U$
Y=Z + DU
Where, $\Lambda = M^{-1}AM$; = CM , = $M^{-1}B$ and M = Modal matrix.
In this case the necessary and sufficient condition for complete controllability is that, the matrix must have no row with all zeros. If any row of the matrix is zero then the corresponding state variable is uncontrollable.
Case (ii) when eigen values have multiplicity:
In this case the state modal can be converted to Jordan canonical form shown below :
Z= JZ + U
Y=Z + DU Where, $J = M^{-1}AM$

In this case the system is completely controllable, if the elements of any row of that correspond to the last row of each Jordan block are not all zero.

- **In Kalmans method Find Qo and Qc. The value of Qo does not contain zero value then the system is completely controllable. The value of Qo does not contain zero value then the system is completely observable.(4M)**

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PART * C

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Test the controllability of the following state model by using both the methods. (15M) (nov/dec 2016) BTL4

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$$\begin{bmatrix}\dot{x}_1\\\dot{x}_2\\\dot{x}_3\end{bmatrix}=\begin{bmatrix}0&0&1\\-2&-3&0\\0&+2&-3\end{bmatrix}\begin{bmatrix}x_1\\x_2\\x_3\end{bmatrix}+\begin{bmatrix}0\\2\\0\end{bmatrix}u;\ y=\begin{bmatrix}1&0&0\end{bmatrix}\begin{bmatrix}x_1\\x_2\\x_3\end{bmatrix}.$$

Answer : Page 2.26 - Nagoor Kani

- **From the state model identify A,B,C Matrix (2M)**
- **Use Gillberts method or Kalmans method (2M)**
- **In Gillberts method Find $\dot{B}$ and C. The value of $\dot{B}$ does not contain zero value then the system is completely controllable. The value of C does not contain zero value then the system is completely observable.(6M)**

Case (i) when the eigen values are distinct:

Consider the canonical form of state model shown below which is obtained by using the transformation X=MZ.

$\dot{X}= \Lambda Z + U$

$Y=Z + DU$

Where, $\Lambda = M^{-1}AM$; = CM , = $M^{-1}B$ and M = Modal matrix.

In this case the necessary and sufficient condition for complete controllability is that, the matrix must have no row with all zeros. If any row of the matrix is zero then the corresponding state variable is uncontrollable.

Case (ii) when eigen values have multiplicity:

In this case the state modal can be converted to Jordan canonical form shown below :

$Z= JZ + U$

$Y=Z + DU$ Where, $J = M^{-1}AM$

In this case the system is completely controllable, if the elements of any row of that correspond to the last row of each Jordan block are not all zero.

- **In Kalmans method Find Qo and Qc. The value of Qo does not contain zero value then the system is completely controllable. The value of Qo does not contain zero value then the system is completely observable.(5M)**

2.

Verify the system is completely controllable and observable.(15N) (nov/dec 2016) BTL4

$$[\dot{x}(t)]=\begin{bmatrix}0&0&1\\-2&-3&0\\0&2&-3\end{bmatrix}\begin{bmatrix}x_1(t)\\x_2(t)\\x_3(t)\end{bmatrix}+\begin{bmatrix}0\\2\\0\end{bmatrix}u(t);\ y(t)=\begin{bmatrix}1&0&0\end{bmatrix}\begin{bmatrix}x_1(t)\\x_2(t)\\x_3(t)\end{bmatrix}.$$

Answer : Page 5.82 - Nagoor Kani

- **From the state model identify A,B,C Matrix (2M)**
- **Use Gillberts method or Kalmans method (2M)**

	➢ **In Gillberts method Find $\dot{B}$ and C. The value of $\dot{B}$ does not contain zero value then the system is completely controllable. The value of C does not contain zero value then the system is completely observable.(6M)** **Case (i) when the eigen values are distinct:** Consider the canonical form of state model shown below which is obtained by using the transformation X=MZ. $\dot{X}= \Lambda Z + U$ $Y=Z + DU$ Where, $\Lambda = M^{-1}AM$; = CM , = $M^{-1}B$ and M = Modal matrix. In this case the necessary and sufficient condition for complete controllability is that, the matrix must have no row with all zeros. If any row of the matrix is zero then the corresponding state variable is uncontrollable. **Case (ii) when eigen values have multiplicity:** In this case the state modal can be converted to Jordan canonical form shown below : $Z= JZ + U$ $Y=Z + DU$ Where, $J = M^{-1}AM$ In this case the system is completely controllable, if the elements of any row of that correspond to the last row of each Jordan block are not all zero. ➢ **In Kalmans method Find Qo and Qc. The value of Qo does not contain zero value then the system is completely controllable. The value of Qo does not contain zero value then the system is completely observable.(5M)**
3.	**Check the controllability of the following state model. (15M) (nov/dec 2015)** BTL4 $$A=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ -6 & -11 & -6\end{bmatrix}; B=\begin{bmatrix}1\\ 0\\ 1\end{bmatrix}; C^T=\begin{bmatrix}10\\ 5\\ 1\end{bmatrix};$$ **Answer : Page 5.84 - Nagoor Kani** ➢ **From the state model identify A,B,C Matrix (2M)** ➢ **Use Gillberts method or Kalmans method (2M)** ➢ **In Gillberts method Find $\dot{B}$ and C. The value of $\dot{B}$ does not contain zero value then the system is completely controllable. The value of C does not contain zero value then the system is completely observable.(6M)** **Case (i) when the eigen values are distinct:** Consider the canonical form of state model shown below which is obtained by using the transformation X=MZ.

$\dot{X}= \Lambda Z + U$

$Y=Z + DU$

Where, $\Lambda = M^{-1}AM$; = CM , = $M^{-1}B$ and M = Modal matrix.

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- **In Kalmans method Find Qo and Qc. The value of Qo does not contain zero value then the system is completely controllable. The value of Qo does not contain zero value then the system is completely observable.(5M)**

OBJECTIVE TYPE QUESTIONS

UNIT –I SYSTEMS AND THEIR REPRESENTATION

1) Which terminology deals with the excitation or stimulus applied to the system from an external source for the generation of an output?

a. Input signal
b. Output signal
c. Error signal
d. Feedback signal

ANSWER: (a) Input signal

2) Which among the following is not an advantage of an open loop system?

a. Simplicity in construction & design
b. Easy maintenance
c. rare problems of stability
d. Requirement of system recalibration from time to time

ANSWER: (d) Requirement of system recalibration from time to time

3) Which notation represents the feedback path in closed loop system representation?

a. b (t)
b. c (t)
c. e (t)
d. r (t)

ANSWER: (a) b (t)

4) Which among the following represents an illustration of closed loop system?

a. Automatic washing machine
b. Automatic electric iron
c. Bread toaster
d. Electric hand drier

ANSWER: (b) Automatic electric iron

5) How is an output represented in the control systems?

a. r (t)
b. c (t)
c. x (t)
d. y (t)

ANSWER: (b) c (t)

6) The output is said to be zero state response because ______conditions are made equal to zero.

a. Initial
b. Final
c. Steady state
d. Impulse response

ANSWER: (a) Initial

7) Basically, poles of transfer function are the Laplace transform variable values which causes the transfer function to become ___________

a. Zero
b. Unity
c. Infinite
d. Average value

ANSWER :(c) Infinite

8) By equating the denominator of transfer function to zero, which among the following will be obtained?

a. Poles
b. Zeros
c. Both a and b
d. None of the above

ANSWER: (a) Poles

9) The output signal is fed back at the input side from the _________point

a. Summing
b. Differential
c. Take-off
d. All of the above

ANSWER: (c) Take-off

10) In a parallel combination, the direction of flow of signals through blocks in parallel must resemble to the main _______

a. Forward
b. Feedback
c. opposite
d. Diagonal

ANSWER: (a) Forward

11) While shifting a take-off point after the summing point, which among the following should be added?

a. Summing point in series with take-off point
b. Summing point in parallel with take-off point
c. Block of reciprocal transfer function
d. Block of inverse transfer function

ANSWER: (a) Summing point in series with take-off point

12) Consider the assertions related to block diagram. Which among them represents the precise condition?

A. Block diagram is used for analysis & design of control system.
B. Block diagram also provides the information regarding the physical construction of the system.

a. A is true, B is false
b. A is false, B is true
c. Both A & B are true
d. Both A & B are false

ANSWER: (a) A is true, B is false

13) In a signal flow graph, nodes are represented by small _____

a. Circles
b. Squares
c. Arrows
d. Pointers

ANSWER: (a) Circles

14) According to signal flow graph, which among the following represents the relationship between nodes by drawing a line between them?

a. Branch
b. Self-loop
c. Semi-node
d. Mesh

ANSWER: (a) Branch

15) Which type of node comprises incoming as well as outgoing branches?

a. Source node
b. Sink node
c. Chain node
d. Main node

ANSWER: (c) Chain node

16) Where are the dummy nodes added in the branch with unity gain?

a. at input & output nodes
b. between chain nodes
c. Both a and b
d. None of the above

ANSWER: (a) At input & output nodes

17) According to the property of impulse test signal, what is the value of an impulse at t = 0?

a. Zero
b. Unity
c. Infinite
d. Unpredictable

ANSWER: (c) Infinite

18)Amount of additional open loop phase shift required at unity gain to make the closed loop system unstable is called

a. gain margin

b.phase margin

c.amplitude margin

d.frequency margin

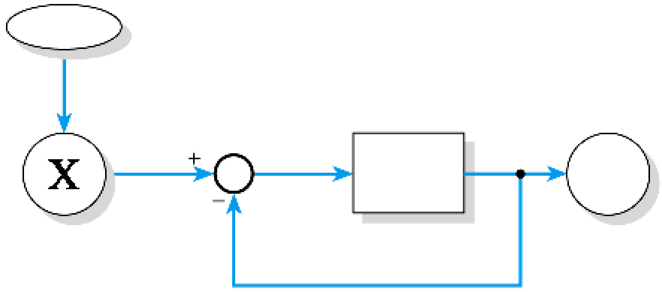
19) The diagram below shows a closed loop control system. What element is represented by the circle labelled X?

a. The goal

b. The forward path

c. The error signal

d. The user



20) **Under what conditions does the gain of a feedback system approximate to 1/*B*?**

a. The loop gain AB>>1

b. The feedback path gain B >>1.

c. The forward path gain A>>1

d. The loop gain AB<<1

UNIT –II TIME RESPONSE

21) On the basis of an output response, into how many parts can the s-plane be divided?

a. 2
b. 3
c. 4
d. 6

ANSWER: (b) 3

22) If the complex conjugate poles are located at RHP, what would be the nature of corresponding impulse response?

a. Exponential
b. damping oscillations
c. increasing amplifier
d. Constant amplitude oscillations

ANSWER: (c) Increasing amplifier

23) Which among the following are solely responsible in determining the speed of response of control system?

a. Poles
b. Zeros
c. Speed of input
d. All of the above

ANSWER: (a) Poles

24) If a pole is located at s = -5 in left-hand plane (LHP), how will it be represented in Laplace domain?

a. 1/ s + 5
b. 1/ s – 5
c. s/ s + 5
d. s/ s – 5

ANSWER: (a) 1/ s + 5

25) In second order system, which among the following remains independent of gain (k)?

a. Open loop poles
b. closed loop poles
c. Both a and b
d. None of the above

ANSWER: (a) Open loop poles

26) If a linear system is subjected to an input r (t) = Asin(ωt), what output will be generated?

a. c (t) = B sin (ωt + Φ)
b. c (t) = B cos (ωt + Φ)
c. c (t) = B tan (ωt + Φ)
d. c (t) = B cot (ωt + Φ)

ANSWER: (a) c (t) = B sin (ωt + Φ)

27) If an error signal e (t) of an ON-OFF controller is found to be greater than zero, what would be its output?

a. 10%
b. 50%
c. 80%
d. 100%

ANSWER: (d) 100%

28) Which time is responsible for introducing an error in the temperature regulation of applications associated with ON-OFF controllers?

a. Rise time
b. Dead time
c. switching time
d. Decay time

ANSWER: (b) Dead time

29) Which controller has the potential to eliminate/overcome the drawback of offset in proportional controllers?

a. P-I
b. P-D
c. Both a and b
d. None of the above

ANSWER: (a) P-I

30) In P-I controller, what does an integral of a function compute?

a. Density of curve
b. Area under the curve
c. Volume over the curve
d. Circumference of curve

ANSWER: (b) Area under the curve

31) Which among the following controls the speed of D.C. motor?

a. Galvanometer
b. Gauss meter
c. Potentiometer
d. Tachometer

ANSWER: (d) Tachometer

32) Into which energy signal does the position sensor convert the measured position of servomotor in servomechanisms?

a. Mechanical
b. Electrical
c. Thermal
d. Light

ANSWER: (b) Electrical

33) What is the value of steady state error in closed loop control systems?

a. Zero
b. Unity
c. Infinity
d. Unpredictable

ANSWER: (a) Zero

34) A good control system should be sensitive to __________

a. Internal disturbances
b. Environmental parameters
c. parametric variations
d. Input signals (except noise)

ANSWER: (d) Input signals (except noise)

35) If a signal is passed through an integrator, it _____the amplitude of noise signal.

a. Enhances
b. Reduces
c. Stabilizes
d. Factorizes

ANSWER: (b) Reduces

36) Laplace transform of an impulse response is regarded as _____function of the system

a. Analytic
b. Parabolic
c. Transfer
d. Hypothetical

ANSWER: (c) Transfer

37) The fundamental function of a tachometer is the conversion of angular _______ into voltage

a. Velocity
b. Displacement
c. Acceleration
d. Current

ANSWER: (a) Velocity

38) If finite number of blocks are connected in series or cascade configuration, then how are the blocks combined algebraically?

a. by addition
b. By multiplication
c. By differentiation
d. By integration

ANSWER: (b) By multiplication

39) Associative law for summing point is applicable only to those summing points which are __________connected to each other.

a. Directly
b. Indirectly
c. Orthogonally
d. Diagonally

ANSWER: (a) Directly

40) For the elimination of feedback loops, the derivation based on transfer function of ______ loop is used.

a. Open
b. Closed
c. Both a and b
d. None of the above

ANSWER: (b) Closed

UNIT –III FREQUENCY RESPONSE

41) Which plots in frequency domain represent the two separate plots of magnitude and phase against frequency in logarithmic value?

a. Polar plots
b. Bode plots
c. Nyquist plots
d. All of the above

ANSWER: (b) Bode plots

42) How is the sinusoidal transfer function obtained from the system transfer function in frequency domain?

a. Replacement of 'jω' by 's'
b. Replacement of 's' by 'ω'
c. Replacement of 's' by 'jω'
d. Replacement of 'ω' by 's'

ANSWER: (c) Replacement of 's' by 'jω'

43) According to the principle of log-scales, if the ratio between two points is same, then the two points get ________equally.

a. United
b. Separated
c. Multiplexed
d. Mixed

ANSWER: (b) Separated

44) If a pole is located at origin, how does it get represented on the magnitude plot?

a. -10 log (ω) dB
b. -20 log (ω) dB
c. -40 log (ω) dB
d. -60 log (ω) dB

ANSWER: (b) -20 log (ω) dB

45) Due to an addition of pole at origin, the polar plot gets shifted by ___ at ω = 0?

a. -45°
b. -60°
c. -90°
d. -180°

ANSWER: (c) -90°

46) Consider the system represented by the equation given below. What would be the total phase value at $\omega = 0$?
$200/ [s^3 (s + 3) (s + 6) (s + 10)]$

a. -90°
b. -180°
c. -270°
d. -360°

ANSWER: (c) -270°

47) At which condition of 'ξ', resonant peak does not exist and its maximum value is considered to be unity along with zero resonant frequency?

a. $0 < \xi < 0.707$
b. $\xi > 0.707$
c. $\xi = 0$
d. $\xi = 1$

ANSWER: (b) $\xi > 0.707$

48) If the damping of the system becomes equal to zero, which condition of the resonant frequency is likely to occur?

a. $\omega_r = \omega_d$
b. $\omega_r > \omega_n$
c. $\omega_r < \omega_n$
d. $\omega_r = \omega_n$

ANSWER: (d) $\omega_r = \omega_n$

49) If the resonant peak is estimated to be '5', which among the following would be the correct value of damping?

a. $\xi = 0.3$
b. $\xi = 1$
c. $\xi = 3.2$
d. $\xi = 5.55$

ANSWER: (a) ξ = 0.3

50) If a system is said to have a damping ξ = 0.5532 with the natural frequency ω_n = 2 rad/sec, what will be the value of resonant frequency (ω_r)?

a. 1.2456 rad/s
b. 1.7352 rad/s
c. 2.3421 rad/s
d. 3.66 rad/s

ANSWER: (a) 1.2456 rad/s

51) In frequency response, the resonance frequency is basically a measure of _______ of response.

a. Speed
b. Distance
c. Angle
d. Curvature

ANSWER: (a) Speed

52) The frequency at which the phase of the system acquires ____ is known as 'Phase crossover frequency'.

a. 90°
b. -90°
c. 180°
d. -180°

ANSWER: (d) -180°

53) At which frequency does the magnitude of the system becomes zero dB?

a. Resonant frequency
b. Cut-off frequency
c. Gain crossover frequency
d. Phase crossover frequency

ANSWER: (c) Gain crossover frequency

54) If the phase angle at gain crossover frequency is estimated to be -105°, what will be the value of phase margin of the system?

a. 23°
b. 45°

c. 60°
d. 75°

ANSWER: (d) 75°

55) The system is said to be marginally stable, if gain margin is ______

a. 0
b. 1
c. +∞
d. None of the above

ANSWER: (c) +∞

56) If the constant 'k' is positive, then what would be its contribution on the phase plot?

a. 0°
b. 45°
c. 90°
d. 180°

ANSWER: (a) 0°

57) If the unity feedback system is given by the open loop transfer function $G(s) = ks^2 / [(1 + 0.3s) (1+ 0.05s)]$, what would be the initial slope of magnitude plot?

a. 20 dB/decade
b. 40 dB/decade
c. 60 dB/decade
d. Unpredictable

ANSWER: (b) 40 dB/decade

58) If the system is represented by $G(s) H(s) = k (s+7) / s (s +3) (s + 2)$, what would be its magnitude at $\omega = \infty$?

a. 0
b. ∞
c. 7/10
d. 21

ANSWER: (a) 0

59) While specifying the angle and magnitude conditions, angles are added whereas magnitudes get ________

a. Subtracted
b. Multiplied
c. Divided
d. All of the above

ANSWER: (b) Multiplied

60) The magnitude & phase relationship between _________input and the steady state output is called as frequency domain.

a. Step
b. Ramp
c. Sinusoidal
d. Parabolic

ANSWER: (c) Sinusoidal

61) Which unit is adopted for magnitude measurement in Bode plots?

a. Degree
b. Decimal
c. Decibel
d. Deviation

ANSWER: (b) Decibel

62) In an octave frequency band, the ratio of f_2 / f_1 is equivalent to ________

a. 2
b. 4
c. 8
d. 10

ANSWER: (a) 2

63) In polar plots, what does each and every point represent w.r.t magnitude and angle?

a. Scalar
b. Vector
c. Phasor
d. Differentiator

ANSWER: (c) Phasor

UNIT –IV STABILITY AND COMPENSATOR DESIGN

64) Root locus specifies the movement of closed loop poles especially when the gain of system ________

a. Remains constant
b. Exhibit variations
c. gives zero feedback
d. Gives infinite poles

ANSWER :(b) Exhibit variations

65) Which condition is used to verify the existence of a particular point on the root locus?

a. Amplitude
b. Frequency
c. Magnitude
d. Angle

ANSWER: (d) Angle

66) In polar plots, if a pole is added at the origin, what would be the value of the magnitude at Ω = 0?

a. Zero
b. Infinity
c. Unity
d. Unpredictable

ANSWER: (b) Infinity

67) Conventional control theory is applicable to ______ systems

a. SISO
b. MIMO
c. Time varying
d. Non-linear

ANSWER: (a) SISO

68) For the transfer function given below, where does the zero of the system lie?

G(s) = 5s -1 / s^2 + 5s + 4

a. s = -1 & s = -1/4
b. s = -4 & s = -1

c. s = 1/5
d. s = -1/5

ANSWER: (c) s = 1/5

69) Consider that the pole is located at origin and its Laplace representation is 1/s. What would be the nature of pole response?

a. Rising exponential
b. Decaying exponential
c. Sinusoidal
d. Constant value

ANSWER: (d) Constant value

70) In accordance to relative stability, the settling time exhibits inversely proportional nature to ________parts of roots

a. Real positive
b. real negative
c. Imaginary positive
d. Imaginary negative

ANSWER: (b) Real negative

71) In Routh array, if zero is found in the first column, then by which term it needs to be replaced?

a. δ
b. η
c. σ
d. ε

ANSWER: (d) ε

72) In a second order system, if the damping ratio is greater than equal to '1', then what would be the nature of roots?

a. Imaginary
b. Real and equal
c. real but not equal
d. Complex conjugate

ANSWER: (c) Real but not equal

73) For drawing root locus, the angle of asymptote yields the direction along which _________branches approach to infinity.

a. p + z
b. p – z
c. p / z
d. p x z

ANSWER: (b) p – z

74) Which point on root locus specifies the meeting or collision of two poles?

a. Centroid
b. Break away point
c. Stability point
d. Anti-break point

ANSWER: (b) Break away point

75) What should be the nature of root locus about the real axis?

a. Asymmetric
b. Symmetric
c. Exponential
d. Decaying

ANSWER: (b) Symmetric

76) If the system is specified by open loop transfer function G(s) H(s) = k / s(s+3) (s + 2), how many root loci proceed to end at infinity?

a. 2
b. 3
c. 5
d. 6

ANSWER: (b) 3

77) Which among the following are the interconnected units of state diagram representation?

a. Scalars
b. Adders
c. Integrators
d. All of the above

ANSWER: (d) All of the above

78) Which among the following plays a crucial role in determining the state of dynamic system?

a. State variables
b. State vector
c. State space
d. State scalar

ANSWER: (a) State variables

79) In P-D controller, the derivative action plays a significant role in increasing _______ of response.

a. Time
b. Distance
c. Speed
d. Volume

ANSWER :(c) Speed

80) In addition to storage instructions, PLC controls __________

a. Logic sequence timing
b. counting
c. Arithmetic operations
d. All of the above

ANSWER: (d) All of the above

81) Which is the correct sequence of operational steps necessary for proper operation of an elevator (lift) control mechanism?1. Up switch
2. Stop switch
3. Down switch
4. Start switch

a. 1-2-3-4
b. 2-1-4-3
c. 4-2-1-3
d. 3-1-2-4

ANSWER: (c) 4-2-1-3

82) How many digital inputs are present in PLCs?

a. 4
b. 8
c. 16
d. 32

ANSWER: (c) 16

83) Which system exhibits the initiation of corrective action only after the output gets affected?

a. Feed forward
b. Feedback
c. Both a and b
d. None of the above

ANSWER: (b) Feedback

84) Consider the equation $S^3 + 3s^2 + 5s + 2 = 0$. How many roots are located in left half of s-plane?

a. Zero
b. Two
c. Three
d. Four

ANSWER: (c) Three

84) If the system is represented by characteristic equation $s^6 + s^4 + s^3 + s^2 + s + 3 = 0$, then the system is_________

a. Stable
b. unstable
c. marginally stable
d. Unpredictable

ANSWER: (b) Unstable

85) If poles are added to the system, where will the system tend to shift the root locus?

a. to the left of an imaginary axis
b. To the right of an imaginary axis
c. At the center
d. No shifting takes place

ANSWER: (b) To the right of an imaginary axis

86) For a unity feedback system with $G(s) = 10 / s^2$, what would be the value of centroid?

a. 0
b. 2
c. 5
d. 10

ANSWER: (a) 0

87) According to Nyquist stability criterion, where should be the position of all zeros of q(s) corresponding to s-plane?

a. On left half
b. At the center
c. On right half
d. Random

ANSWER: (a) On left half

88) Consider a feedback system with gain margin of about 30. At what point does Nyquist plot crosses negative real axis?

a. -3
b. -0.3
c. -30
d. -0.03

ANSWER :(b) -0.3

89) For Nyquist contour, the size of radius is _______

a. 25
b. 0
c. 1
d. ∞

ANSWER :(d) ∞

90) If a Nyquist plot of G (jω) H (jω) for a closed loop system passes through (-2, j0) point in GH plane, what would be the value of gain margin of the system in dB?

a. 0 dB
b. 2.0201 dB
c. 4 dB
d. 6.0205 dB

ANSWER: (d) 6.0205 dB

91) Which principle specifies the relationship between enclosure of poles & zeros by s-plane contour and the encirclement of origin by q(s) plane contour?

a. Argument
b. Agreement
c. Assessment
d. Assortment

ANSWER: (a) Argument

UNIT –V STATE VARIABLE ANALYSIS

92) Which among the following is/are an/the illustration/s of a sinusoidal input?

a. Setting the temperature of an air conditioner
b. Input given to an elevator
c. checking the quality of speakers of music system
d. All of the above

ANSWER: (c) Checking the quality of speakers of music system

93) State space analysis is applicable even if the initial conditions are _____

a. Zero
b. Non-zero
c. Equal
d. Not equal

ANSWER: (b) Non-zero

94) In block diagram representation, what do the lines connecting the blocks, known as?

a. Branches
b. Nodes
c. Datums
d. Sources

ANSWER :(a) Branches

95) In a signal flow graph method, how is an overall transfer function of a system obtained?

a. Poisson's equation
b. Block diagram reduction rules
c. Mason's equation
d. Lagrange's equation

ANSWER: (c) Mason's equation

96) While solving signal flow graph using Mason's gain equation, what does the second letter in two subscript notation of 'L' stand for?

a. Serial number of loop
b. Parallel number of loop
c. Number of touching loops
d. Number of non-touching loops

ANSWER: (d) Number of non-touching loops

97) For which systems are the signal flow graphs applicable?

a. Causal
b. Invertible
c. linear time invariant system
d. Dynamic

ANSWER: (c) Linear time invariant system

98) Two loops are said to be non-touching only if no common ______exists between them.

a. Loop
b. Feedback path
c. Branch
d. Node

ANSWER: (d) Node

99) In time domain system, which response has its existence even after an extinction of transient response?

a. Step response
b. Impulse response
c. Steady state response
d. All of the above

ANSWER: (c) Steady state response

100) which among the following is represented by a parabolic input signal?

a. Position
b. Force

c. Velocity
d. Acceleration

ANSWER: (d) Acceleration

101) Type 0 systems are unsuitable ___________

a. for ramp inputs
b. If the input is parabolic in nature
c. Both a and b
d. None of the above

ANSWER: (c) Both a and b

102) if a type 0 system is subjected to step input, what is its effect on steady state error?

a. It increases continuously
b. It remains constant
c. It decreases monotonically
d. It gets subjected to another input

ANSWER: (b) It remains constant

103) what should be the nature of bandwidth for a good control system?

a. Large
b. Small
c. Medium
d. All of the above

ANSWER: (a) Large

104) if an impulse response of a system is e^{-5t}, what would be its transfer function?

a. 1/ s – 5
b. 1/ s + 5
c. (s+1) / (s+5)
d. $(s^2 – 5s)/ (s-5)$

ANSWER: (b) 1/ s + 5

105) which among the following constitute the state model of a system in addition to state equations?

a. Input equations
b. Output equations

c. State trajectory
d. State vector

ANSWER: (b) Output equations

106) State model representation is possible using _________

a. Physical variables
b. Phase variables
c. Canonical state variables
d. All of the above

ANSWER: (d) All of the above

107) which mechanism in control engineering implies an ability to measure the state by taking measurements at output?

a. Controllability
b. Observability
c. Differentiability
d. Adaptability

ANSWER: (b) Observability

108) According to the property of state transition method, e^0 is equal to _____

a. I
b. A
c. e^{-At}
d. $-e^{At}$

ANSWER: (a) I

109) which among the following is a disadvantage of modern control theory?

a. Implementation of optimal design
b. Transfer function can also be defined for different initial conditions
c. Analysis of all systems take place
d. Necessity of computational work

ANSWER: (d) Necessity of computational work

110) which among the following is a unique model of a system?

a. Transfer function
b. State variable
c. Both a and b
d. None of the above

ANSWER: (a) Transfer function

111) which architectural unit/block of PLC decides the sequence of different operations to be executed by means of instructions written in memory?

a. Memory
b. Programming software
c. I/O interface
d. CPU

ANSWER: (d) CPU

112) which among the following units of PLC is adopted to convey the control plan to CPU?

a. Memory
b. Power supply unit
c. I/O interface
d. Programming software

ANSWER: (d) Programming software

113) which among the following are the elements of rotational motion?

a. Mass, spring, Friction
b. Inertia, Damper, spring
c. Work, Energy, Power
d. Force, Pressure, Viscosity

ANSWER: (b) Inertia, Damper, spring

114) match the following notations with their meanings:

A. G(s) ——— 1) Laplace of error signal
B. H(s) ——— 2) Laplace of output signal
C. C(s) ——— 3) Forward transfer function
D. E(s) ——— 4) Feedback transfer function

a. A- 2, B- 3, C- 1, D- 4
b. A- 3, B- 4, C- 2, D- 1

c. A- 2, B- 3, C- 4, D- 1
d. A- 1, B- 2, C- 3, D- 4

ANSWER: (b) A- 3, B- 4, C- 2, D- 1

115) at summing point, more than one signal can be added or _________

a. Subtracted
b. Multiplied
c. Both a and b
d. None of the above

ANSWER: (a) Subtracted

116) the value of variables at each node is _________the algebraic sum of all signals arriving at that node.

a. Less than
b. Equal to
c. Greater than
d. None of the above

ANSWER: (b) Equal to

117) in signal flow graph, the product of all ______gains while going through a forward path is known as 'Path gain'.

a. Branch
b. Path
c. Node
d. Loop

ANSWER: (a) Branch

118) if a type 1 system is subjected to parabolic input, what will be the value of steady state error?

a. 0
b. 100
c. Constant k
d. Infinite

ANSWER: (d) Infinite

119) on which factor does the steady state error of the system depend?

a. Order
b. Type
c. Size
d. Prototype

ANSWER: (b) Type

120) if ‘ξ’ approaches to zero, the peak resonance would ________

a. Also be zero
b. be unity
c. Tend to infinity
d. become equal to peak overshoot

ANSWER: (c) Tend to infinity