JEPPIAAR
INSTITUTE OF TECHNOLOGY
"Self-Belief | Self Discipline | Self Respect"

QUESTION BANK

Regulation : 2017

Year : III

Semester : 06

Batch : 2017-2021

Academic Year : 2019-2020

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Vision of the Institution:

Jeppiaar Institute of Technology aspires to provide technical education in futuristic technologies with the perspective of innovative, industrial and social application for the betterment of humanity.

Mission of the Institution:

- To produce competent and disciplined high-quality professionals with the practical skills necessary to excel as innovative professionals and entrepreneurs for the benefit of the society.
- To improve the quality of education through excellence in teaching and learning, research, leadership and by promoting the principles of scientific analysis, and creative thinking.
- To provide excellent infrastructure, serene and stimulating environment that is most conducive to learning.
- To strive for productive partnership between the Industry and the Institute for research and development in the emerging fields and creating opportunities for employability.
- To serve the global community by instilling ethics, values and life skills among the students needed to enrich their lives.

Department Vision

To foster contemporary Skills in the field of Electrical and Electronics Engineering with innovatory Skills, Global Understanding and Nation building for the progress of Humankind.

Department Mission

- To Encompass Quality Engineers with skills as persevere to enrich the global technically.
- To engage in research activities leading to innovative application of technology with Industrial approach for the benefit of mankind.
- To provide quality structure and beneficial learning system.
- To enable them as responsible human who value Ethics and environment.

PEO's of the Department

PEO1: To provide students with the fundamental Knowledge, methodologies and use of cutting-edge Technologies.

PEO2: To provide students with an awareness and skills in lifelong learning and self-education.

PEO3: To Cultivate Teamwork, Technical writing and Oral communication skills.

PEO4: To provide students with an appreciation of engineering impact on society and the Professional responsibilities of an engineers.

Program Specific Outcomes (PSO's)

PSO1: Apply the fundamentals of mathematics, Science and Engineering knowledge to identify, formulate, design and investigate complex engineering problems of electric circuits, analog and digital electronics, electrical machines and systems.

PSO2: Apply appropriate technique and modern Engineering hardware and software tools in power systems to engage in life-long learning and to successfully adapt in multi-disciplinary environments.

PSO3: Understand the impact of Professional Engineering solutions in societal and environment context, commit to professional ethical and communicate effectively.

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 specificity. 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 CONTENTS

EE8601 **SOLID STATE DRIVES** **L T P C**
3 0 0 3

OBJECTIVES:

- To impart knowledge on the following Topics
- Steady state operation and transient dynamics of a motor load system.
- Analyze the operation of the converter/chopper fed dc drive, both qualitatively and quantitatively.
- Operation and performance of AC motor drives.
- Analyze and design the current and speed controllers for a closed loop solid state DC motor drive.

UNIT I DRIVE CHARACTERISTICS **9**

Electric drive – Equations governing motor load dynamics – steady state stability – multi quadrant Dynamics: acceleration, deceleration, starting & stopping – typical load torque characteristics – Selection of motor.

UNIT II CONVERTER / CHOPPER FED DC MOTOR DRIVE **9**

Steady state analysis of the single and three phase converter fed separately excited DC motor drive– continuous conduction – Time ratio and current limit control – 4 quadrant operation of converter / chopper fed drive-Applications.

UNIT III INDUCTION MOTOR DRIVES **9**

Stator voltage control–V/f control– Rotor Resistance control-qualitative treatment of slip power recovery drives-closed loop control–– vector control- Applications.

UNIT IV SYNCHRONOUS MOTOR DRIVES **9**

V/f control and self-control of synchronous motor: Margin angle control and power factor control-Three phase voltage/current source fed synchronous motor- Applications

UNIT V DESIGN OF CONTROLLERS FOR DRIVES **9**

Transfer function for DC motor / load and converter – closed loop control with Current and speed feedback–armature voltage control and field weakening mode – Design of controllers; current controller and speed controller- converter selection and characteristics.

TOTAL: 45 PERIODS

OUTCOMES:

- Ability to understand and suggest a converter for solid state drive.
- Ability to select suitability drive for the given application.
- Ability to study about the steady state operation and transient dynamics of a motor load system.
- Ability to analyze the operation of the converter/chopper fed dc drive.
- Ability to analyze the operation and performance of AC motor drives.
- Ability to analyze and design the current and speed controllers for a closed loop solid state DC motor drive.

TEXT BOOKS:

- Gopal K.Dubey, Fundamentals of Electrical Drives, Narosa Publishing House, 1992.
- Bimal K.Bose. Modern Power Electronics and AC Drives, Pearson Education, 2002.
- R.Krishnan, Electric Motor & Drives: Modeling, Analysis and Control, Pearson, 2001.

REFERENCES

- Vedam Subramanyam, “ Electric Drives Concepts and Applications ”, 2e, McGraw Hill, 2016 76

- Shaahin Felizadeh, “Electric Machines and Drives”, CRC Press (Taylor and Francis Group), 2013.
- John Hindmarsh and Alasdain Renfrew, “Electrical Machines and Drives System,” Elsevier 2012.
- Theodore Wildi, “ Electrical Machines ,Drives and power systems ,6th edition, Pearson Education ,2015 5. N.K. De., P.K. SEN” Electric drives” PHI, 2012..

Subject code: EE8601 **Year/semester:III/06**

Subject Name: Solid State Drives **Subject Handler: D.Thaniga**

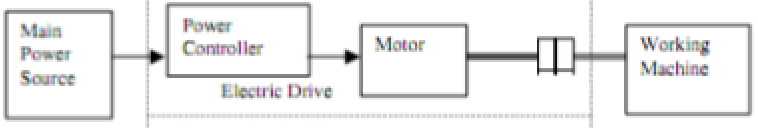
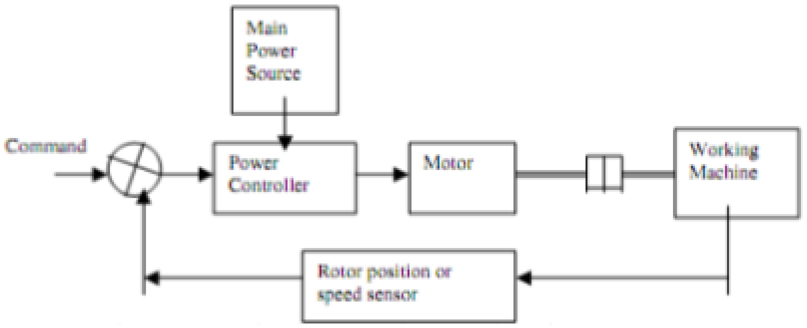
UNIT I DRIVE CHARACTERISTICS 9

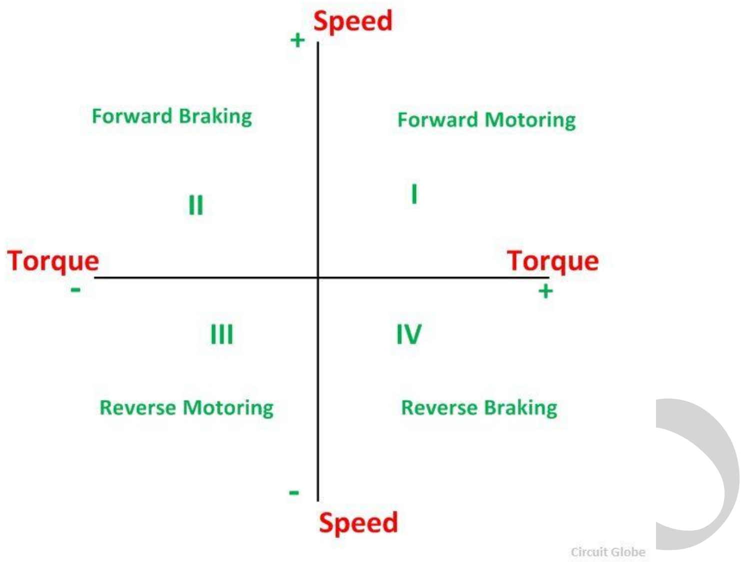
Electric drive – Equations governing motor load dynamics – steady state stability – multi quadrant Dynamics: acceleration, deceleration, starting & stopping – typical load torque characteristics – Selection of motor

PART * A

Q.No.	Questions
1.	**What are Active & Passive load torque? Give examples.(Nov/Dec 2016)** BTL 2 **Active load torque:** Load torques which retain its sign when the direction of the drive rotation changes are known as active load torques. Torque due to force of gravity and torque due to tension, compression and torsion undergone by an elastic body come under this category. **Passive load torque:** Load torques which changes the sign when the direction of the drive rotation changes are known as passive load torques. Torques due to friction, cutting and so on.
2.	**What is meant by electrical drive?** BTL 2 The aggregate of electric motor, the energy transmitting shaft and the control equipment by which the motor characteristics are adjusted and their operating conditions with respect to mechanical load varied to suit particular requirement is called an electrical drive.
3.	**List the applications of electrical drives. (Nov/Dec 2016)** BTL 4 • Paper mills • Electric traction • Cement mills • Steel mills
4.	**State the conditions for steady state stability of motor load system. (May/June 2016)** BTL 6 Steady state operation takes place when motor torque Tm equals load torque Tl. The steady state operation for a given speed is realized by the adjustment of steady state motor speed-torque curve such that the motor and load torques are equal at this speed. When the motor parameters are adjusted to provide speed-torque curve 1, drive runs at the desired speed.
5.	**List out the examples of active load torque in drive system. (Apr/May 2017)** BTL 4 Gravitational pull obtained in case of hoists, lifts (or) elevators and railway locomotives operating on gradients, torque developed due to compression (or) release of springs.
6.	**What are the typical elements of electric drive? (Nov/Dec 2017)** BTL 2 Source, power modulator, motor, load, sensing unit control unit.
7.	**What are the different methods of operation of an electric drive? (Nov/Dec 2017)** BTL 2 • Steady state • Acceleration including starting • Deceleration including starting
8.	**What is meant by regenerative braking? (Apr/May 2018)** BTL 2 Regenerative braking occurs when the motor speed exceeds the synchronous speed. In this

	case the IM runs as the induction m\c is converting the mechanical power into electrical power which is delivered back to the electrical system. This method of braking is known as regenerative braking.
9.	**What are the types of load torques? (Apr/May 2018)** BTL 2 Active load torques-load torques which retains its sign through the direction of the drive rotation is changed. Eg, Gravitational force, compression and torsion undergone by elastic body. Passive load torque-load torque which always oppose the motion and change their sign on the reversal of motion. Eg, friction windage and cutting.
10	**Mention the types of braking?** BTL 3 • Regenerative braking • Dynamic braking • Plugging
11	**Define four quadrant operation.** BTL 1 The motor operates in two mode: motoring and braking. In motoring, it converts electrical energy into mechanical energy which supports its motion. In braking, it works as a generator, converting mathematical energy into electrical energy and thus opposes the motion. Motor can provide motoring and braking operations for both forward and reverse directions.
12	**What is meant by plugging?** BTL 2 It is one method of braking of IM. When phase sequence of supply of the motor running at the speed is reversed by interchanging connections of any two phases of stator with respect to supply terminals, operation shifts from motoring to plugging region
13	**What is meant by dynamic braking?** BTL 2 Dynamic braking of electric motors occurs when the energy stored in the rotating mass is dissipated in an electrical resistance. This requires a motor to operate as a gen. to convert the stored energy into electrical.
14	**Mention the different factors for the selection of electric drives?** BTL 4 • Steady state operation requirements. • Transient operation requirements. • Requirements related to the source. • Capital and running cost, maintenance needs, life. • Space and weight restriction. • Environment and location. • Reliability.
15	**What are the functions performed by electric drives?** BTL 2 Various functions performed by electric drives include the following. a. Driving fans, ventilators, compressors and pumps etc. b. Lifting goods by hoists and cranes c. Imparting motion to conveyors in factories, mines and warehouses and d. Running excavators and escalators, electric locomotives, trains, cars, trolley buses, lifts and drums winders etc.
16	**What are the advantages of group drive over individual drive?** BTL 2 The advantages of group drive over individual drive are • Initial cost: Initial cost of group drive is less as compared to that of the individual drive. • Sequence of operation : Group drive system is useful because all the operations are stopped simultaneously. • Space requirement : Less space is required in group drive as compared to individual drive. • Low maintenance cost: It requires little maintenance as compared to individual drive**.**
17	**What are the functions performed by electric drives?** BTL 2 Various functions performed by electric drives include the following. a. Driving fans,

	ventilators, compressors and pumps etc. b. Lifting goods by hoists and cranes c. Imparting motion to conveyors in factories, mines and warehouses and d. Running excavators and escalators, electric locomotives, trains, cars, trolley buses, lifts and drums winders etc.
18	**What is meant by electrical drives?** BTL 2 Systems employed for motion control are called drives and they employ any of the prime movers such as diesel or petrol engines, gas or steam turbines, hydraulic motors and electric motors for supplying mathematical energy for motion control. Drives employing electric motion are called electric drives.
19	**Draw the electric drive system.** BTL 3  Fig. An electric-drive system 
20	**Mention the types of enclosures?** BTL 4 • Screen projected type • Drip proof type • Totally enclosed type • Flame proof type
21	**Why regenerative braking is not possible in dc series motors?** BTL 2 E>V , Ia is negative Field flux cannot be increased substantially beyond rated because of saturation. So according to the above equation, for a fixed source voltage, reg. braking is possible for speeds higher than the rated. For a variable voltage, regenerative braking is possible for speeds lower than the rated speeds. But in series motor, as speed increases, armature current and flux therefore decreases. So regenerative braking is not possible.
22	**Give any one example of active load torque.(MAY 2012)** BTL 3 • Torque due to force of gravity • Torque due to tension of elastic body
	PART *B
1	**i) Explain in detail the multi quadrant dynamics of a drive with an example. (8M) (Nov/Dec 2016, 2017) (Nov 2018)** BTL 2 Answer page: 1.13 – J. Gnanavadivel • **Multi quadrant dynamics of a drive** **(5M)** Four Quadrant Operation **of any drives or DC Motor means that the machine operates in four quadrants. They are** Forward Braking**,** Forward motoring**,** Reverse motoring **and** Reverse braking**. A motor operates in two modes** – Motoring and Braking**. A motor** drive capable of operating in both directions of rotation and of producing both motoring and regeneration is called a Four Quadrant variable speed drive.



Circuit Globe

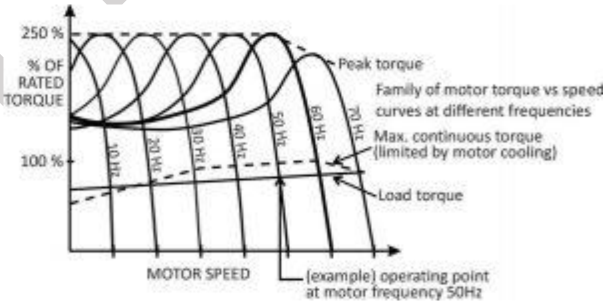
- **Classification of loads** **(3M)**
  1. Continuous constant mode
  2. Continuous variable type mode
  3. Pulsating loads
  4. Impact loads
  5. Short time intermittent loads
  6. Short time loads

ii) List the common factors to be considered for selecting a motor. (5M) (Nov/Dec 2016)

Answer Page: 1.4- J.Gnanavadivel

BTL 2

- Nature of electric supply
- Nature of the drive
- Nature of load



- Electrical characteristics of motor
- Size and rating of the motor
- Mechanical considerations

2

Describe the equation governing load dynamics of drive. Drive the mathematical condition for steady state stability analysis of equilibrium operating point.(13M) (Nov/Dec 2016) (Apr/May 2018) BTL 4

Answer page: 1.19 – J.Gnanavadivel

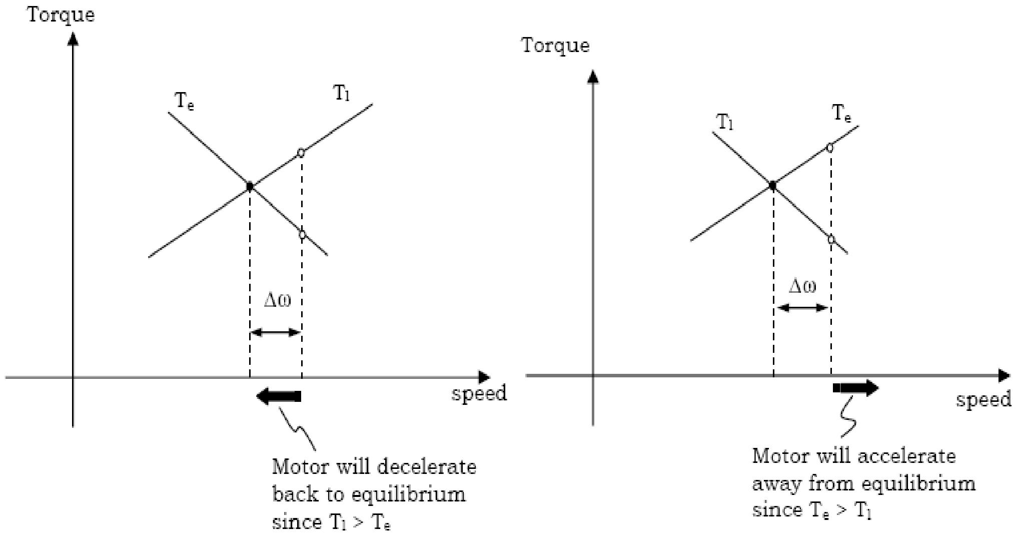
- **Steady state stability (2M)**

Steady state operation takes place when motor torque Tm equals load torque Tl. The steady state operation for a given speed is realized by the adjustment of steady state motor speed-torque curve such that the motor and load torques are equal at this speed. When the motor parameters are adjusted to provide speed-torque curve 1, drive runs at the desired speed.

- **Equilibrium condition (4M)**
  Equilibrium speed of a motor load system is obtained when the motor torque, T_e equals the load torque T_l.

1. Stable state of equilibrium point: The equilibrium point is termed as stable, if the operating point is restored after a small. Departure from it due to disturbance in the motor or load.
2. Unstable state of equilibrium point: The equilibrium point is termed as stable, if the operating point will not be restored after a small departure from it due to disturbance in the motor or load.

- **Torque-speed characteristics & expression (7M)**



Steady state stability

- Mathematical condition for the stability of equilibrium point

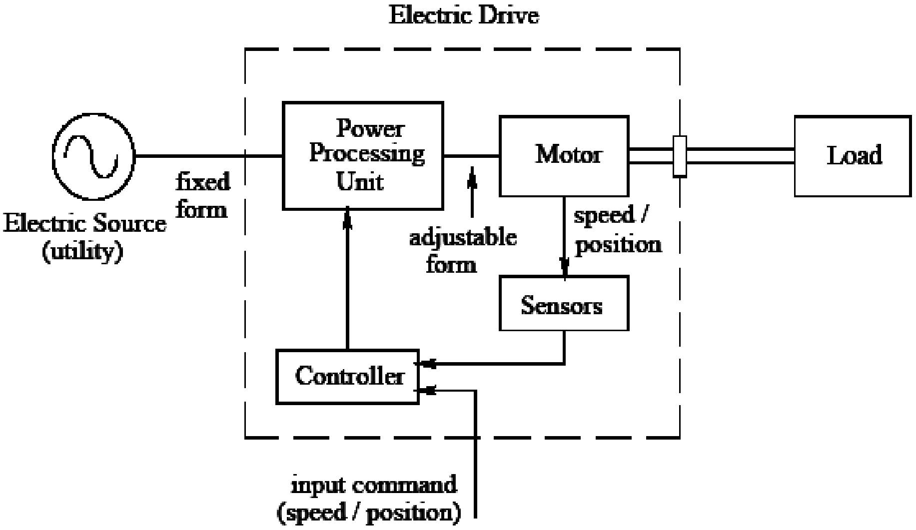
$$\frac{dT_l}{d\omega} - \frac{dT_e}{d\omega} > 0$$

3

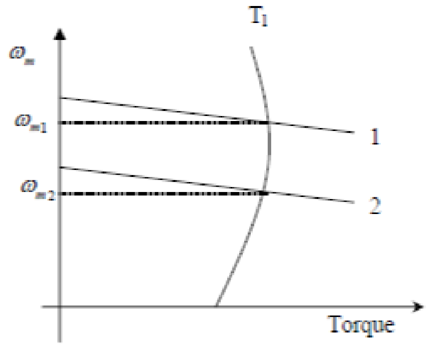
Classify and explain various types of load of electrical drive based on the speed-torque characteristics. (13M) (May/June 2016) BTL 3

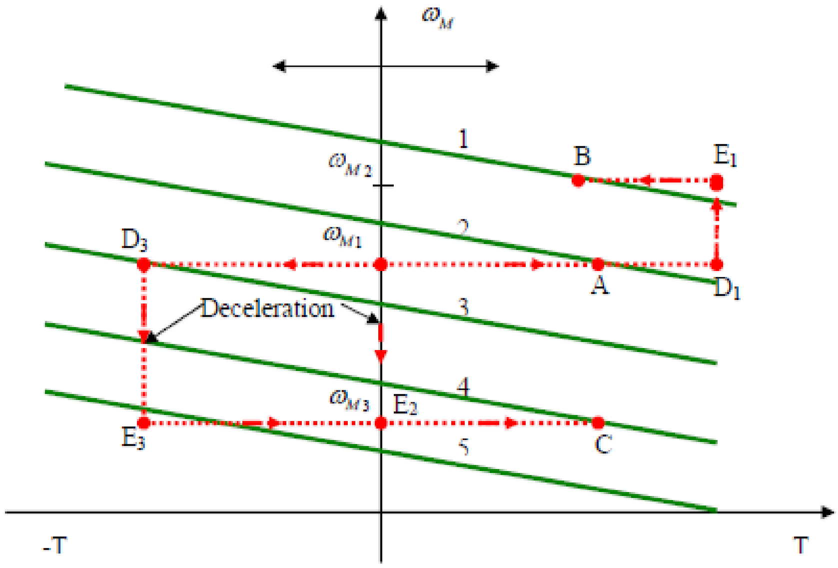
Answer page: 1.8- J.Gnanavadivel

- **Fundamental torque equation** **(2M)**
  $T-T_L = d/dt(J\omega_m)$
- **Types of load torque** **(4M)**
  1. Active load torque: Active torques continues to act in the same direction irrespective of the direction of the drive. e.g. gravitational force or deformation in elastic bodies.
  2. Passive load torque: the sense of the load torque changes with the change in the direction of motion of drive. e. g. torques due to friction, due to shear and deformation of in elastic bodies.
- **Characteristics of different types of loads** **(7M)**
  1. Constant torque type load
  2. Torque proportional to speed(generator type load)
  3. Torque proportional to square of the speed(fan type load)
  4. Torque inversely proportional to speed (constant power type load)

4	**Sketch the essential parts of an electrical drive. Explain the functions of each component. (13M) (Apr/May 2107) (Nov/dec 2018)** BTL 2 Answer page: 1.5– J.Gnanavadivel • **Block diagram of electric drive (5M)**  • **Parts of electric drive & explanation (8M)** 1. Electrical motors and load Induction motors, synchronous motors 2. Power modulator a. Converters b. Inverters c. Ac voltage controllers d. DC choppers e. Cycloconverter 3. Sources 4. Control unit **5.** Sensing unit a. Speed sensing b. Current sensing
5	**Discuss the different modes of operation of an electrical drive. (13M)** BTL 3 Answer page: 1.21 – J.Gnanavadivel • **Three modes of operation (3M)** 1. Steady –state 2. Acceleration including starting 3. Deceleration including stopping • **Explanation of each mode (10M)** According to the above expression the steady state operation takes place when motor torque equals the load torque. The steady state operation for a given speed is realized by adjustment of steady state motor speed torque curve such that the motor and load torques are equal at this speed. Acceleration and Deceleration modes are transient modes. Drive operates in Acceleration mode. Whenever an increase in its speed is required. For this motor speed torque curve must be changed so that motor torque exceeds the load torque. Time taken

for a given change in speed depends on inertia of motor load system and the amount by which motor torque exceeds the load torque.





6 **Describe about classification, comparison of AC & DC drives & Applications of electric drives. (13M)** BTL 2

Answer page: 1.6 – J.Gnanavadivel

- **Classifications of drives** **(2M)**
  1. Ac drives
  2. **2.** DC drives
- **Comparison between AC & DC drives:** **(9M)**

Commonly ran by an AC variable frequency drive, an AC electric motor operates by applying alternating current (AC) power to the electric motor. An AC electric motor consists of several parts but the main parts are the stator and rotor. The AC electric motor's stator has coils that are supplied with the alternating current and produces a rotating magnetic field. The AC electric motor’s rotor rotates inside the electric motor’s coils and is attached to an output shaft that produces torque by the rotating magnetic field. There are two different types of AC electric motors and each of them uses a different type of rotor. The first type of AC motor is called an induction motor (also known as an asynchronous motor).

An induction motor uses a magnetic field on the rotor of an induction motor that’s created by an induced current. The other type of AC motor is called a synchronous motor and rotates precisely at the supply frequency or on a sub-multiple of the supply frequency. A synchronous motor is able to operate with precision supply frequency because it doesn’t reply on induction. The magnetic field on a synchronous motor is generated by current delivered through slip rings or a permanent magnet. Synchronous motors run faster than induction motors because the speed is reduced by the slip of the asynchronous motor.

- **Applications** **(2M)**

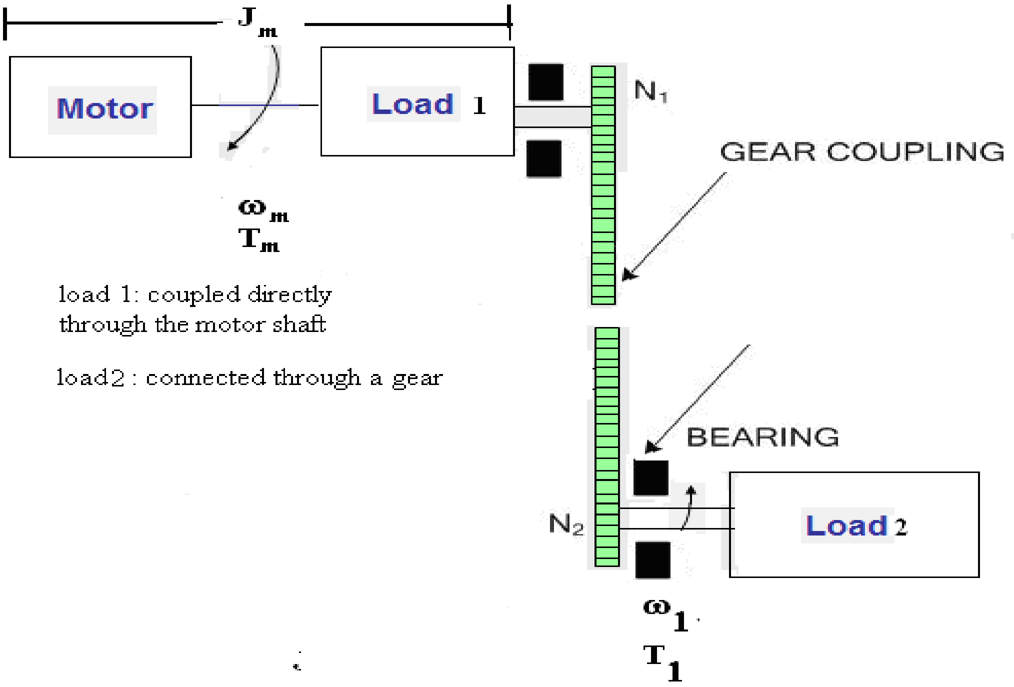
Paper mills, Cement mills, Textile mills, Steel mills, Sugar mills

7

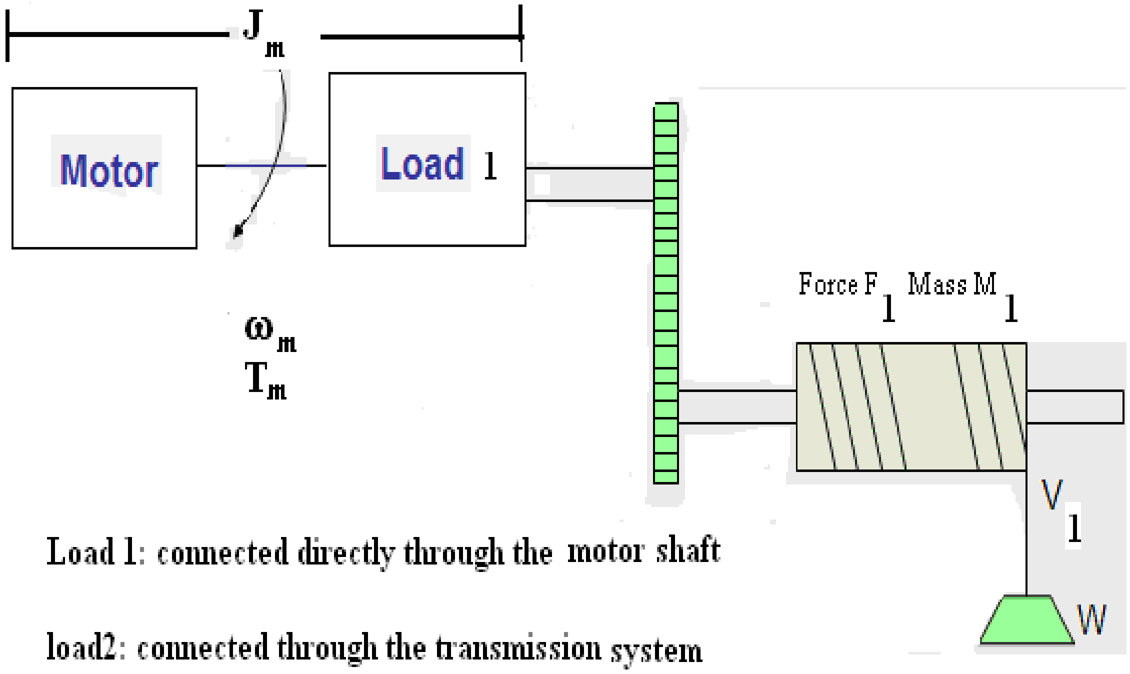
Derive the expressions to find the equivalent load torque and equivalent inertia of loads in translational and rotational motion. (13M) BTL 4

Answer page: 1.15- J.Gnanavadivel

- **Loads with rotational motion** **(7M)**



- **Load with translational motion** **(6M)**

	
	PART * C
1	**A motor load system has following details: Quadrant I & II T= 400-0. 4N-m, N is speed in rpm. Motor is coupled to an active load torque. Tl=+ 200 N-m. Calculate the motor speeds for motoring and braking operations in the forward direction. When operating in quadrants III & IV, T=-400-0.4 N-m, calculate the equilibrium speed in quadrant III. (15M)(Apr'18)** BTL 3 Sol: Motor speed in forward motoring operation i.e. Ist quadrant operation in which load is fully loaded cage]. Therefore Tl= 200 Tm= Tl 400-0.4 N= 200 200 -0.4 N = 0 N= 200/0.4 = 500 rpm Motor speed in forward braking (II quadrant operation) Tl= -200 N-m Tm=Tl 400-0.4 N=-200 600 = 0.4 N N= 600/0.4 = 1500 rpm Equilibrium speed in III quadrant Tm=Tl -400-0.4 N= -200 N= -200/0.4= -500 rpm
2	**A motor load system has following details: Quadrat I & II T - 400-0. 4N -m, N is speed In rpm. Motor is coupled to a active& IV e load torque. Tl= +200 N-m. calculate the motor**

	speeds for motoring a braking operation in the forward direction. When operating In quardrats III & IV , T= -400-0.4 N-M. calculate the equilibrium speed I quardrats III.(15M) (BTL 5) Answer page: 1.24-J S. Saranya • Motor speed I forward motoring operation Tl= 200 Tm=Tl 400-0.4 N= 200 200- 0.4 N =0 N=200/0.4 = 500 rpm • Motor speed In forward braking Tl =200-m Tm=Tl N= 600/0.4 **= 1500 rpm**

UNIT II CONVERTER / CHOPPER FED DC MOTOR DRIVE **9**

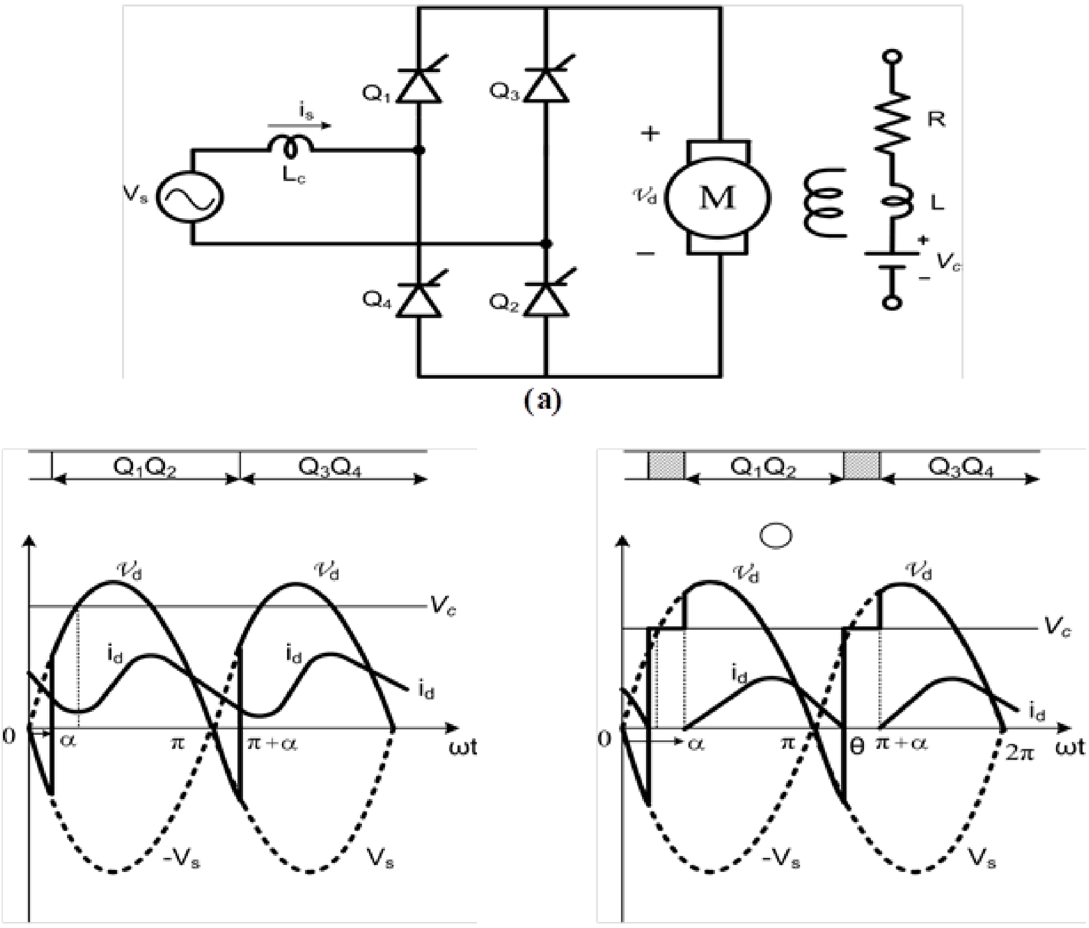
Steady state analysis of the single and three phase converter fed separately excited DC motor drive– continuous conduction – Time ratio and current limit control – 4 quadrant operation of converter / chopper fed drive-Applications.

PART * A

Q.No.	**Questions**
1.	**State the functions of freewheeling diode in phase controlled rectifier. (Nov/Dec 2016)** BTL 2 It is used for load equalization. It is mounted on the motor shaft in compound motor.
2.	**List out the draw backs of rectifier fed dc drive. (Nov/Dec 2016)** BTL 4 • Distortion of supply: source current of the rectifier has harmonics. In a weak ac source, with high internal impedance, current harmonics distort source voltage. Furthermore temporary short circuit of lines during commutation of thyristors causes sharp current pulses, with further distortion in source voltage. This causes undesirable effect including interference with other loads and radio frequency interference. • Low power factor
3.	**What is armature voltage control? (Apr/ May 2017)** BTL 2 Armature voltage control is a type of speed control in DC motor. Armature voltage is varied by keeping the field constant. In this method speed of the motor can be controlled below the rated speed. Armature voltage can be controlled by conventional method such as resistive network (or) using power electronics converters.
4.	**List the disadvantages of frequency modulation in generating PWM waveform. (Apr/May 2017)** BTL 4 • Frequency has to be varied over a wide range to provide the full output voltage range. • Filter design for variable frequency operation is difficult • Large off time at low output voltage will make the current of a dc motor load

	discontinuous.
5.	**List the drawbacks of ac-dc converter fed dc drives. (Apr/May 2018)** BTL 4 • Low power factor • Ripples in motor current • Harmonics in line current • High copper loss • Distortion is more with discontinuous load current
6.	**What are the advantages of chopper fed dc drives? (Apr/May 2018)** BTL 2 • High efficiency • Flexibility in control • Quick response • Regeneration down to very low speed • Control and power circuit are simple
7.	**Why self-commutated devices are preferred over thyristors for chopper circuits?** BTL 2 Self-commutated devices such as power MOSFETs power transistors, IGBTs, GTOs are preferred over thyristors for building choppers because they can be commutated by a low power control signal and don't need commutation circuit.
8.	**A 230V, 960rpm, 200A separately excited motor has armature resistance of 0.02Ω. The source voltage of 230V. If motor field is controlled, Calculate the field current as a fraction of its rated speed of 1200rpm.** BTL 4 Solution: If = 960/1200 = 0.8
9.	**What do you mean by current limit control?** BTL 2 It is also known as point by point control, As current reaches maximum value, load is disconnected from the source. As current reaches minimum value, load is connected to the source, As the on & off operation depends upon the current, it is called as current limit control
10	**How the duty cycle can be changed?** BTL 4 The duty cycle can be changed by two ways: By keeping the chopping frequency constant and varying the on-time, to get a changing duty cycle, Keeping the on-time constant and varying the chopping frequency to obtain various values of the duty cycle.
11	**What are the advantages of converter fed drives? (MAY 2012)** BTL 2 Compact, Flexible, Simple commutation, Good efficiency, Fast response
12	**What are the limitations of the DC drives?** BTL 2 The sparking at the brushes limits the highest speed of operation, Power/weight ratio is small, The operating voltage and armature current to be commutated have upper limits, The commutator is a sensible part and increases the cost of the motor, It cannot be used in place like hazardous environment
13	**List out the drawbacks of ac-dc converter fed dc drive? (May 2011)** BTL 3 Source voltage and source current distortion, Low power factor and Ripple in motor current.
14	**What is TRC scheme? (May 2011)** BTL 2 TRC Time ratio control is also known as pulse width control, the ratio of on time to chopper period is controlled. The TRC can be further divided as, (i) constant frequency TRC (ii) Variable frequency TRC.

15	**How the D.C. motor is affected at the time of starting?** BTL 4 A D.C. motor is started with full supply voltage across its terminals, a very high current will flow, which may damage the motor due to heavy sparking at commuter and heating of the winding. Therefore, it is necessary to limit the current to a safe value during starting.
16	**Define and mention different types of braking in a dc motor?** BTL 1 In braking, the motor works as a generator developing a negative torque which opposes the motion. Types are regenerative braking, dynamic or rheostat braking and plugging or reverse voltage braking.
17	**What is static Ward-Leonard drive?** BTL 2 Controlled rectifiers are used to get variable d.c. voltage from an a.c. source of fixed voltage controlled rectifier fed dc drives are also known as static Ward-Leonard drive
18	**List the drawbacks of armature resistance control?** BTL 4 In armature resistance control speed is varied by wasting power in external resistors that are connected in series with the armature. Since it is an inefficient method of speed control it was used in intermittent load applications where the duration of low speed operations forms only a small proportion of total running time.
19	**How is the stator winding changed during constant torque and constant horse power operations?** BTL 4 For constant torque operation, the change of stator winding is made form series – star to parallel – star, while for constant horsepower operation the change is made from series-delta to parallel-star. Regenerative braking takes place during changeover from higher to lower speeds.
20	**Why self -commutated devices are preferred over thyristors for chopper circuits?** BTL 3 Self -commutated devices such as power MOSFETs power transistors, IGBTs, GTOs and IGCTs are preferred over thyristors for building choppers because they can be commutated by a slow power control signal and don’ t need commutation circuit.
21	**What are the limitations of series motor? Why series motor is not used in traction applications now a days?** BTL 2 1. The field of series cannot be easily controlled. If field control is not employed, the series motor must be designed with its base speed equal to the highest desired speed of the drive. 2. Further, there are a number of problems with regenerative braking of a series motor. Because of the limitations of series motors, separately excited motors are now preferred even for traction applications.
22	**What is known as half-controlled rectifier and fully controlled rectifier?** BTL 2 The rectifiers that provide control of dc voltage in either direction and therefore, allow motor control in quadrants I and IV. They are known as fully-controlled rectifiers. The rectifiers that allow dc voltage control only in one direction and motor control in quadrant I only. They are known as half-controlled rectifiers.
	PART *B
1	**Explain in detail, the operation of a single phase fully controlled converter fed separately excited dc motor in continuous and discontinuous modes with steady state analysis and waveforms. (13M) (Apr/May 2018)** BTL 2 Answer page: 2.45 – J.Gnanavadivel • **Circuit diagram and waveform (7M)**

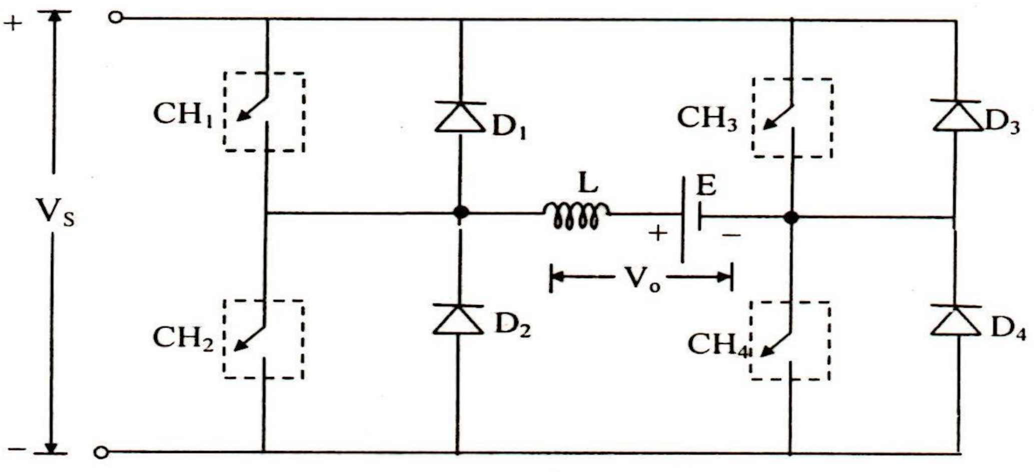


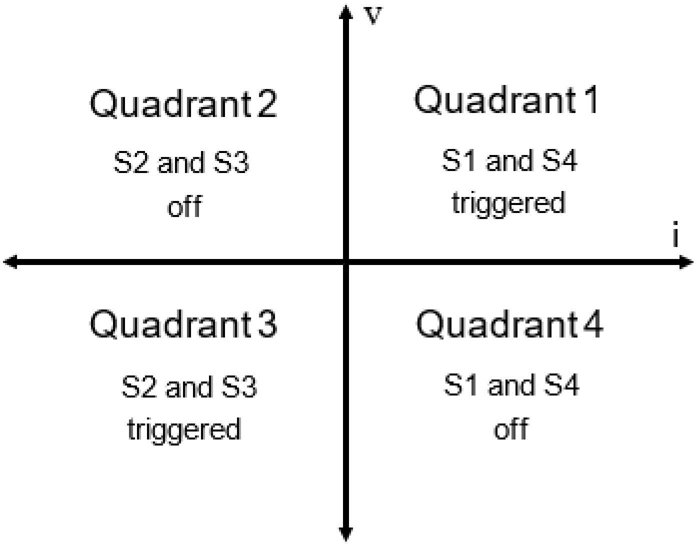
(a)

(b) (c)

Fig. (a) 1-PHASE THYRISTOR BRIDGE WITH R-L-E LOAD
(b) CONTINUOUS CONDUCTION RECTIFICATION (Mode-A)
(c) DISCONTINUOUS CONDUCTION RECTIFICATION (Mode-B)

- **Derivation of steady state condition of continuous & dis continuous condition (6M)**

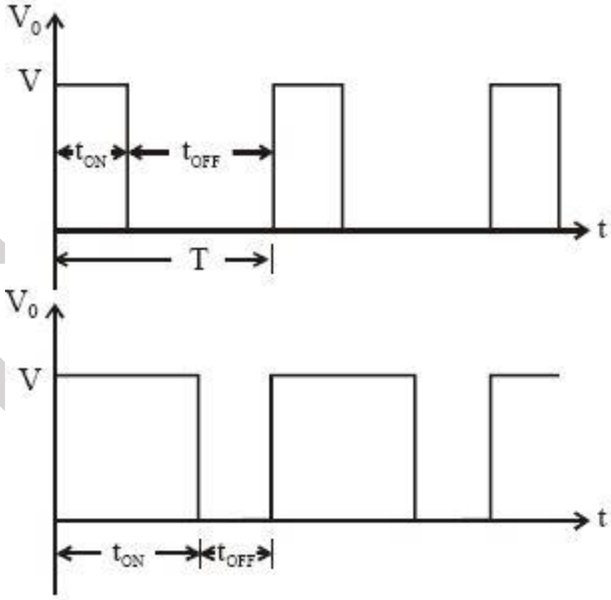
	Back voltage: $e_g = K_a\Phi n$ Average Back Voltage $E_g = K_a\Phi N$ Developed torque: $t = K_a\Phi i_a$ Average developed torque: $T = K_a\Phi I_a$ The armature circuit voltage equation is $e_a = R_a i_a + L_a \frac{di_a}{dt} + e_g$
2	**i) Explain the operation of four quadrant chopper fed dc separately excited motor drive with necessary diagrams. (7M) (Nov/Dec 2018)** BTL 2 Answer page: 3.37 – J.Gnanavadivel - **Four quadrant operation** 



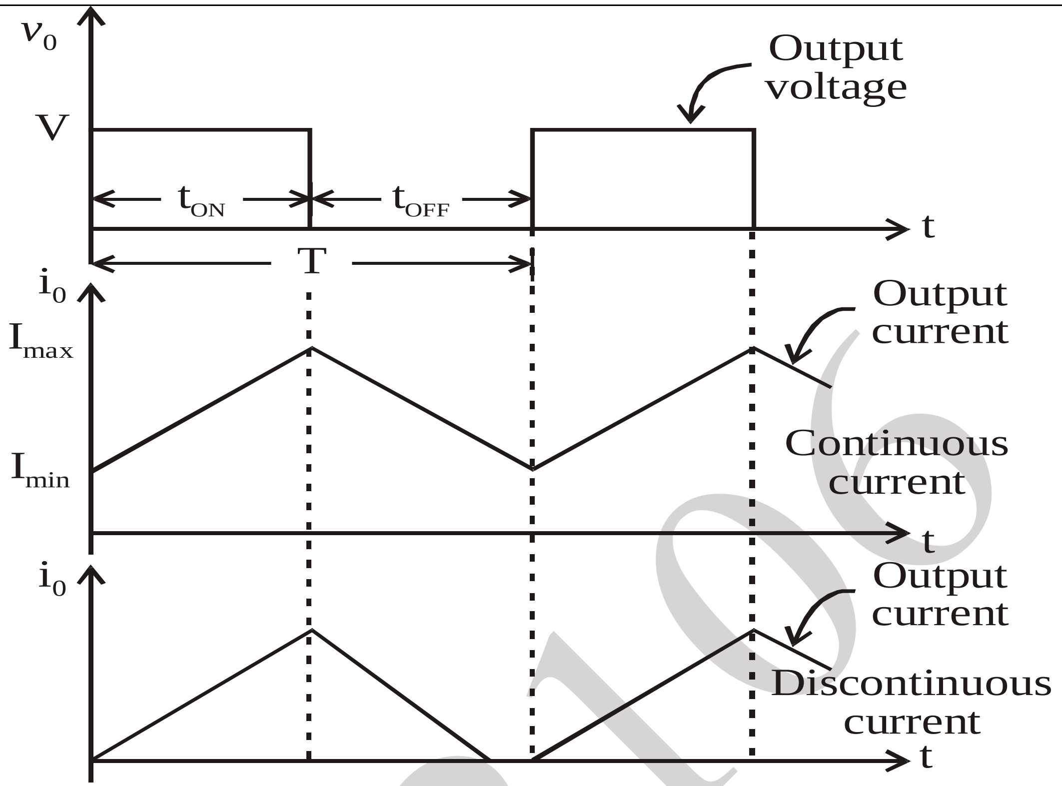
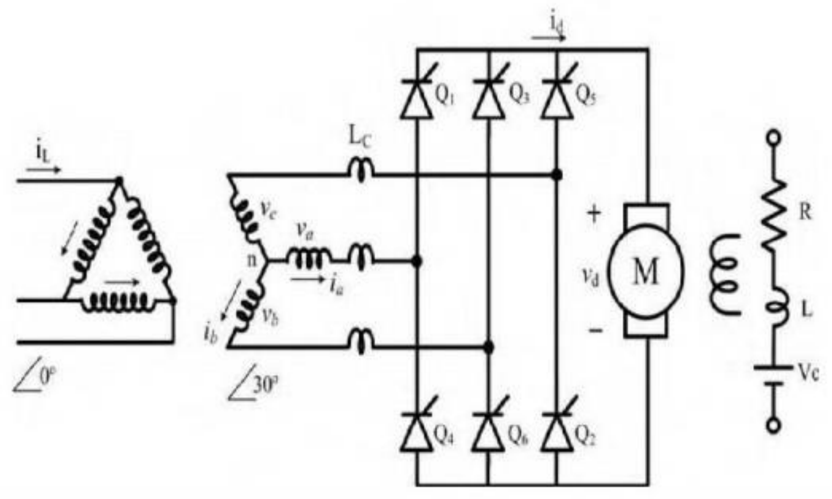
ii) What are the types of control strategies in a dc chopper? (6M) BTL 2

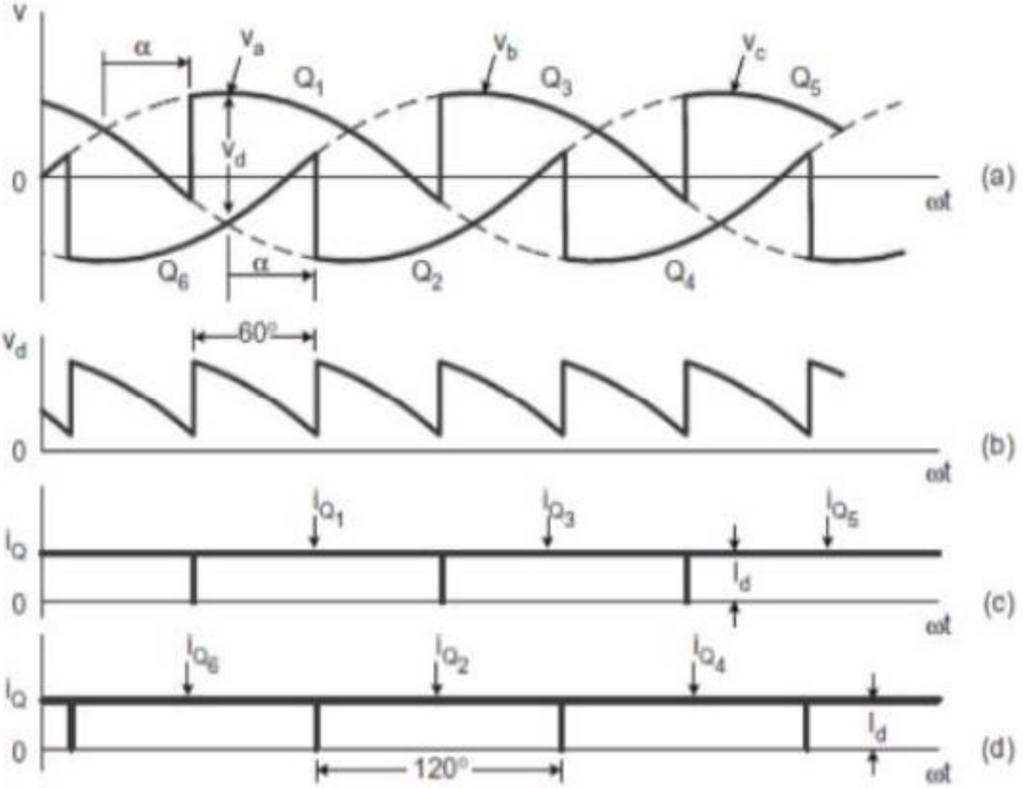
Answer page: 3.9 – J.Gnanavadivel

- Time ratio control



- Current limit control

	
3	**Explain in detail, the operation of a three phase fully controlled converter fed separately excited dc motor and obtain the expression of motor speed and torque for continuous conduction mode. (13M) (Apr/May 2018)** BTL 2 Answer page: 2.81- J.Gnanavadivel - **Circuit diagram & waveform (7M)**  Figure 2.13



- **Derivation** **(6M)**

The average motor armature voltage is given by

$$V_a = \frac{3}{\pi}\int_{\frac{\pi}{6}+\alpha}^{\frac{\pi}{2}+\alpha} V_{ab}\, d(\omega t)$$

In the above substitute $V_{ab} = \sqrt{3}V_m \sin\left(\omega t + \frac{\pi}{6}\right) d(\omega t)$

We have $V_a = \frac{3\sqrt{3}}{\pi} V_m \cos\alpha$

Speed Torque Relations:

The drive speed is given by

$$V_a = E_b + I_a R_a \qquad \text{Where } E_b = K_a \phi \omega$$

Then $V_a = K_a \phi \omega_m + I_a R_a$

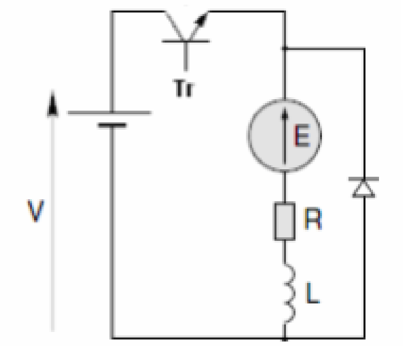
$$\omega_m = \frac{V_a - I_a R_a}{K_{.}\phi}$$

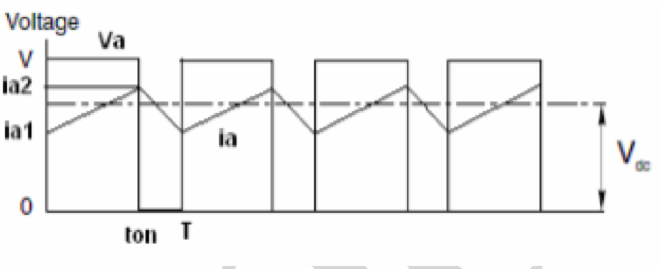
4

Explain the operation of chopper for forward motoring and braking control of separately excited dc motor with aid of diagram, waveforms and speed torque curves. (13M) (May’13) BTL 2

Answer page: 3.2-J.Gnanavadivel

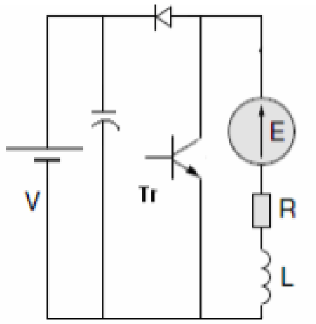
- **Motoring operation** **(6M)**

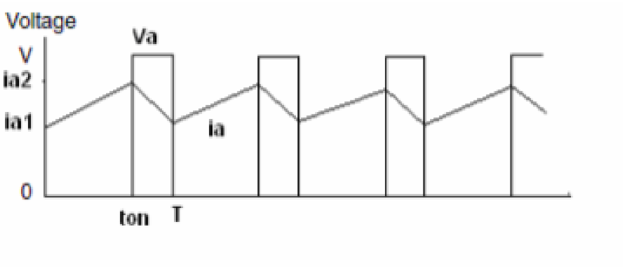




- A transistor is used to chop the DC input voltage in to pieces and chopped DC Voltage is given to the motor .Current limit control is used in chopper. In current limit control, the load current is allowed to vary between two given limits (i.e. Upper and lower limits).
- The ON and OFF times of the transistor is adjusted automatically, when the current increases beyond the upper limit the chopper is turned off, the load current free wheels and starts to decrease. When the current falls below the lower limit the chopper is turned ON.
- The current starts increasing if the load. The load current and voltage waveforms. By assuming proper limits of current, the amplitude of ripple can be controlled.
- **Regenerative braking** **(7M)**

  Regenerative braking operation by chopper is shown in the figure 2.20. Regenerative braking of a separately excited motor is fairly simple and can be carried out down to very low speeds.



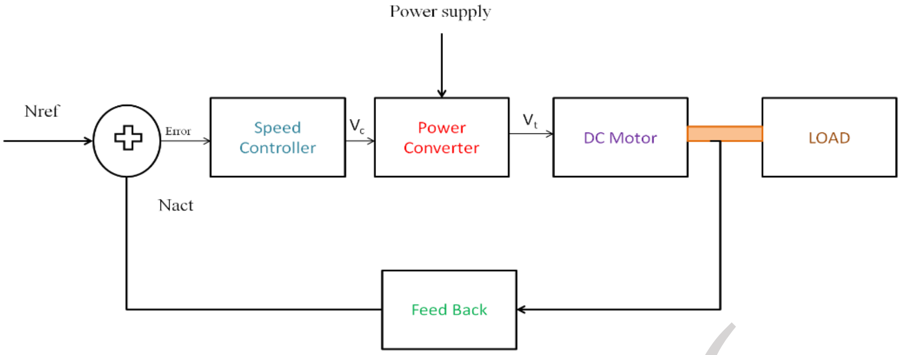


5

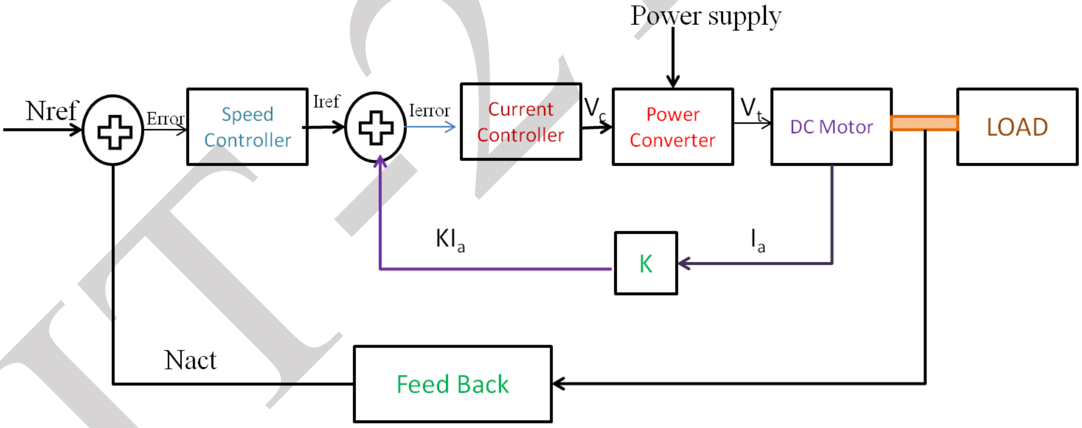
Describe about closed loop control of DC drives with schematic diagram. (13M) BTL 4

Answer Page: 3.62 – V.Thiyagarajan

- **Current limit control scheme** **(4M)**



- DC Motor is very extensively used machine where the speed control is desired. The operation of DC motor in different steps is easy compared to AC motors. By the open loop control the DC motor can be operated at any intermediate speed by changing the voltage, armature current etc. But in open loop (Prediction based) control accuracy in speed cannot be obtained i.e. the speed will not be constant for load variations on the motor. There will not be any feedback to the controller to indicate the change in speed due to load. This disadvantage restricts the use of open loop speed control DC motor in applications where constant speed is essential.
- **Improved closed loop speed control with inner loop current control** **(7M)**
  Here the speed output signal generates a corresponding armature current signal and this signal is compared with the existing armature fed back to the comparator circuit. The difference in the current drives the current loop controller and produces a control signal to the power converter.



- **Advantages of closed loop speed control** **(2M)**
  1. Greater accuracy with fine control of speed
  2. Improved dynamic response
  3. The motor can be operated at constant torque and constant speed
  4. Stabilized operation without any major deviations
  5. Circuit protections also can be incorporated in the closed loop speed control.

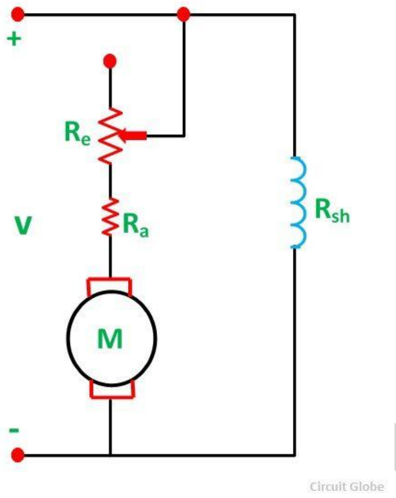
6 **Explain the armature voltage control with field weakening mode operation of separately excited DC motor drive.**

(13M) BTL 2

Answer Page: 2.15 – J.Gnanavadivel

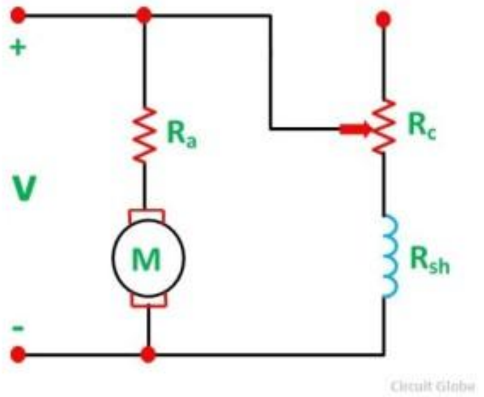
1. **Armature resistance control** **(4M)**
   The connection diagram of a shunt motor of the armature resistance control method is shown below. In this method, a variable resistor R_e is put in the armature circuit. The

variation in the variable resistance does not effect the flux as the field is directly connected to the supply mains.

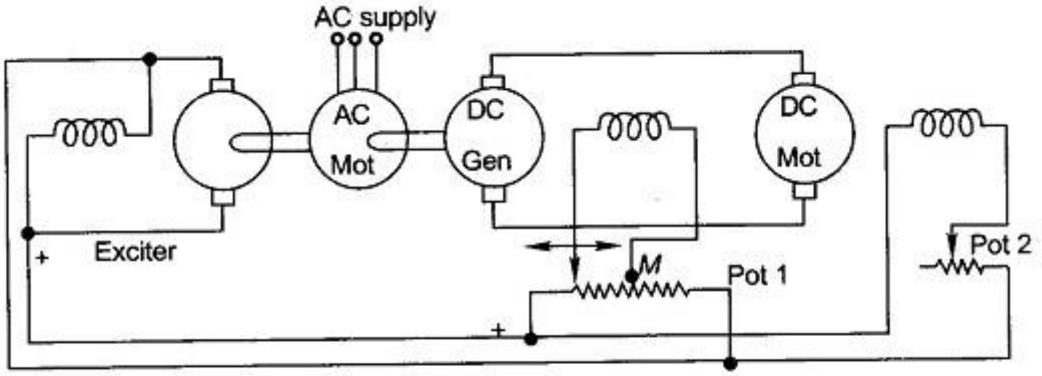


2. **Flux control method** **(4M)**

In a Shunt Motor, the variable resistor R_c is connected in series with the shunt field windings as shown in the figure below. This resistor R_c is known as a **Shunt Field Regulator.**



3. **Ward – Leonard control system** **(5M)**



(a) Ward-Leonard speed control system

The main advantages of the Ward Leonard drive are as follows:-

4. Smooth speed control of DC motor over a wide range in both the direction is possible.

It has an inherent braking capacity. The lagging reactive volt-amperes are compensated by using an overexcited synchronous motor as the drive and thus, the overall power factor improves. When the load is intermittent as in rolling mills, the drive motor is an induction motor with a flywheel mounted to smooth out the intermittent loading to a low value.

7

A Separately excited dc motor rated at 10Kw, 240V, and 1000 rpm is supplied from a fully controlled two pulse bridge converter. The converter is supplied at 250V, 50Hz supply. An extra inductance is connected in the load circuit to make the condition continuous. Determine the speed, power factor and efficiency of operation for thyristor firing angles of 0 and 60 assuming the armature resistance of 0.40 Ω and an efficiency of 87% at rated conditions. Assume constant torque load. (13M) (Dec'14) BTL 5

Answer page: 3.100 – V.Thiyagarajan

Solution:

For the given efficiency, the input to the motor at rated condition is ,

Input Power Pi= 11.494KW

The supply current to the motor Ia= Power/ Va= 47.89A

The back EMF at rated condition is Eb= Va-Ia.Ra

= 220.84V

(i) At α=0, the converter voltage V= 0.9 x 250 x cos 0^o

V= 225v

Speed= 909.4 rpm

(ii) At α= 60 , the converter voltage V= 0.9 x 250 x cos 60^o

V= 112.5V

The back emf E_b = 112.5 – 47.89 X 0.40

E_b = 93.34 V

Speed N = 422.7 rpm

PART * C

1

A 220V, 875 rpm, 150A separately excited DC motor has an armature resistance of 0.06 ohm. It is fed from a single phase fully controlled rectifier with AC source voltage of 220V, 50 hz. Assume continuous conduction mode and find

(i) Firing angle for rated torque at 750 rpm and -500 rpm

(ii) (ii) motor speed for α= 160^o at rated torque. (15M) (Apr'17) BTL 5

Sol:

i) At rated operation

E= V-IaRa

= 211V.

E at 750 rpm

E= 180.8V

Va= 180.8 + 150(0.06)

= 189.8 V

Cos α= 0.958

α= 16.61^o

At -500 rpm

E= -120.5V

Va=E+ IaRa

= -111.5

Cos α= -0.580

α = 125.4^o

	ii) At $\alpha= 160^{o}$ Va=- 186V E= - 195V N=- 808.6 rpm
2	**A 230V, 960 rpm and 200A separately excited dc motor has an armature resistance of 0.02Ω. The motor is fed from a chopper which provided both motoring and braking operations. The source has a voltage of 230v. Assume continuous conduction.** **i) Calculate duty ratio of chopper for motoring operation at rated torque and 350rpm.** **ii) Calculate duty ratio of chopper for braking operation at rated torque and 350 rpm.** **iii) If maximum duty ratio of chopper is limited to 0.95 and maximum permissible motor current is twice the rated, calculated maximum permissible motor speed obtainable without field weakening and power fed to the source. (15M) (Apr'17)** BTL 5 **Sol:** 1) E= 226V E at 350rpm: 350/960 *226= 82.4 V Motor terminal voltage Va= E+ IaRa = 82.4+ (200 * 0.02) Duty ration S= 86.4/230 = 0.376 2) Va= E- IaRa = 78.4V S= 0.34 3) Maximum available va= 0.95 * 230= 218.5V E= Va+ IaRa = 226.5 V. Maximum permissible motor speed= 226.5/226 * 960 =962 rpm Assuming lossless chopper, power fed into the source VaIa= 218.5 * 400 = 87.4 kW.

UNIT III INDUCTION MOTOR DRIVES 9

Stator voltage control–V/f control– Rotor Resistance control-qualitative treatment of slip power recovery drives-closed loop control–– vector control- Applications.

PART * A

Q.No.	Questions
1.	**What are the various applications of stator voltage control scheme? (Apr/May 2108)** BTL 2 The stator voltage control method is suitable for applications where torque demand reduces with speed, which points towards its suitability for - Fan - Pump drives
2.	**What are the three regions in the speed torque characteristics of induction motor? (Apr/May 2018)** BTL 2 - Motoring region - Generating region - Breaking region

3. **Discuss the constant torque and power mode with respect to induction motor. (Apr/May 2017)**

BTL 4

In constant torque mode the voltage and frequency are varied in proportion to make flux constant. Since torque of a induction motor is directly proportional to the square of the flux. Voltage can be varied upto the rated value, above base voltage is kept constant for any increase (or) decrease in frequency flux varies and torque decrease and power remains constant.

4. **What is energy efficient drive? (Apr/May 2017)** BTL 2

Drive is said to be an energy efficient, if the power consumption from source by a drive is minimum. In induction motor efficient drive is realized by using V/F control. Power factor is near to unity.

5. **What are the advantages of induction motors over D.C. Motors? (Nov/Dec 2017)** BTL 2

- Cheaper
- Light in weight
- Rugged in construction
- More efficient
- Require less maintenance
- It can be operated in dirty and explosive environment.

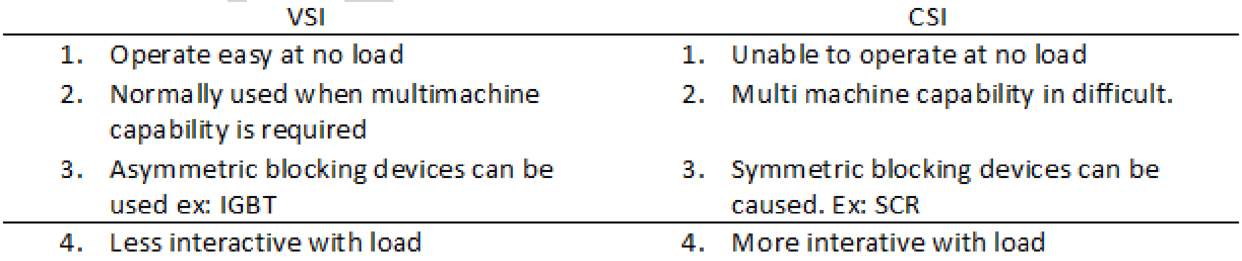
6. **Highlight the feature of variable frequency control. (Nov/Dec 2016)** BTL 3

- Smooth speed control
- Small i/p current and improved power factor at low frequency start.
- Higher starting torque for low case resistance.

7. **Enumerate the advantages of AC drives with PWM inverters. (Nov/Dec 2016)** BTL 3

- Absence of low frequency harmonics
- Losses decreases
- Torque pulsations are reduced
- Smooth motion is obtained at low speeds

8. **Compare current source and voltage source inverter fed drives.** BTL 5



VSI	CSI
1. Operate easy at no load	1. Unable to operate at no load
2. Normally used when multimachine capability is required	2. Multi machine capability in difficult.
3. Asymmetric blocking devices can be used ex: IGBT	3. Symmetric blocking devices can be caused. Ex: SCR
4. Less interactive with load	4. More interative with load

9. **What are the disadvantages of stator voltage control method? (May 2005)** BTL 2

- Voltage and current waveforms are highly distorted due to harmonics, which affects the efficiency of the motor.
- Performance is poor under running condition at low speeds
- Operating efficiency is low as resistance losses are high

10 **What is meant by slip power recovery system? (Dec 2009)** BTL 2

In chopper method of speed control for SRIM, the slip power is wasted in the external resistance and the efficiency also reduced. However, instead of wasting the slip power can be recovered by various schemes for the sped control of slip ring induction motor. This system called as slip

	power recovery system.
11	**Name the methods of speed control applicable on the stator side of a three phase induction motor. (May 2006)** BTL 3 - Stator voltage control - Stator frequency control - v/f control - stator current control - pole changing method
12	**When is an induction motor said to be working in the field weakening mode. (May 2006)** BTL 3 The induction motor is working in the field weakening mode when constant rated supply voltage and increased supply frequency.
13	**What are the disadvantages of static rotor resistance control? (May 2009)** BTL 2 - Slip power is wasted in the rotor circuit resistance - Efficiency is less
14	**What is static Kramer drive? (May 2006)** BTL 2 Instead of wasting the slip power in the rotor circuit resistance, it can be converted to 50 Hz A.C. and pumped back to the line. The slip power controlled drive that permits only a sub synchronous range of speed control through a converter cascade is known as static Kramer drive.
15	**Why the control of a three-phase induction motor is more difficult than D.C. motors?** BTL 3 The control of a three-phase induction motor, particularly when the dynamic performance involved is more difficult than D.C. motors. This is due to a. Relatively large internal resistance of the converter causes voltage fluctuations following load fluctuations because the capacitor cannot be ideally large. b. In a D.C. motor there is a decoupling between the flux producing magnetizing current and torque producing armature current. They can be independently controlled. This is not the case with induction motors. c. An induction motor is very poorly damped compared to a D.C. motor
16	**Give some drawbacks and uses of Ward-Leonard drive.** BTL 4 The drawbacks of Ward Leonard drive area. High initial cost b. Low efficiency The Ward-Leonard drive is used in rolling mills , mine winders, paper mills, elevators, machine tools etc.
17	**Why the power factor of the slip power recovery scheme of speed control of induction motor is low? (May 2005)** BTL 4 Drive input power is the difference between motor input power and power fed back. Reactive input power is the sum of the motor and inverter reactive powers. Therefore, this drive has poor power factor throughout the range of operation.
18	**What is soft –Start? (Dec 2003)** BTL 2 The AC voltage controllers allow a stepless control of supply voltage from zero to rated voltage. They are used for soft start of motors.
19	**Where is the V/f control used?** BTL 3 The V/f control would be sufficient in some applications requiring variable torque, such as centrifugal pumps, compressors and fans. In these, the torque varies as the square of the speed. Therefore at small speeds the required torque is also small and V/f control would be sufficient to drive these leads with no compensation required for resistance drop. This is true also for the case of the liquid being pumped with minimal solids.

20 **Why the static scherbius drive has a poor power factor?** BTL 4

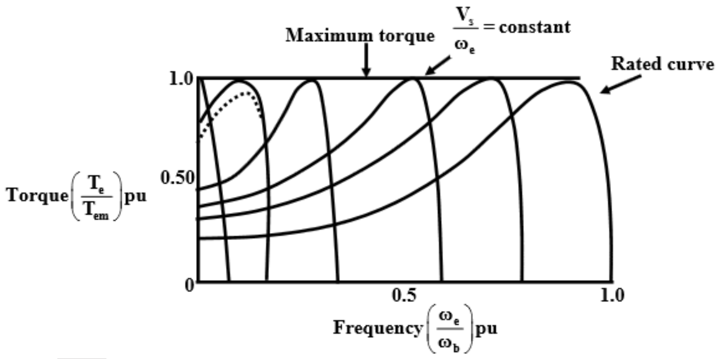
Drive input power is difference between motor input power and the power fed back. Reactive input power is the sum of motor and inverter reactive power. Therefore, drive has a poor power factor throughout the range of its options.

PART *B

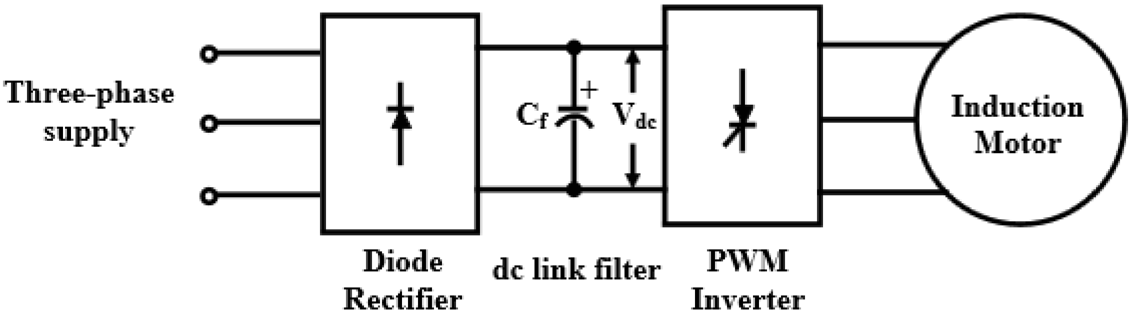
1 **Explain in detail with suitable diagrams and waveforms of (v/f) control applied to induction motor drives. (13M) (May'17' 16) (Nov 2018)** BTL 2

Answer Page: 5.63 – J.Gnanavadivel

- **Voltage/frequency control (6M)**
  1. The torque-speed curves for constant V/f operation. The maximum torque Tem remains approximately constant.
  2. Since the air gap flux of the machine is kept at the rated value, the torque per ampere is high. Therefore fast variations in acceleration can be achieved by stator current control.
  3. 3. Since the supply frequency is lowered at low speeds, the machine operates at low slip always, so the energy efficiency does not suffer.
  4. Majority of industrial variable-speed ac drives operate with a variable voltage variable frequency power supply.
- **Speed Torque characteristics (3M)**



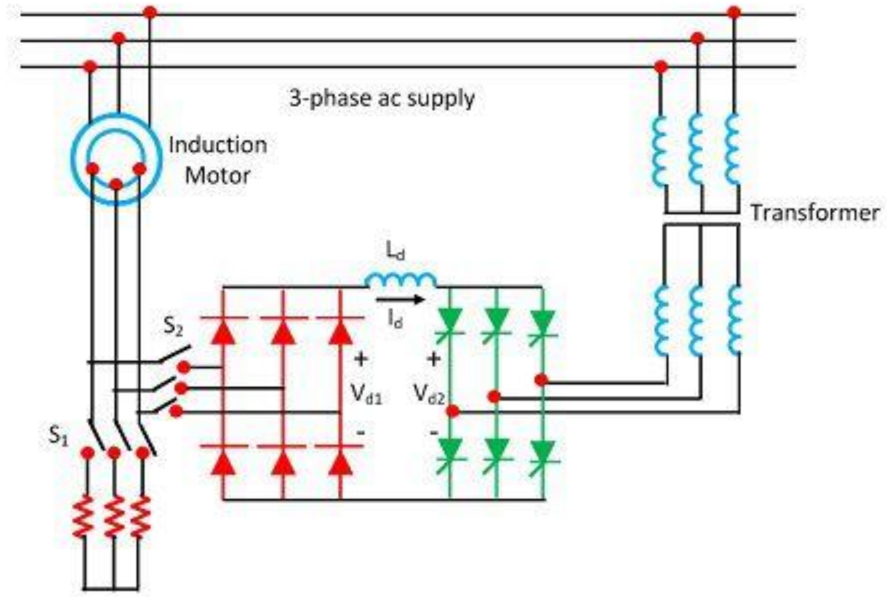
- **PWM Inverter fed induction motor drive (4M)**



Explain with neat diagram and equations the static scherbius system of slip power recovery scheme. (13M) (May/June 07, 12, 17) BTL 2

Answer Page: 5.168 – J.Gnanavadivel

- **Static scherbius drive (5M)**



Static Scherbius Drive

Circuit Globe

- **Explanation** **(8M)**
  1. The Static Scherbius Drive provides the speed control of a wound rotor motor below synchronous speed.
  2. The portion of rotor AC power is converted into DC by a diode bridge. The controlled rectifier works as an inverter and converts the DC power back into AC and feeds it back to the AC source.
  3. This drive has the ability of flow the power both in the positive as well as the negative direction of the injected voltage. This increases the operating condition of the drive.

The drive input power is the difference of the DC input power and the power fed back. Reactive input power is the sum of the motor and input reactive power.Thus, the drive has poor power factor throughout the range of its operation.

$$V_{d1} = \frac{3\sqrt{6}}{\pi} \times \frac{sV}{n}$$

$$V_{d2} = \frac{3\sqrt{6}}{\pi} \times \frac{V}{m} cos\alpha$$

Where α is the inverter firing angle and n, and m are respectively the stator to the rotor turn ratio of motor and source side to convert side turns ratio of the transformer. The neglecting drop across the inductor.

$$V_{d1} + V_{d2} = 0$$

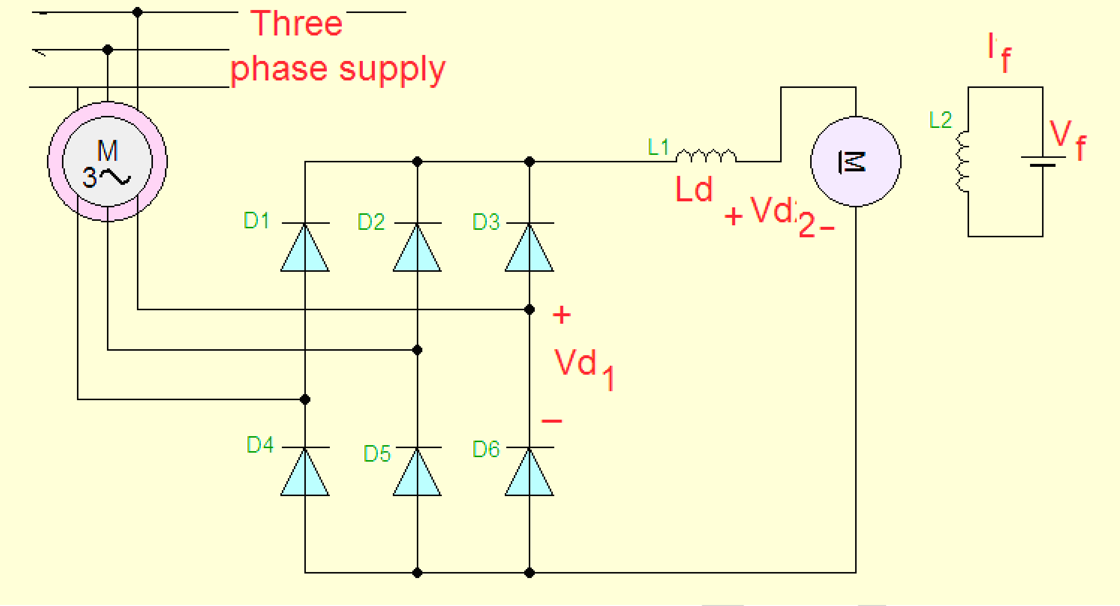
3

Explain using a power circuit the working of a static Kramer drive system & slip power recovery scheme of Kramer drive. (13M) (May/June'15,08) BTL 2

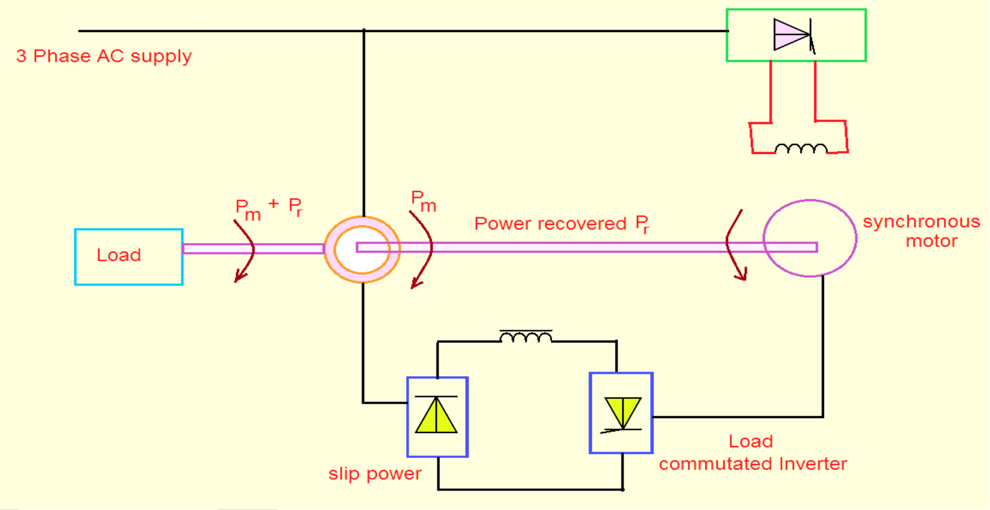
Answer Page: 4.53 – J.Gnanavadivel

- **Static Kramer system** **(5M)**

In this method the rotatory slip power is converted into DC by a diode bridge. The DC power is fed to the DC motor which is mechanically coupled with the Induction motor. The speed control is done by varying the field current I_f.



- **Modified Kramer system** **(8M)**



- The static Kramer drive system is modified by placing commutator less DC motor instead of DC machine. The DC motor consists of synchronous motor fed by load commutated inverter, the speed is controlled by field current.
- If field current and inverter voltage reduced to zero then the drive runs at synchronous speed. This drive has better power factor and less harmonic content in line current compared to static Kramer drive. In this system the power is not fed back to the line.

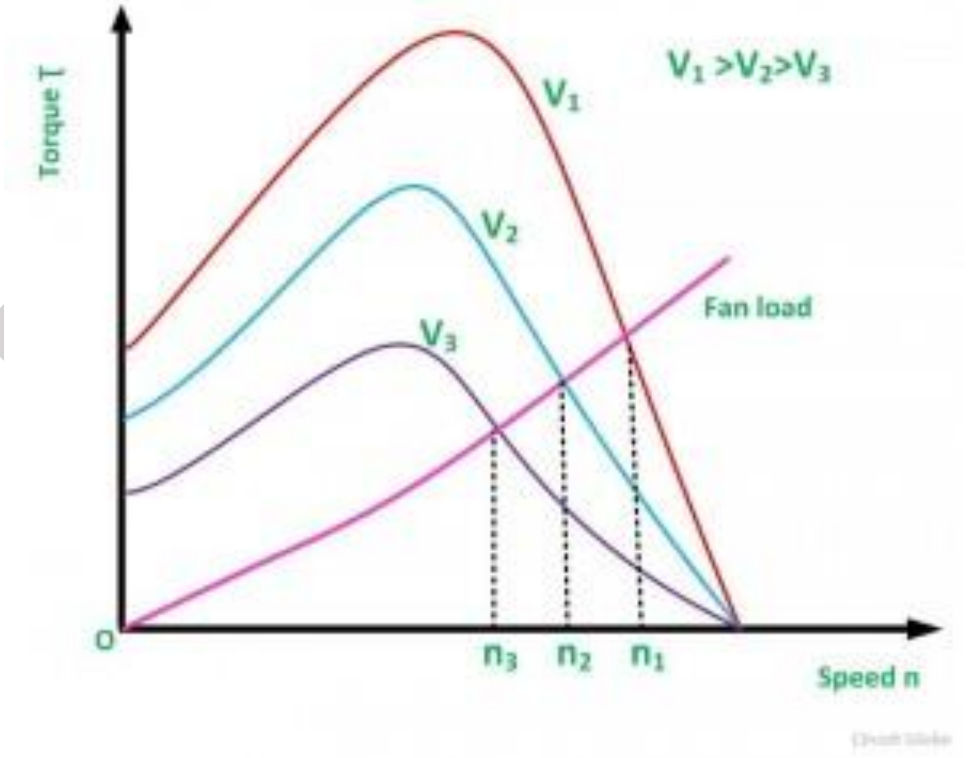
4

Describe the speed control scheme of induction motor drive with stator voltage and also state the disadvantages of this method. (13M) (Nov'17) BTL 4
Answer Page: 5.23– J.Gnanavadivel

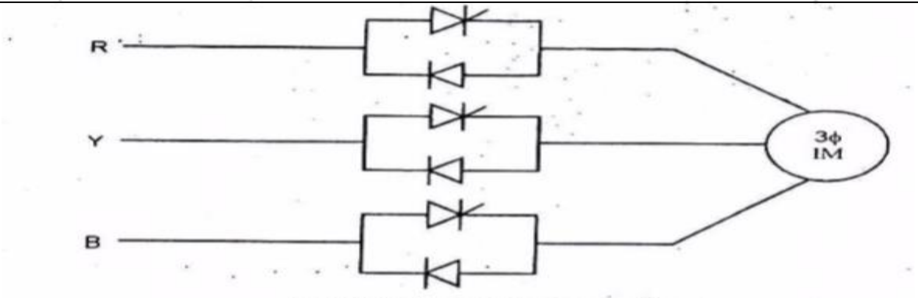
Conventional Method of stator voltage control (6M)

- If field current and inverter voltage reduced to zero then the drive runs at synchronous speed. This drive has better power factor and less harmonic content in line current compared to static Kramer drive. In this system the power is not fed back to the line.
- By varying the **supplying voltage**, the speed can be controlled. The voltage is varied until the torque required by the load is developed, at the desired speed. The torque developed is proportional to the square of the supply voltage and the current is proportional to the voltage.
- Hence, to reduce the speed for the same value of the same current, the value of the voltage is reduced and as a result, the torque developed by the motor is reduced. This stator voltage control method is suitable for the applications where the load torque decreases with the speed. **For example-** In the fan load.

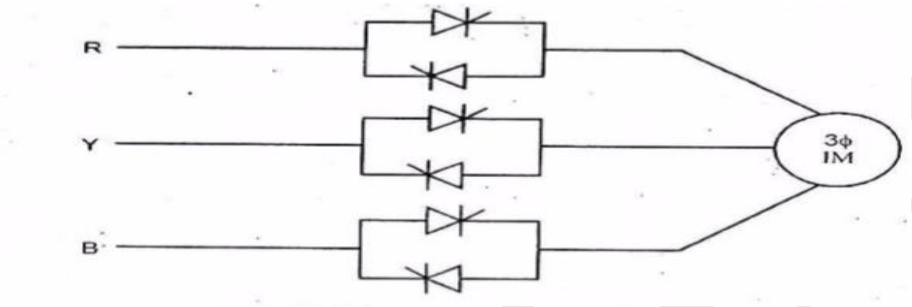
- By varying the **supplying voltage**, the speed can be controlled. The voltage is varied until the torque required by the load is developed, at the desired speed. The torque developed is proportional to the square of the supply voltage and the current is proportional to the voltage.
- Hence, to reduce the speed for the same value of the same current, the value of the voltage is reduced and as a result, the torque developed by the motor is reduced. This stator voltage control method is suitable for the applications where the load torque decreases with the speed. **For example-** In the fan load.



- **Solid state control method (7M)**
  1. **Ac voltage control method :**



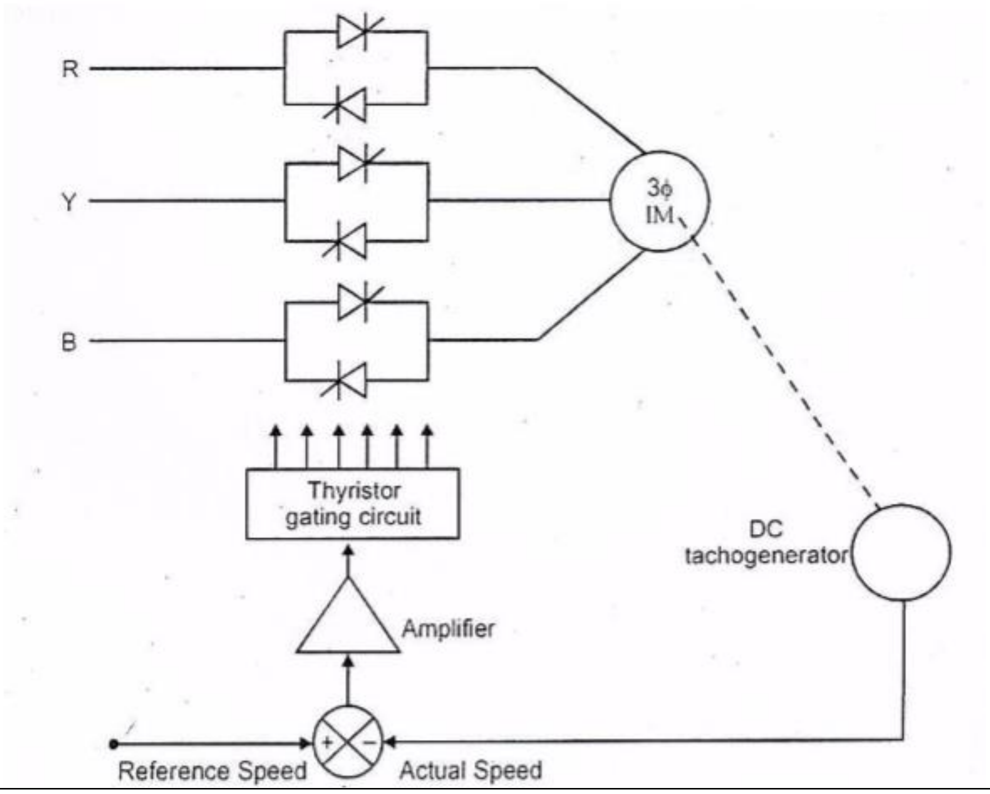
(a) Half wave ac voltage controller



- In on off control, the thyristors are employed as switches to connect the load circuit to the source for a few cycles of source voltage and then disconnect it for another few cycles. Thyristors acts as high speed switch (contactor). This method is known as integral cycle control .In phase control the thyristors are employed as switches connect the load to the ac source for a portion of each cycle of input voltage.

2. Closed loop control control method:

<u>Closed loop speed control</u>

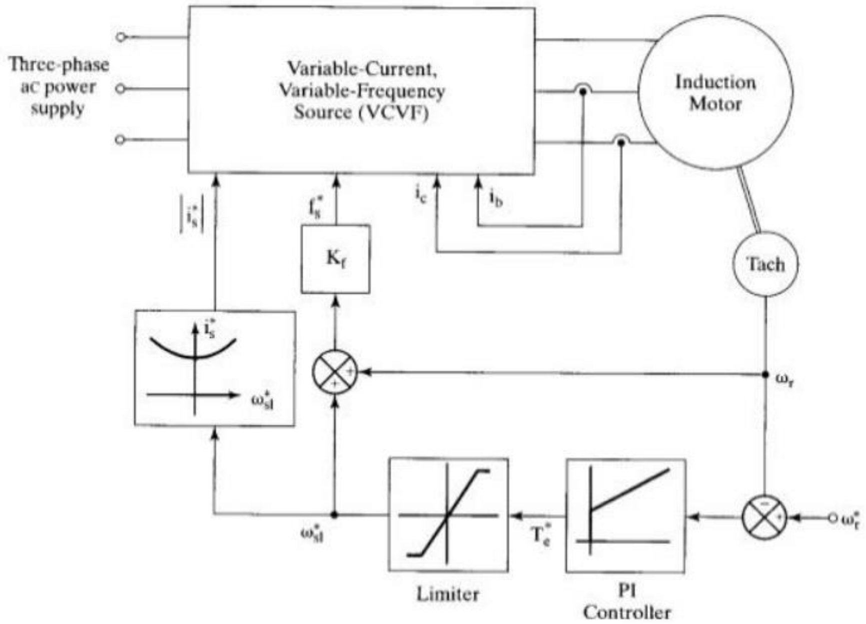


5

Discuss about the adjustable frequency constant air gap flux control method of speed control of induction motor drives. (13M) (May/June 2009) BTL 3

Answer Page: 5.75 – J.Gnanavadivel

Constant air gap flux control diagram & Explanation (6M & 7M)



3. Equivalent separately-excited dc motor in terms of its speed but not in terms of decoupling of flux and torque channel.
4. Constant air gar flux linkages

$$\lambda_m= L_m i_m=E_1/\omega_s$$

- The rotor flux magnitude and position is key information for the AC induction motor control. With the rotor magnetic flux, the rotational coordinate system (d-q) can be established.
- There are several methods for obtaining the rotor magnetic flux. The implemented flux model utilizes monitored rotor speed and stator voltages and currents. It is calculated in the stationary reference frame (α,β) attached to the stator.
- The error in the calculated value of the rotor flux, influenced by the changes in temperature, is negligible for this rotor flux model

7

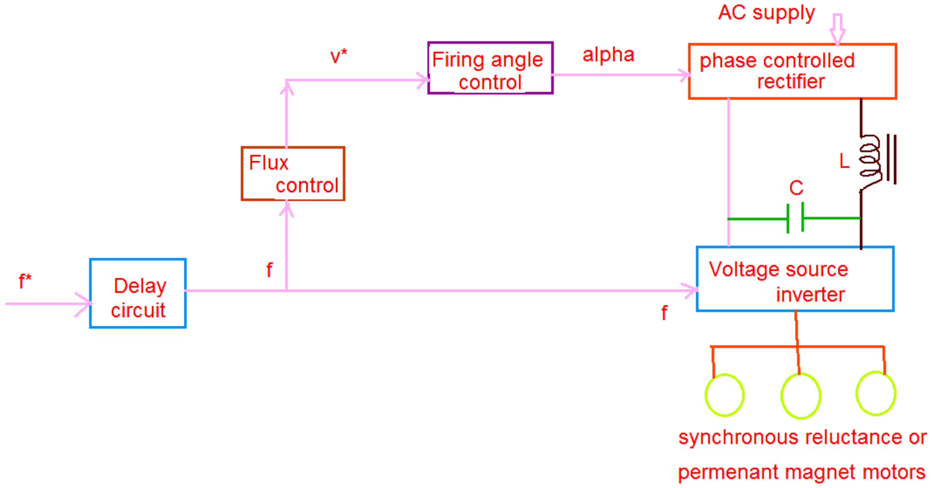
Describe the closed loop speed control of VSI fed and CSI fed induction motor droves. (13M) (May/June'13,15) (Nov 2018)

BTL 4

Answer Page: 5.88, 5.92 – J.Gnanavadivel

- **Voltage source inverter fed drive (7M)**

  Most of the applications preferred VSI fed to 3 phase Induction motor due to its self-starting nature. A normal VSI with 180° conducting mode required only forces commutation.



- There are two techniques to get desirable outputs:

1. Controlling the inverter voltage by PWM technique
2. Connecting the DC chopper in between rectifier and inverter.

- A VSI is a self or separate control feeding Induction motor. Open loop and closed loop operation is possible but VSI provides instability and hunting problems.
- The stator current drawn by the motors when fed to VSI has sharp peaks and is rich in harmonic content which causes additional losses and heating. This technique is used for high and medium speed applications.

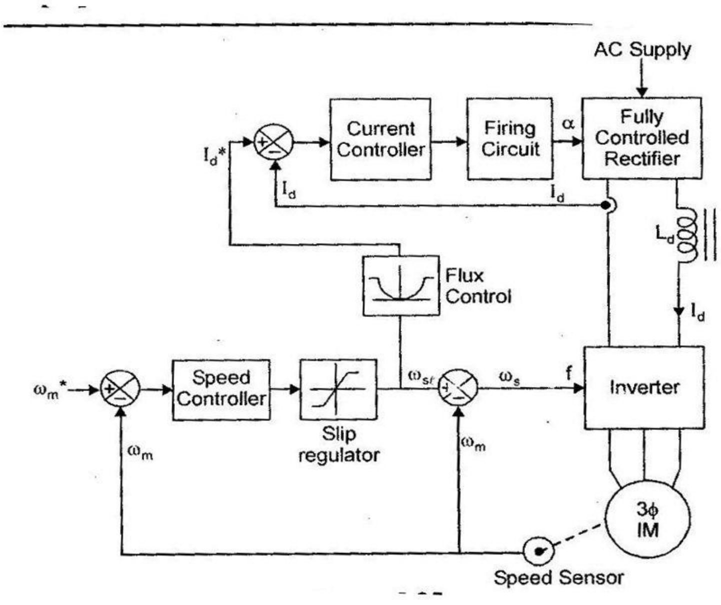
Current source Inverter (6M)

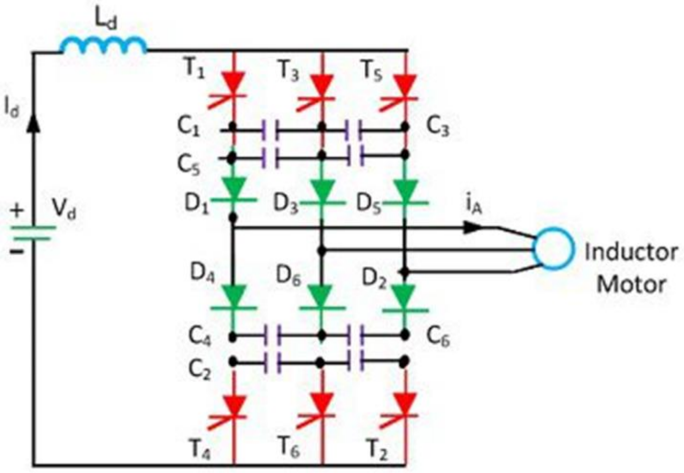
- CSI is used in many applications due to its flexibility, reliability and commutation. CSI operates on closed loop and capable of generation, by using CSI variable frequency is obtained.
- Advantages:

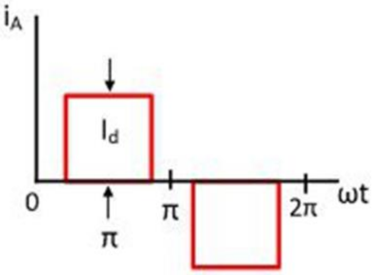
1. CSI is robust and simple
2. Four quadrant operation is possible.
3. Controlling the speed in simple way
4. Better controlled performance.

- Disadvantages:

1. Cost is expensive with PWM technique
2. Unsupported for multi-motor operation

	
	Part*C
1	**Write about CSI induction motor drives and also closed loop control for CSI induction motor drives. (13M) (Nov/Dec , 13) (Nov 2018)** BTL 4 Answer Page: 4.23 – J.Gnanavadivel **Definition : (2M)** The current source inverter converts the input direct current into an alternating current. In current source inverter, the input current remains constant but this input current is adjustable. The current source inverter is also called current fed inverter. The output voltage of the inverter is independent of the load. The magnitude and nature of the load current depends on the nature of load impedance. **Current source inverter control (4M)**

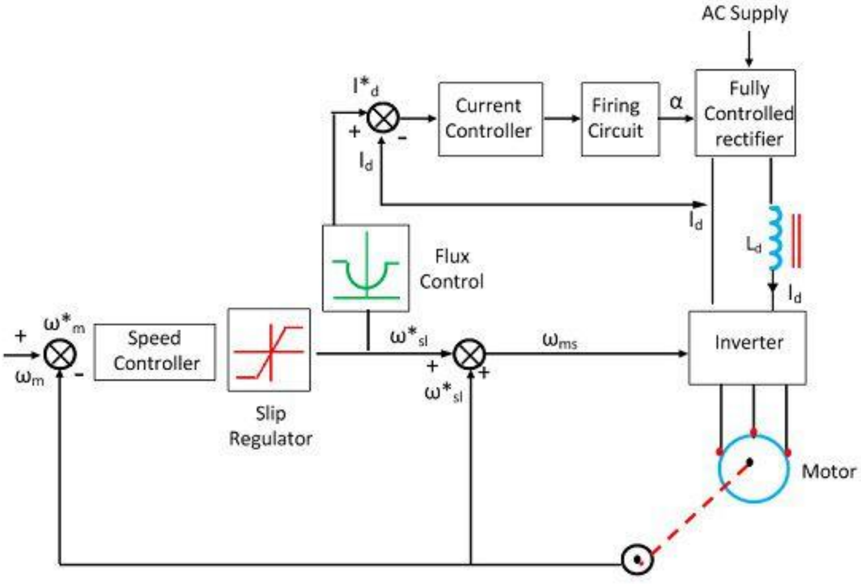




- The torque is controlled by varying DC link current I_d by changing the value of V_d. When the supply is AC, a controlled rectifier is connected between the supply and inverter. When the supply is, DC a chopper is interposed between the supply and inverter.

Closed loop control of CSI drives: (9M)

- The closed loop CSI drive is shown is shown in the figure below. The actual speed ω_m is compared with the reference speed ω^*_m. The speed error is controlled through PI controller and slip regulator. The slip regulator sets the slips speed command ω^*_{sl}. The synchronous speed obtained by adding ω_m, ω^*_{sl} determines the inverter frequency. Constant flux is obtained when slip speed ω_{sl} and I_s have the relationship. Since I_d is proportional to I_s, according to the equation shown below a similar relation exists between ω_{sl} and I_d for constant flux operation.



Closed Loop Slip Controlled CSI Drive with Regenerative Braking

Circuit Globe

2

Write about VSI induction motor drives and also closed loop control for VSI induction motor drives. (13M) (Nov/Dec , 13) BTL 4

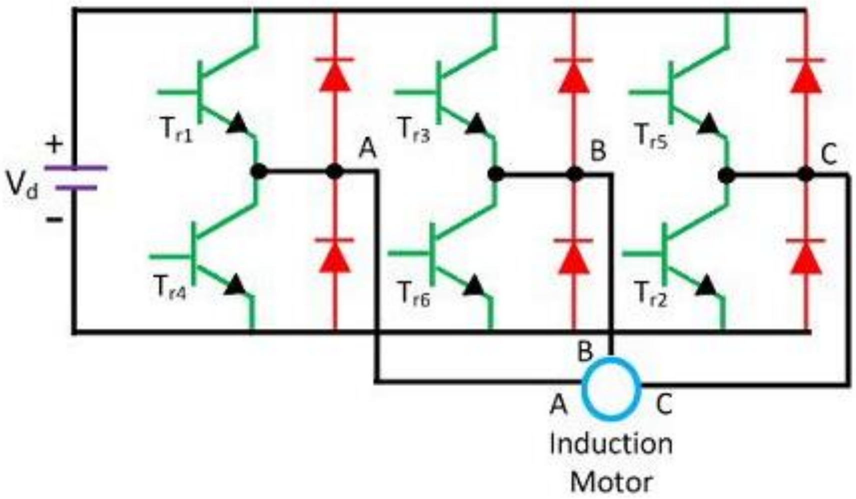
Answer Page: 4.23 – J.Gnanavadivel

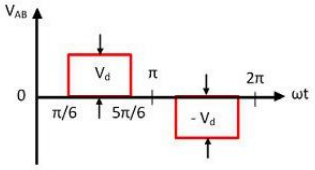
Definition (2M)

Definition: The voltage source inverter is defined as the inverter which takes a variable frequency from a DC supply. The input voltage of the voltage source inverter remains constant, and their output voltage is independent of the load. The magnitude of the load current depends on **the** nature of the load impedance**.**

Voltage source inverter motor drive: (13M)

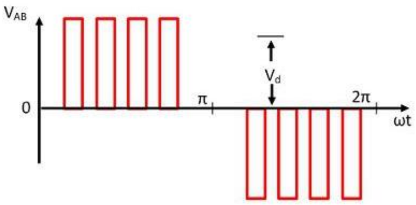
The voltage source inverter use self-commutated device like MOSFET, IGBT, GTO, etc. It is operated as a stepped-wave inverter or a pulse width modulation. When the voltage source inverter is operated as a stepped-wave inverter, then the transistor is switched in the Sequence of their numberwithtimedifference





Stepped Wave Inverter Line Voltage Waveform

Circuit Globe



UNIT IV SYNCHRONOUS MOTOR DRIVES 9

V/f control and self-control of synchronous motor: Margin angle control and power factor control-Three phase voltage/current source fed synchronous motor- Applications

PART * A

Q.No	Questions
1	**What are the advantages of permanent magnet synchronous motors? (Apr/May 2018)** BTL 2 • Open loop volts/hertz control • Self- control method • Vector control
2	**Which synchronous machine is said to be self -controlled?** BTL 3 A machine is said to be self- controlled if it gets its variable frequency from an inverter whose thrusters are freed in a sequence, using the information of rotor position or stator voltages. In the former a rotor position sensor is employed which measures the rotor position with respect to the stator and sends pulses to the thyristors. Thus frequency of the inverter output is decided by the rotor speed.
3	**What are the advantages of permanent magnet synchronous motors?(Apr/May'18)** BTL 2 • Elimination of field copper loss • Higher power density • Low rotor inertia • Robust construction
4	**Compare sinusoidal PMAC with trapezoidal PMAC motor. (Apr/May 2017)** BTL 4 In sinusoidal PMAC the stator windings are sinusoid ally distributed throughout the periphery. The induced EMF is sinusoidal. Stator current is harmonics free. In trapezoidal type PMAC the stator windings are concentrated, the induced EMF is of trapezoidal shape. Stator current are rich in harmonics.
5	**List the applications of synchronous motor drives. (Apr/May 2017)** BTL 3 Fiber spinning mills, rolling mills, cement mills, electric vehicles, servo and robotic drives, MAGLEV and variable frequency starters.
6	**Why a self- controlled synchronous motor is free from hunting operation?(Nov/Dec '17)** BTL 3 In a self -control mode, the stator supply frequency is changed so that synchronous speed is same as rotor speed. This ensures that rotor runs at synchronous speed for all operating points. Consequently rotor cannot pull out of step and hunting oscillations are eliminated. Here motor may not require damper winding.
7	**What are the advantages of constant margin angle control of synchronous motor drive fed by an inverter? (May 2003, Dec 2004)** BTL 2 • Eliminates the hunting and stability problems • It does not require commutation circuits
8	**What is self -control mode of synchronous motors? (May 2006, 2004)** BTL 2 In self-control mode, the stator supply frequency is changed in proportion to the rotor speed so that the rotating field produced by the stator always moves at the same speed as that of the rotor.
9	**What is constant margin angle control of synchronous motor drive? (Dec 2004, May 2004)** BTL 2 In self -controlled synchronous motor drive, the load side converter is operated as an inverter and maximizes motor power factor. This control is called constant margin angle control.

10	**Why a synchronous motor without damper winding is used, in the drive system employing a Cycloconverter? (May 2005)** BTL 3 A synchronous motor without the damper winding is used, because the damper winding reduces the inductances of the machine, and therefore, its ability to filter out harmonics in the output voltage of Cycloconverter. Since the drive operates in self-controlled mode, the damper is not needed for its conventional roles.
11	**What is brushless dc motor? (May 2005)** BTL 2 An inverter fed trapezoidal permanent magnet AC motor drive operating in self -controlled mode is called a brushless dc motor.
12	**When can be the synchronous motor be load commutated? (May 2008)** BTL 4 When the synchronous motor operates at a leading power factor thyristors of the load side converter can be commutated by the motor induced voltages same way as the thyristors of a line commutated converter are commutated by line voltages.
13	**What are the major applications of Cycloconverter fed synchronous motor? (May 2005)** BTL 2 The Cycloconverter drive is attractive for low speed operation and frequently employed in large low speed reversing mills requiring rapid acceleration & deceleration. Also used for as gearless drives in mines and hoists.
14	**What are the disadvantages and advantages of chopper controlled resistance in the rotor resistance control circuit method?** BTL 2 The method is very inefficient because of losses in the resistance. It is suitable for intermittent loads such as elevators. At low speeds, in particular the motor has very poor efficiency. The rotor current is non-sinusoidal. They harmonics of the rotor current produce torque pulsations. These have a frequency which is six times the slip frequency. Because of the increased rotor resistance, the power factor is better.
15	**Where is Kramer electrical drive system used?** BTL 2 Some continuous rolling mills, large air blowers, mine ventilators, centrifugal pumps and any other mechanisms including pumps drives of hydraulic dredgers require speed adjustment in the range from 15 to 30% below or above normal . If the induction motor is of comparatively big size (100 to 200 KW) it becomes uneconomical to adjust speed by mean' s pf external resistances due to copper losses as slip power is wasted as heat in the retort circuit resistance. In this case, the Kramer electrical drive system is used, where slip power recovery takes places.
16	**Give the four modes of operation of a Scherbius drive.** BTL 4 The four modes of operation of static Scherbius drive are, 1. Sub synchronous motoring. 2. Sub synchronous regeneration 3. Super synchronous motoring 4. Super synchronous regeneration
17	**How is the braking action produced in plugging?** BTL 4 In plugging, the barking torque is produced by interchange any two supply terminals, so that the direction of rotation of the rotating magnetic field is reversed with respect to the rotation of the motor. The electromagnetic torque developed provides the braking action and brings the rotor to a quick stop**.**
18	**How is the speed control by variation of slip frequency obtained?** BTL 4 Speed control by variation of slip frequency is obtained by the following ways. 1. Stator voltage control using a three-phase voltage controller. 2. Rotor resistance control using a chopper controlled resistance in the rotor circuit. 3. Using a converter cascade in the rotor circuit to recover slip energy. 4. Using a cyclo converter in the rotor circuit.

19 **Give some advantages of Ward-Leonard drive.** BTL 3

The advantages of Ward-Leonard drive are,

1. Inherent regenerative braking capability
2. Power factor improvement.

20 **What are the advantages of armature voltage control?** BTL 2

The advantages of armature voltage control are,

1. High efficiency
2. Good transient response
3. Good speed regulation.

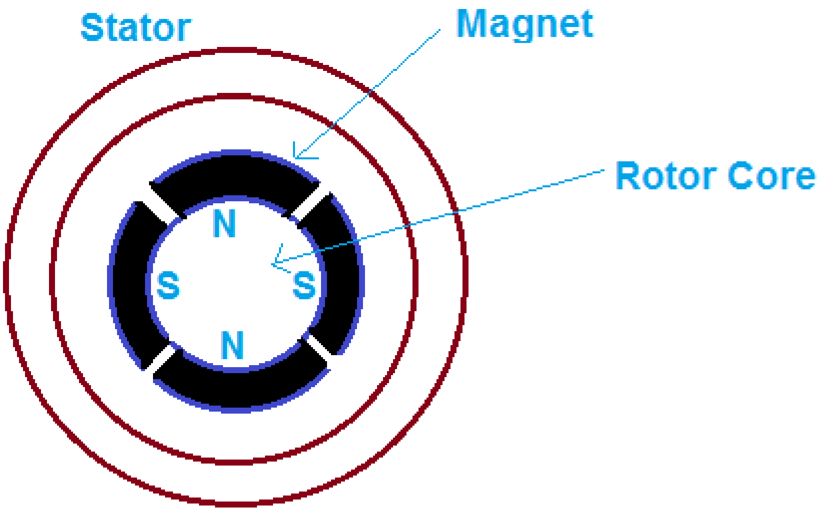
Part*B

1 **Explain the construction and working of permanent magnet synchronous motor. (13M) (Nov'17, May 11)** BTL 2

Answer Page: 5.26 – V.Thiyagarajan

Construction and working (8M)

- The basic construction of PMSM is same as that of synchronous motor. The only difference lies with the rotor. Unlike synchronous motor, there is no filed winding on the rotor of PMSM. Field poles are created by using permanent magnet. These Permanent magnets are made up of high permeability and high coactivity materials like Samarium-Cobalt and Neodium-Iron-Boron. Neodium-Iron-Boron is mostly used due to its ease of availability and cost effectiveness. Theses permanent magnets are mounted on the rotor core.
- Based on the mounting arrangement of magnet on rotor core, Permanent Magnet Synchronous Motor (PMSM) can be categorized into two types: Surface Mounted PMSMs and Buried or interior PMSMs.



- This type of PMSM is not robust and therefore not suited for high speed application. Since the permeability of magnet and air gap is almost same, therefore this type of construction provides a uniform air gap. Therefore, there is no reluctance torque present. Thus the dynamic performance of this motor is superior and hence used in high performance machine tool drives and robotics.

- **Advantages** **(3M)**
  1. Eliminates of field copper loss
  2. Higher power density
  3. Lower rotor inertia
  4. More robust construction of the rotor
  5. Higher efficiency
- **Disadvantages** **(2M)**
  1. Loss of flexibility of field flux control
  2. Remagnetization effect
  3. Higher costs.

2 **Explain the margin angle control of synchronous motor drives. (13M) (Apr/May'17)** BTL 2

- **Margin angle control closed loop diagram** **(7M)**

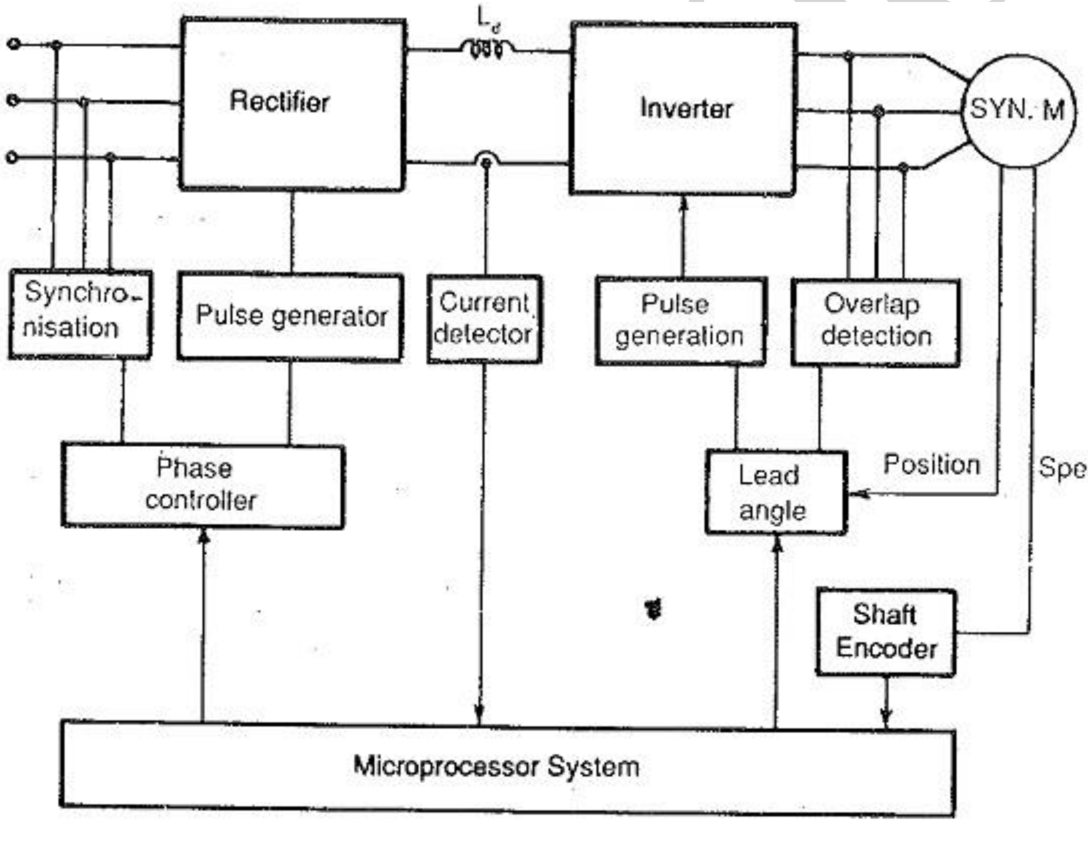


Fig. 8.20 *Implementation of margin angle control of a synchronous motor on a microprocessor*

- **Working explanation** **(6M)**

1. The commutation Margin Angle Control of Synchronous Motors is defined as the angle measured from the end of commutation to the crossing of the phase voltage which was under commutation (**natural firing instant**). For satisfactory operation, without commutation failure, this margin angle must be greater than the turn off angle (ωt_q) of the thyristors. In the constant Margin Angle Control of Synchronous Motors it is always observed that the margin angle does not go below a minimum value.

There are two ways of implementing the constant margin angle control:

1. The margin angle ψ is detected and controlled directly.
2. Control is effected invoking the relationship between the link current I_d and the margin angle ψ. The margin angle is controlled using a function j generator or a correction as a function of I_d.

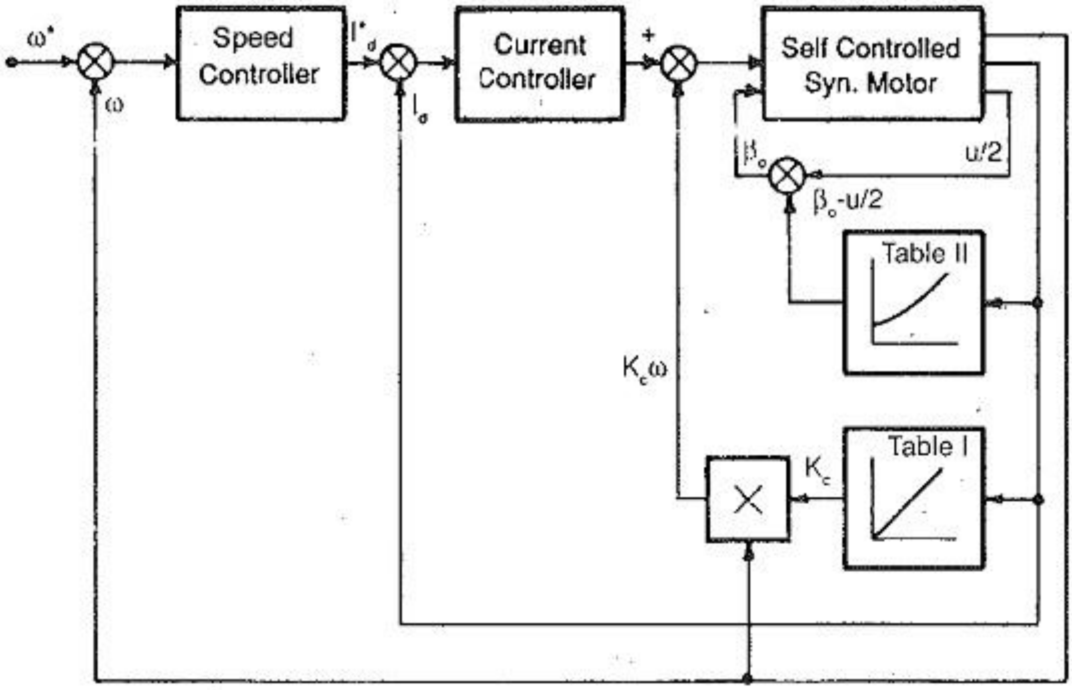


Table I Compensation for voltage drop.

Table II $(\beta_o\text{-}u/2)$ v.d c current in the constant margin angle control.

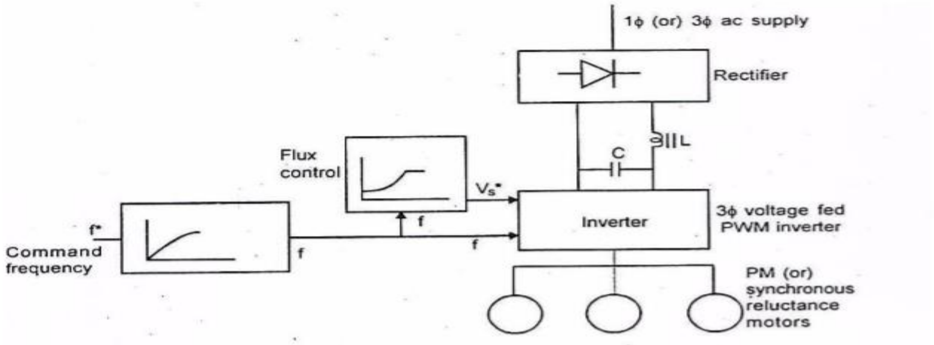
Fig. 8.21 *Block diagram of a self controlled synchronous motor with constant margin angle control*

3

With neat block diagram explain the variable frequency control of multiple synchronous motor. (13M) (Apr/May 14'16'17) (Nov 2018) BTL 3

Answer Page: 5.8 – V.Thiyagarajan

- **True synchronous or separate control mode (5M)**



- **Control characteristics of open loop Volts/Hertz control (5M)**
  Synchronous speed is directly proportional to frequency, similar to induction motors constant flux operation below base speed is achieved by operating the synchronous motor with constant (V / f) ratio.
  The synchronous motor either run at synchronous speed (or) it will not run at all.
  Hence variable frequency control may employ any of the following two modes
  1.True synchronous mode
  2.Separate controlled mode
  3.Self-controlled mode
- A flux control black is used which changes the stator voltage with frequency so as to maintain constant flux for speed below base speed and constant terminal voltage for speed above base speed. **(3M)**

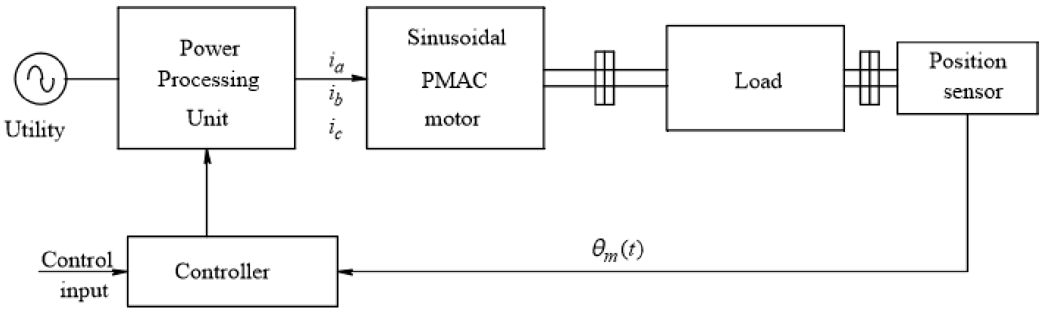
4

Explain the closed loop speed control of sinusoidal PMAC motor drive.(13M) (Nov'17) (Nov 18)

BTL 2

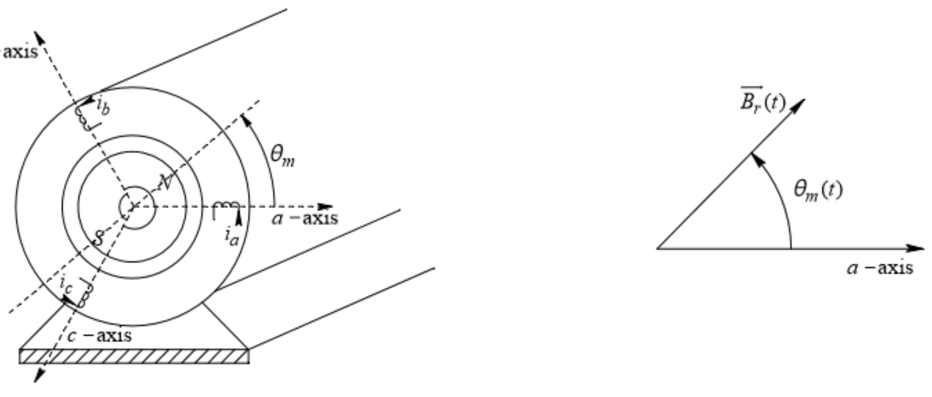
Answer Page: 5.13 – V.Thiyagarajan

- **Closed loop control (4M)**

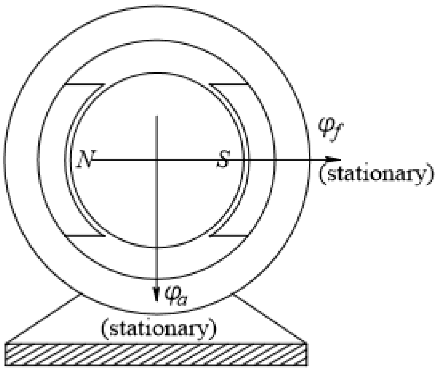


- **Structure of synchronous mode (4M)**

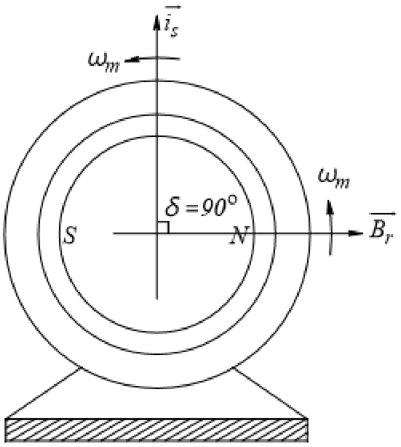
Structure of Permanent-Magnet Synchronous Machines



- **Features and similarity between Dc motor & brushless DC Motor (5M)**



DC motor



Brush-Less DC motor drive

5

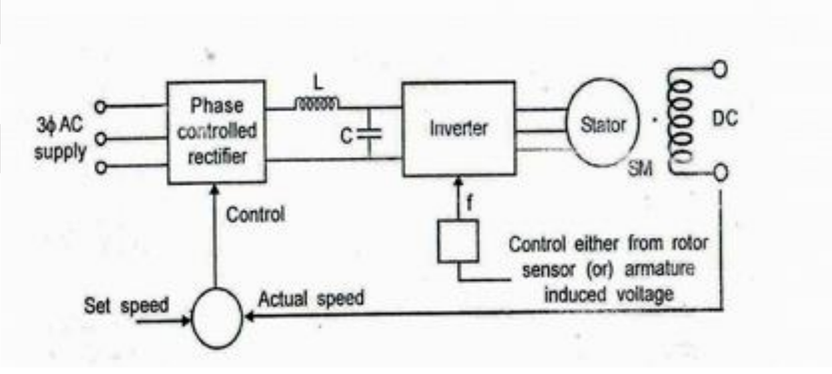
Explain in detail about the open loop v/f control and self - controlled mode of the synchronous motor drives. (13M) (Nov/dec'16,17) BTL 2

Answer Page: 5.9 & 5.26 – V.Thiyagarajan

- **Open loop v/f control (6M)**

The open loop V/F control of an induction motor is the most common method of speed control because of its simplicity and these types of motors are widely used in industry. Traditionally, induction motors have been used with open loop 50Hz power supplies for constant speed applications. For adjustable speed drive applications, frequency control is natural. However, voltage is required to be proportional to frequency so that the stator flux. The PWM converter is merged with the inverter block. Some problems encountered in the operation of this open loop drive are the following .The speed of the motor cannot be controlled precisely, because the rotor speed will be slightly less than the synchronous speed and that in this scheme the stator frequency and hence the synchronous speed is the only control variable.

- **Self- controlled mode (7M)**



- Every synchronous machine supplied by an electronic power converter and functioning with variable speed needs to ensure control of the converter that supplies it, in the sense that the rotational speed of its rotor imposes the frequency of the voltages and of the currents the converter provides to the stator windings.
- However the name "self-synchronous machine" usually refers to the case where the electronic power converter that supplies it is a thyristor bridge whose commutations are ensured by the voltages

6

Discuss using a block diagram & operation of a voltage source inverter fed synchronous motor in the true synchronous mode. (13M) (Apr/May '18) BTL 3

Answer Page: 5.19– V.Thiyagarajan

- VSI Block **diagram** **(6M)**

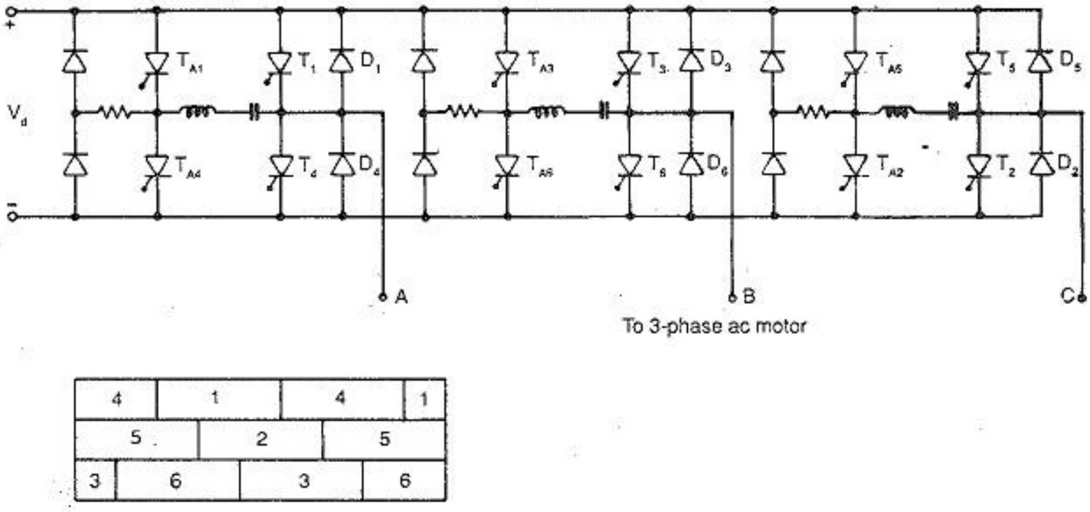


Fig. 4.41 *Power circuit of a VSI*

- **Explanation** **(7M)**
- The voltage control can be obtained external to the inverter using a phase controlled rectifier. The link voltage is variable.
- This has the disadvantage that commutation is difficult at very low speeds. As the output voltage is a square wave the inverter is called variable voltage inverter or square wave inverter. The second alternative is to have voltage control in the inverter itself, using principles of PWM or PSM.

7

Explain the power factor control of synchronous motor with relevant vector diagrams. (13M) (May' 10) BTL 2

Answer Page: 5.38 – V.Thiyagarajan

- **Automatic closed loop adjustment of power factor** **(5M)**

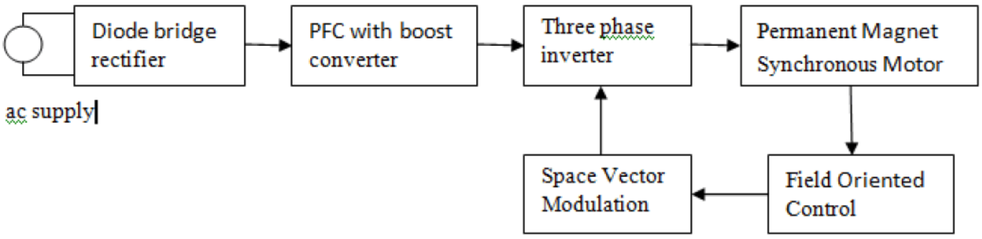
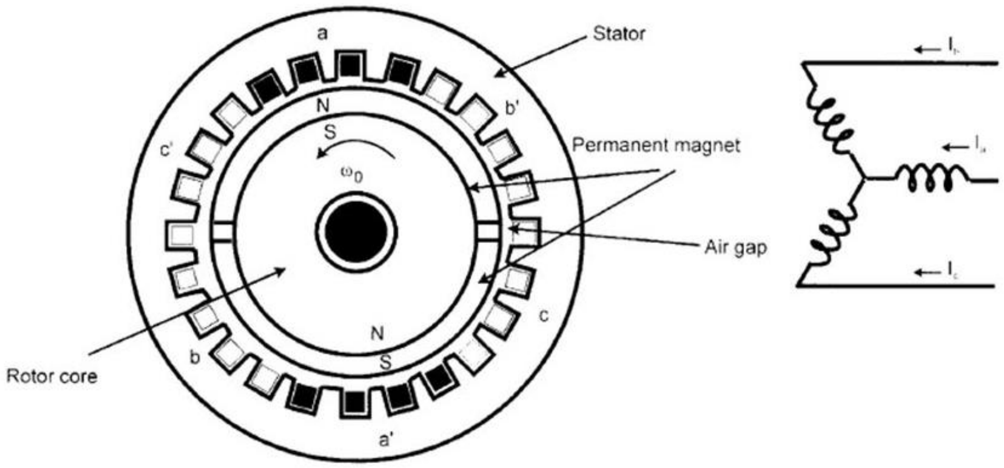
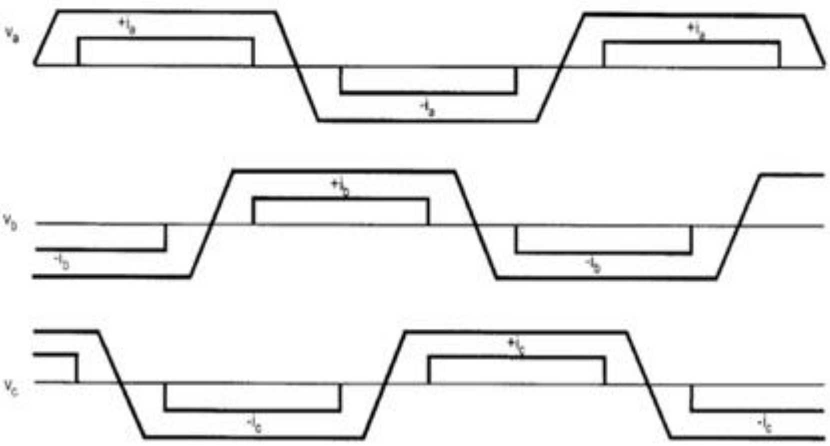


Fig3. PMSM drive with PFC

- **Block diagram Explanation** **(8M)**
- The wound-excited synchronous motor (Ex-SyM) is the only machine capable to operate at unity or leading power factor (PF). ... The stator-field orientation is used for control of the unity power factor and stator- flux, and also for generation of the armature-current control variables.
- Synchronous motors are used for the power factor correction as well. They offer smoother and wider control of power factor compared to the capacitor banks. Overexcited synchronous motor on no load condition or light load condition is known as synchronous condenser and used as a power factor corrective device.
- Synchronous motors are used for the power factor correction as well. They offer smoother

	and wider control of power factor compared to the capacitor banks. • Overexcited synchronous motor on no load condition or light load condition is known as synchronous condenser and used as a power factor corrective device. • In general, synchronous motors offer better power factor than induction motors because in case of induction motors, both the excitations (stator and flux setup) are drawn from the main supply itself whereas in case of synchronous motors, main supply does not contribute in setting up the flux.
8	**Using a power circuit diagram, explain the working of trapezoid ally excited permanent magnet synchronous motor, operating in self -controlled mode. (13M) (Nov'12)** BTL 4 Answer Page: 5.33– V.Thiyagarajan • **Trapezoid ally excited permanent magnet synchronous motor (6M)**  Cross-section of trapezoidal surface magnet machine (two-pole) **(5M)**

	Trapezoidally excited PMAC  Stator phase voltage and current waves in trapezoidal PM machine - **Advantages & disadvantages** **(2M)**
	Part*C
1	**Explain the margin angle control of synchronous motor drives. (15M) (Apr/May'17)** BTL 2 - **Margin angle control closed loop diagram** **(7M)**

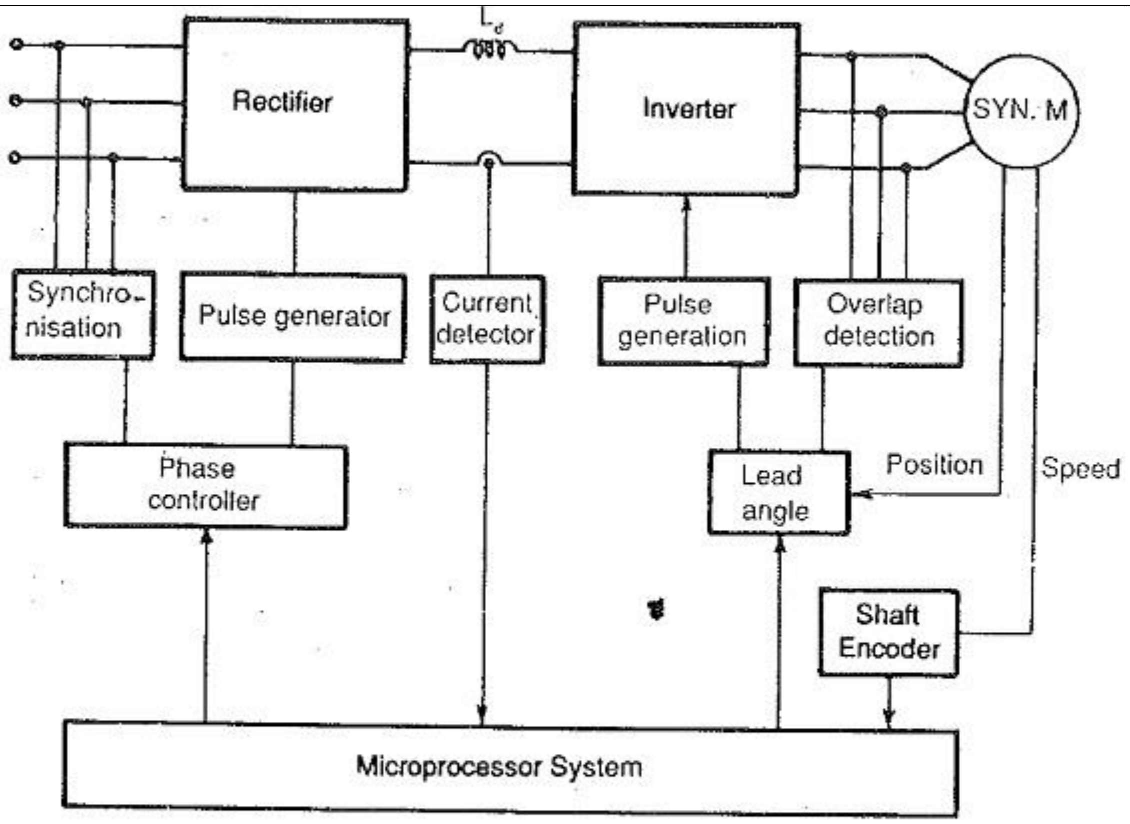


Fig. 8.20 *Implementation of margin angle control of a synchronous motor on a microprocessor*

- **Working explanation** **(8M)**

2. The commutation Margin Angle Control of Synchronous Motors is defined as the angle measured from the end of commutation to the crossing of the phase voltage which was under commutation (**natural firing instant**). For satisfactory operation, without commutation failure, this margin angle must be greater than the turn off angle (ωt_q) of the thyristors. In the constant Margin Angle Control of Synchronous Motors it is always observed that the margin angle does not go below a minimum value.

There are two ways of implementing the constant margin angle control:

3. The margin angle ψ is detected and controlled directly.
4. Control is effected invoking the relationship between the link current I_d and the margin angle ψ. The margin angle is controlled using a function j generator or a correction as a function of I_d.

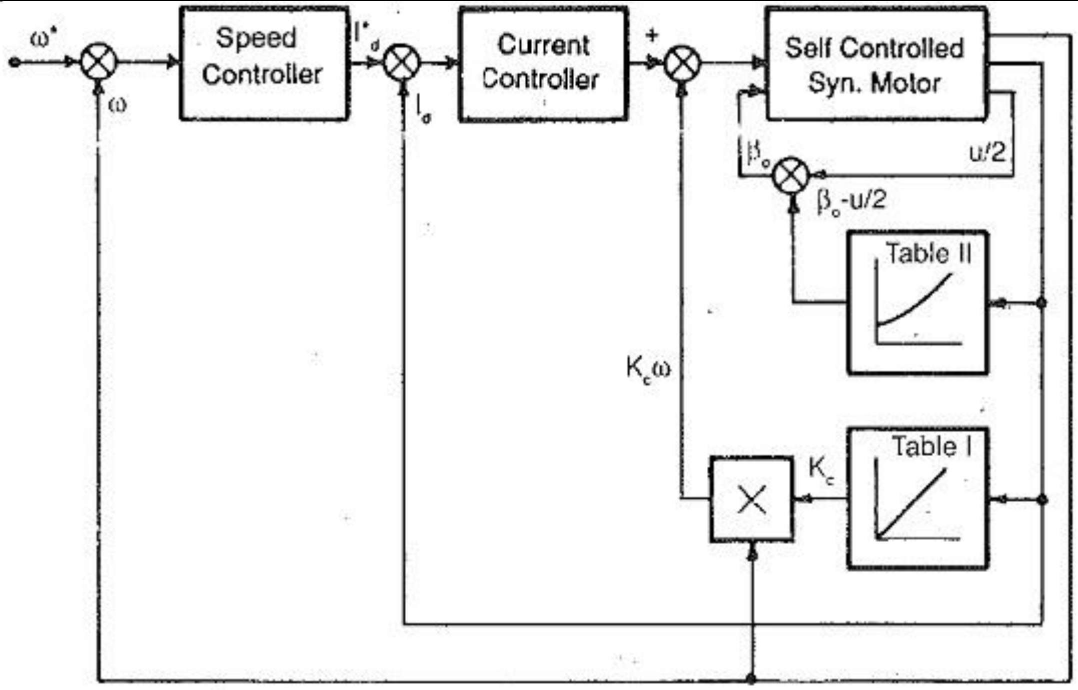


Table I Compensation for voltage drop.

Table II (βo-u/2) v.d c current in the constant margin angle control.

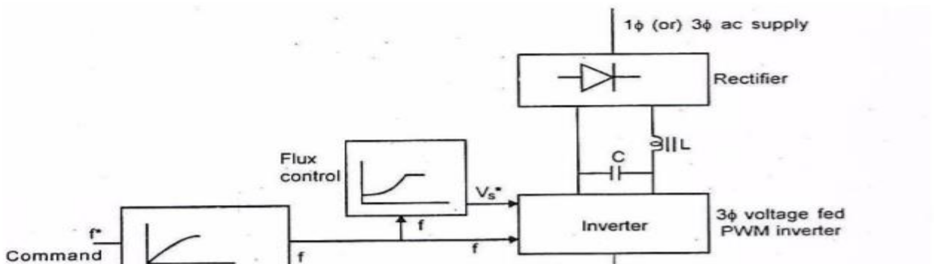
Fig. 8.21 *Block diagram of a self controlled synchronous motor with constant margin angle control*

2

With neat block diagram explain the variable frequency control of multiple synchronous motor. (15M) (Apr/May 14'16'17) BTL 3

Answer Page: 5.8 – V.Thiyagarajan

- **True synchronous or separate control mode (7M)**



- **Control characteristics of open loop Volts/Hertz control (6M)**

  Synchronous speed is directly proportional to frequency, similar to induction motors constant flux operation below base speed is achieved by operating the synchronous motor with constant (V / f) ratio.

  The synchronous motor either run at synchronous speed (or) it will not run at all.

  Hence variable frequency control may employ any of the following two modes

	1.True synchronous mode 2.Separate controlled mode 3.Self-controlled mode • A flux control black is used which changes the stator voltage with frequency so as to maintain constant flux for speed below base speed and constant terminal voltage for speed above base speed. **(2M)**

UNIT V DESIGN OF CONTROLLERS FOR DRIVES **9**

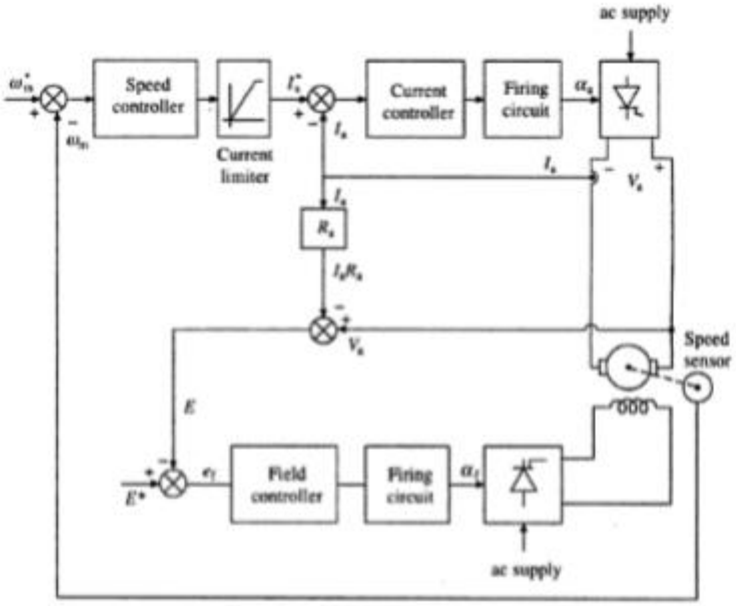
Transfer function for DC motor / load and converter – closed loop control with Current and speed feedback–armature voltage control and field weakening mode – Design of controllers; current controller and speed controller- converter selection and characteristics.

PART * A

Q.No.	**Questions**
1	**How is speed feedback achieved in speed controller design? (Nov/Dec'17)** BTL 4 Speed is sensed by the speed sensor and the sensed speed in compared with error signal. The resultant is fed to speed controller. The output from the speed controller in Ia is fed to current loop which gives as output that will be fed to motor. This cyclic process continuous until the speed error in made zero.
2	**What is the role of current limiter in the closed loop control of dc drives? (Nov/Dec'17)**BTL 2 It saturates and sets current reference for inner current loop at a value corresponding to the maximum allowable current.
3	**Highlight the factors to be considered for converter selection. (Apr/May 17)** BTL 4 • Type of power supply conversion requirement • Rating of drive • Harmonic content in the output • Modes of operation • Motor and load specification
4	**How current and speed controllers are implements in drives? (Apr 17)** BTL 3 Outer speed controller loop and inner current loop can be implemented by using P,PI And PID controller. Speed signal is sensed by the placing appropriate speed sensors such as proximity sensor, encoder, magnetic resolver, current signal is sensed by using current shunt and hall effect current sensor.
5	**What are the advantages of closed loop speed control scheme? (Apr '2018)** BTL 2 • System protection • Greater accuracy • Improved dynamic response • Reduced effect of disturbances such as loading
6	**List out the simultaneous software packages that can be used for electrical drives.(Apr '18)** BTL 4 • MATLAB/SIMULINK • PSIM • PSPICE • EMTP

7	**What are the two types of speed controller? Nov ‘ 14** BTL 2 - Proportional controller - Proportional integral controller
8	**Define self -control of synchronous motor. (May 2011)** BTL 1 In self -control, as the rotor speed changes, the armature supply frequency is also changed proportionately So that the armature field always moves at the same speed as the rotor
9	**What is the necessity of delay unit in a open loop v/f control of synchronous motor? (May 2011)** BTL 2 The delay circuit is necessary to ensure that the change in inverter frequency is slow enough for the motor speed track the evolving field speed
10	**Define torque angle.** BTL 1 The angle between excitation emf and supply voltage. This angle is called torque angle or power angle. It is denoted as δ
11	**What are the classifications of permanent magnet synchronous motor?** BTL 2 According to construction , i)Surface mounted PMSM. ii)Interior mounted PMSM. According to the nature of voltage induced, i)Sinusoidally excited. ii)Trapezoidally excited
12	**Why a synchronous motor without damper winding is used, in the drive system employing a Cycloconverter?** BTL 3 A synchronous motor without damper winding is used, because the damper winding reduces the inductance of the machine, and therefore its ability to filter out harmonics in the output voltage of the Cycloconverter. Since the drive operates in the self-controlled mode, the damper winding is not needed for its conventional roles.
13	**How are the stator and rotor of the synchronous motor supplied?** BTL 4 The stator of the synchronous motor is supplied from a thyristor power converter capable of providing a variable frequency supply. The rotor, depending upon the situation, may be constructed with slip rings, where it conforms to a conventional rotor. It is supplied with D.C. through slip rings. Sometimes rotor may also be free from sliding contacts (slip rings), in which case the rotor is fed from a rectifier rotating with rotor.
14	**Which machine is said to be self -controlled? (May 2012)** BTL 3 A machine is said to be self -controlled if it gets its variable frequency from an inverter whose thyristors are fired in a sequence, using the information of rotor position or stator voltages. In the former a rotor position sensor is employed which measures the rotor position with respect to the stator and sends pulses to the thyristors. Thus frequency of the inverter output is decided by the rotor speed.
15	**Give the application of self-controlled synchronous motor**. BTL 5 A self-controlled synchronous motor is a substitute for a D.C. motor drive and finds application where a D.C. motor is objectionable due to its mechanical commutator, which limits the speed range and power output.
16	**What is meant by margin angle of commutation?** BTL 2 The difference between the lead angle of firing and the overlap angle is called the margin angle of commutation. In this angle of the thyristor, commutation failure occurs. Safe commutation is assured if this angle has a minimum value equal to the turn off angle of the thyristor.
17	**What are the advantages of Constant margin angle control of Synchronous motor drive fed by an inverter?** BTL 2 1. Eliminates the hunting and stability problems, **2.** It does not require commutation circuits.

18	**What is the necessity of delay unit in a open loop v/f control of synchronous motor? (May 2011)** BTL 2 The delay circuit is necessary to ensure that the change in inverter frequency is slow enough for the motor speed track the evolving field speed.
19	**What are the different ways of receiving variable voltage and variable frequency for a synchronous motor?** BTL 2 1. DC link converter. **a) Voltage source inverter.** **b) Current source inverter.** 2. Cycloconverter
20	**What is meant by margin angle of commutation?** BTL 2 The difference between the lead angle of firing and the overlap angle is called the margin angle of commutation. In this angle of the thyristor, commutation failure occurs. Safe commutation is assured if this angle has a minimum value equal to the turn off angle of the thyristor.
	Part*B
1	**Explain the armature voltage control of separately excited dc motor drive with constant field and field weakening mode. (13M) (May/Jun '07, 17)** BTL 2 Answer Page: 6.21- V.Thiyagarajan • **Speed control methods (3M)** 1. Armature voltage control 2. Field flux control **3.** Armature resistance control • **Explanation (10M)** 1. In armature voltage control, the speed of the motor is controlled below base speed. In field current control, the speed of the motor is controlled above base speed. The closed loop speed control scheme. 2. The drive employs an inner current control loop and an outer speed control loop. 3. This drive operates at constant field current and variable armature voltage below the base speed. 4. For above speed, the drive operates with constant armature voltage and variable field current. 5. Both armature and field are separately fed from two fully controlled rectifiers. 6. When a fully controlled rectifier is used, regenerative braking is not possible. Hence braking is possible by deceleration of drive due to the inertia (weight) of the load.



7. Speed of the motor is brought near rated speed. At rated speed, the back emf E will be close to E* and ef will be less. Hence field controller comes out of saturation.
8. If the reference speed is set for a speed above rated speed, the current reference will be set at maximum current.

2

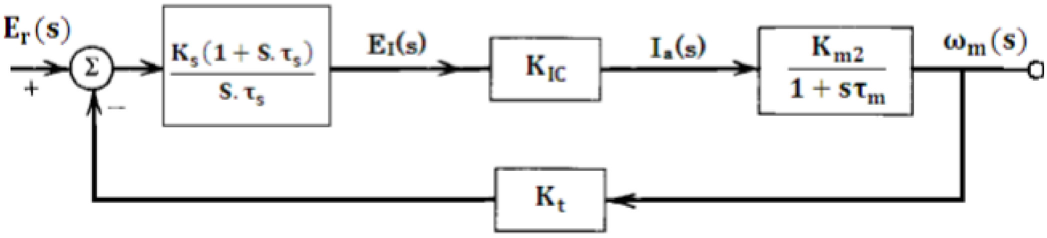
Describe about design of current controller of closed loop speed controller system of dc separately excited dc motor. (13M) (May/June '09, 17) (Nov 18) BTL 4

Answer Page: 6.26- V.Thiyagarajan

Current controller (3M)

- It is always beneficial to limit the motor current to its maximum allowable value. This objective cannot be achieved by using a simple speed control loop.
- In speed control loop, the motor voltage is controlled by speed error. When speed error is reduced, the applied voltage is changed. But no change in current happens.
- Hence a current limit is implemented using a current control loop by using the speed error to produce current reference.
- It is implemented using both P and P-I controllers.

Closed loop transfer function diagram & derivation (4M & 6M)



$$\frac{\omega_m(s)}{E_r(s)} = \frac{K_s.K_{IC}.K_{m2}\left[\frac{(1+S.\tau_s)}{S.\tau_s(1+s\tau_m)}\right]}{1+K_s.K_{IC}.K_{m2}\left[\frac{(1+S.\tau_s)}{S.\tau_s(1+s\tau_m)}\right].K_t}$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{K_s.K_{IC}.K_{m2}\left[\frac{(1+S.\tau_s)}{S.\tau_s(1+s\tau_m)}\right]}{\frac{S.\tau_s(1+s\tau_m)+K_s.K_{IC}.K_{m2}.K_t(1+S.\tau_s)}{S.\tau_s(1+s\tau_m)}}.$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{K_s.K_{IC}.K_{m2}(1+S.\tau_s)}{S.\tau_s(1+s\tau_m)+K_s.K_{IC}.K_{m2}.K_t(1+S.\tau_s)}$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{K_s.K_{IC}.K_{m2}(1+S.\tau_s)}{S.\tau_s+S^2\tau_s\tau_m+K_s.K_{IC}.K_{m2}.K_t+S.K_s.K_{IC}.K_{m2}.K_t.\tau_s}$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{K_s.K_{IC}.K_{m2}(1+S.\tau_s)}{S^2\tau_s\tau_m+S.\tau_s(1+K_s.K_{IC}.K_{m2}.K_t)+K_s.K_{IC}.K_{m2}.K_t}$$

Divide numerator & denominator by $K_s.K_{IC}.K_{m2}.K_t$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{\frac{K_s.K_{IC}.K_{m2}(1+S.\tau_s)}{K_s.K_{IC}.K_{m2}.K_t}}{\frac{S^2\tau_s\tau_m}{K_s.K_{IC}.K_{m2}.K_t}+\frac{S.\tau_s(1+K_s.K_{IC}.K_{m2}.K_t)}{K_s.K_{IC}.K_{m2}.K_t}+\frac{K_s.K_{IC}.K_{m2}.K_t}{K_s.K_{IC}.K_{m2}.K_t}}$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{\frac{(1+S.\tau_s)}{K_t}}{\frac{S^2\tau_s\tau_m}{K_s.K_{IC}.K_{m2}.K_t}+\frac{S.\tau_s(1+K_s.K_{IC}.K_{m2}.K_t)}{K_s.K_{IC}.K_{m2}.K_t}+1}$$

$K_s.K_{IC}.K_{m2}.K_t \ggg 1.$ *Hence,*

$$\frac{\omega_m(s)}{E_r(s)} = \frac{\frac{(1+S.\tau_s)}{K_t}}{\frac{S^2\tau_s\tau_m}{K_s.K_{IC}.K_{m2}.K_t}+\frac{S.\tau_s(K_s.K_{IC}.K_{m2}.K_t)}{K_s.K_{IC}.K_{m2}.K_t}+1}$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{\frac{(1+S.\tau_s)}{K_t}}{\frac{S^2.\tau_s.\tau_m}{K_s.K_{IC}.K_{m2}.K_t}+S.\tau_s+1}$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{1+S.\tau_s}{K_t.(S^2\tau_s\tau_2+S.\tau_s+1)} -----7$$

where $\tau_2 = \frac{\tau_m}{K_s.K_{IC}.K_{m2}.K_t}$

We know that,

$$\frac{I_a(s)}{E_r(s)} = \frac{I_a(s)}{\omega_m(s)} \times \frac{\omega_m(s)}{E_r(s)}$$

3

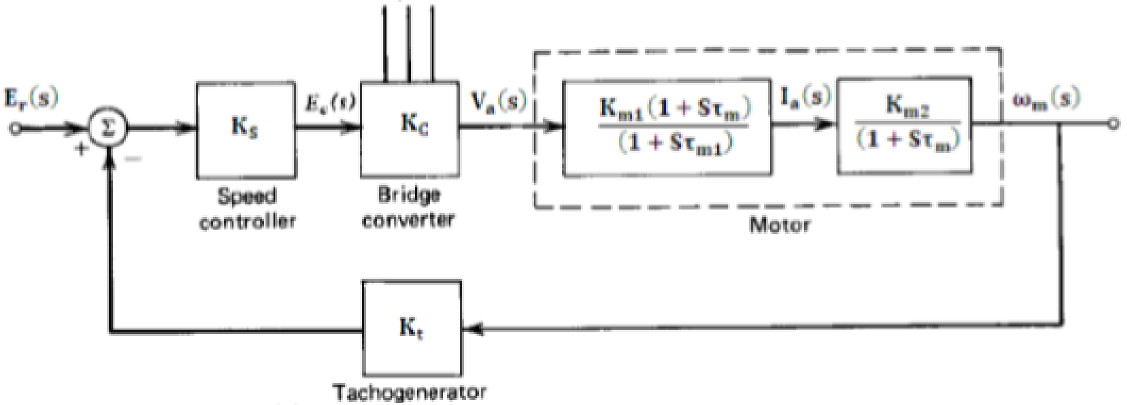
With neat block diagram, discuss the operation of closed loop scheme for speed control of a dc motor, below and above the base speed. (13M) (May/Jun'09) BTL 4

Answer Page: 6.20- V.Thiyagarajan

Speed controller (3M)

- The error in speed is produced by comparing the actual speed and reference speed. This error is used to control the armature voltage.
- The applied armature voltage is controlled by a three phase or single phase converter.

Closed loop block diagram & transfer function (5M & 5M)



$$\frac{\omega_m(s)}{E_r(s)} = \frac{G(s)}{1 + G(s).H(s)}$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{K_S.K_C.\frac{K_{m1}(1+s\tau_m)}{(1+s\tau_{m1})}\left(\frac{K_{m2}}{1+S.\tau_m}\right)}{1+K_S.K_C.\frac{K_{m1}(1+s\tau_m)}{(1+s\tau_{m1})}\left(\frac{K_{m2}}{1+S.\tau_m}\right).K_t}$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{\frac{K_S.K_C.K_{m1}.K_{m2}}{(1+s\tau_{m1})}}{\frac{(1+s\tau_{m1})+K_S.K_C.K_{m1}K_{m2}.K_t}{(1+s\tau_{m1})}}$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{K_S.K_C.K_{m1}.K_{m2}}{1+s\tau_{m1}+K_S.K_C.K_{m1}K_{m2}.K_t}$$

Divide the num & den by $1 + K_S.K_C.K_{m1}K_{m2}.K_t$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{\frac{K_S.K_C.K_{m1}.K_{m2}}{1+K_S.K_C.K_{m1}K_{m2}.K_t}}{\frac{s\tau_{m1}}{1+K_S.K_C.K_{m1}K_{m2}.K_t}+\frac{1+K_S.K_C.K_{m1}K_{m2}.K_t}{1+K_S.K_C.K_{m1}K_{m2}.K_t}}$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{\frac{K_S.K_C.K_{m1}.K_{m2}}{1+K_S.K_C.K_{m1}K_{m2}.K_t}}{\frac{s\tau_{m1}}{1+K_S.K_C.K_{m1}K_{m2}.K_t}+1}$$

$$\frac{\omega_m(s)}{E_r(s)} = \frac{K_1}{1+S.\tau_1} ----1$$

From equation 1 in this section,

$$\frac{\omega_m(s)}{E_r(s)} = \frac{K_1}{1+S.\tau_1}$$

$$\therefore \frac{I_a(s)}{E_r(s)} = \frac{1+S.\tau_m}{K_{m2}} \times \frac{K_1}{1+s\tau_1}$$

$$\frac{I_a(s)}{E_r(s)} = \frac{K_1.(1+S.\tau_m)}{K_{m2}.(1+s\tau_1)}$$

$$I_a(s) = \frac{K_1.(1+S.\tau_m)}{K_{m2}.(1+s\tau_1)} \times E_r(s)$$

$$I_a(s) = \frac{K_1.(1+S.\tau_m)}{K_{m2}.(1+s\tau_1)} \times \frac{E_r}{S}$$

$$I_a(s) = \frac{\left[\frac{K_1.(1+S.\tau_m).E_r}{K_{m2}}\right]}{S.(1+s\tau_1)}$$

$$I_a(s) = \frac{\left[\frac{K_1.(1+S.\tau_m).E_r}{K_{m2}}\right]}{S.\tau_1\left(\frac{1}{\tau_1}+s\right)}$$

$$\left[\frac{K_1.(1+S.\tau_m).E_r}{K}\right]$$

4

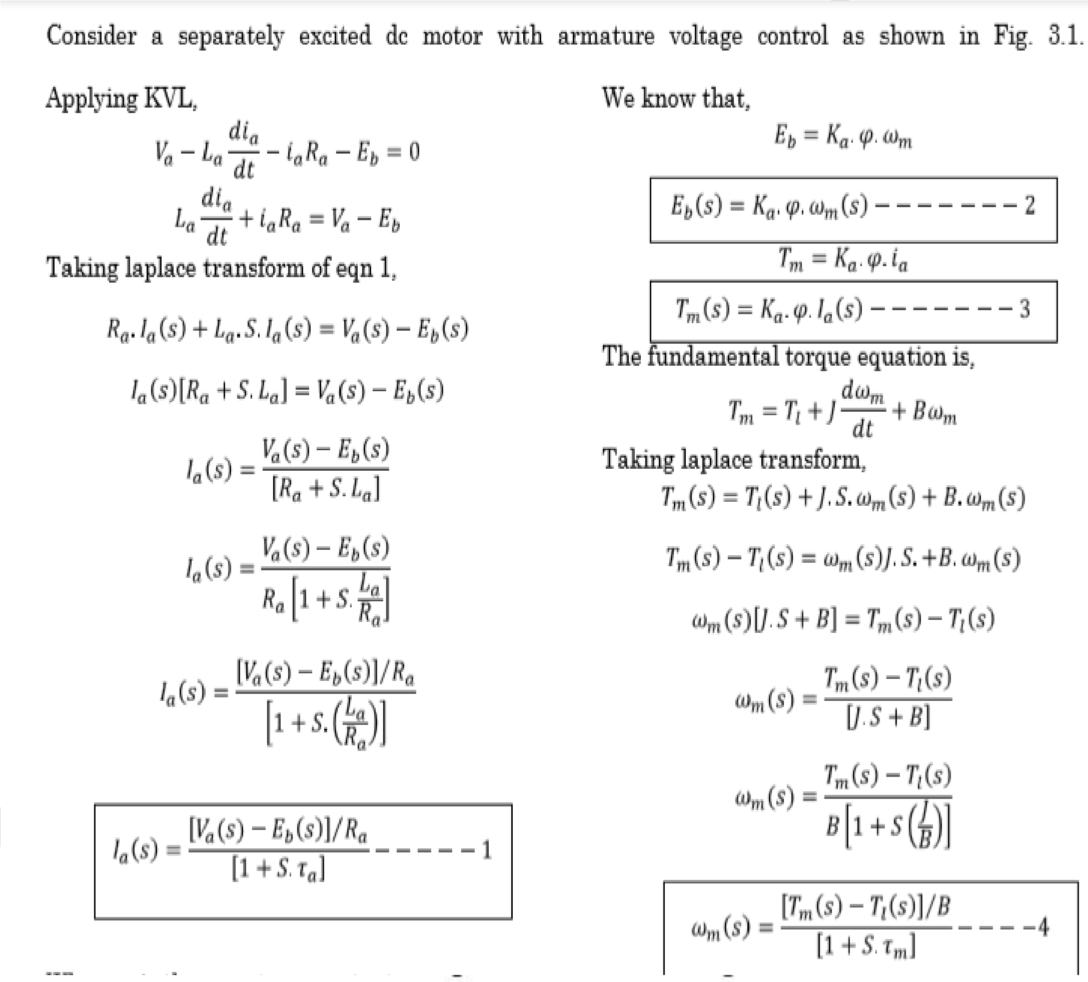
Derive the transfer function of Dc motor –load system with converter fed system. (13M) (Apr/May '10,12,14,17)(Nov 18) BTL 4

Answer Page: 6.11- V.Thiyagarajan

Transfer Function of DC motor: (6M)

- Separate field excitation in a separately excited DC motor makes the speed control relatively easy.
- In most applications, the armature voltage of the motor is controlled in a closed loop feedback system.
- In an armature-current controlled DC motor, the field current (If) is held constant, and the armature current (Ia) is controlled through the armature voltage (Va).

Equivalent circuit of motor –load system & derivation : (7M)



Consider a separately excited dc motor with armature voltage control as shown in Fig. 3.1.

Applying KVL,

$$V_a - L_a\frac{di_a}{dt} - i_aR_a - E_b = 0$$

$$L_a\frac{di_a}{dt} + i_aR_a = V_a - E_b$$

Taking laplace transform of eqn 1,

$$R_a.I_a(s) + L_a.S.I_a(s) = V_a(s) - E_b(s)$$

$$I_a(s)[R_a + S.L_a] = V_a(s) - E_b(s)$$

$$I_a(s) = \frac{V_a(s) - E_b(s)}{[R_a + S.L_a]}$$

$$I_a(s) = \frac{V_a(s) - E_b(s)}{R_a\left[1 + S.\frac{L_a}{R_a}\right]}$$

$$I_a(s) = \frac{[V_a(s) - E_b(s)]/R_a}{\left[1 + S.\left(\frac{L_a}{R_a}\right)\right]}$$

$$\boxed{I_a(s) = \frac{[V_a(s) - E_b(s)]/R_a}{[1 + S.\tau_a]} - - - - - 1}$$

We know that,

$$E_b = K_a.\varphi.\omega_m$$

$$\boxed{E_b(s) = K_a.\varphi.\omega_m(s) - - - - - - - 2}$$

$$T_m = K_a.\varphi.i_a$$

$$\boxed{T_m(s) = K_a.\varphi.I_a(s) - - - - - - - 3}$$

The fundamental torque equation is,

$$T_m = T_l + J\frac{d\omega_m}{dt} + B\omega_m$$

Taking laplace transform,

$$T_m(s) = T_l(s) + J.S.\omega_m(s) + B.\omega_m(s)$$

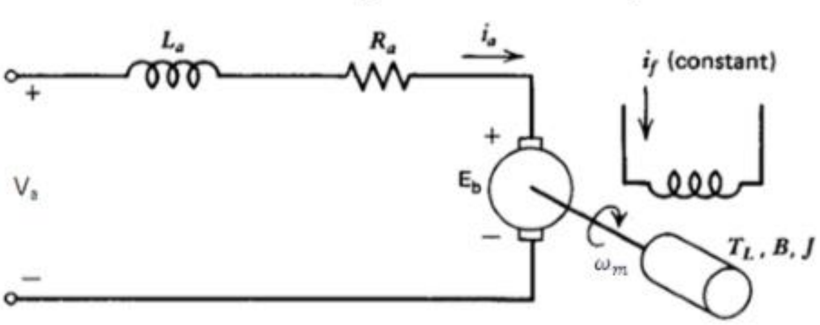
$$T_m(s) - T_l(s) = \omega_m(s)J.S. + B.\omega_m(s)$$

$$\omega_m(s)[J.S + B] = T_m(s) - T_l(s)$$

$$\omega_m(s) = \frac{T_m(s) - T_l(s)}{[J.S + B]}$$

$$\omega_m(s) = \frac{T_m(s) - T_l(s)}{B\left[1 + S\left(\frac{J}{B}\right)\right]}$$

$$\boxed{\omega_m(s) = \frac{[T_m(s) - T_l(s)]/B}{[1 + S.\tau_m]} - - - -4}$$



5

Explain the factors involved in converter selection and equations involved in controller characteristics. (13M) (Nov/Apr'17) BTL 2

Answer Page: 6.31- V.Thiyagarajan

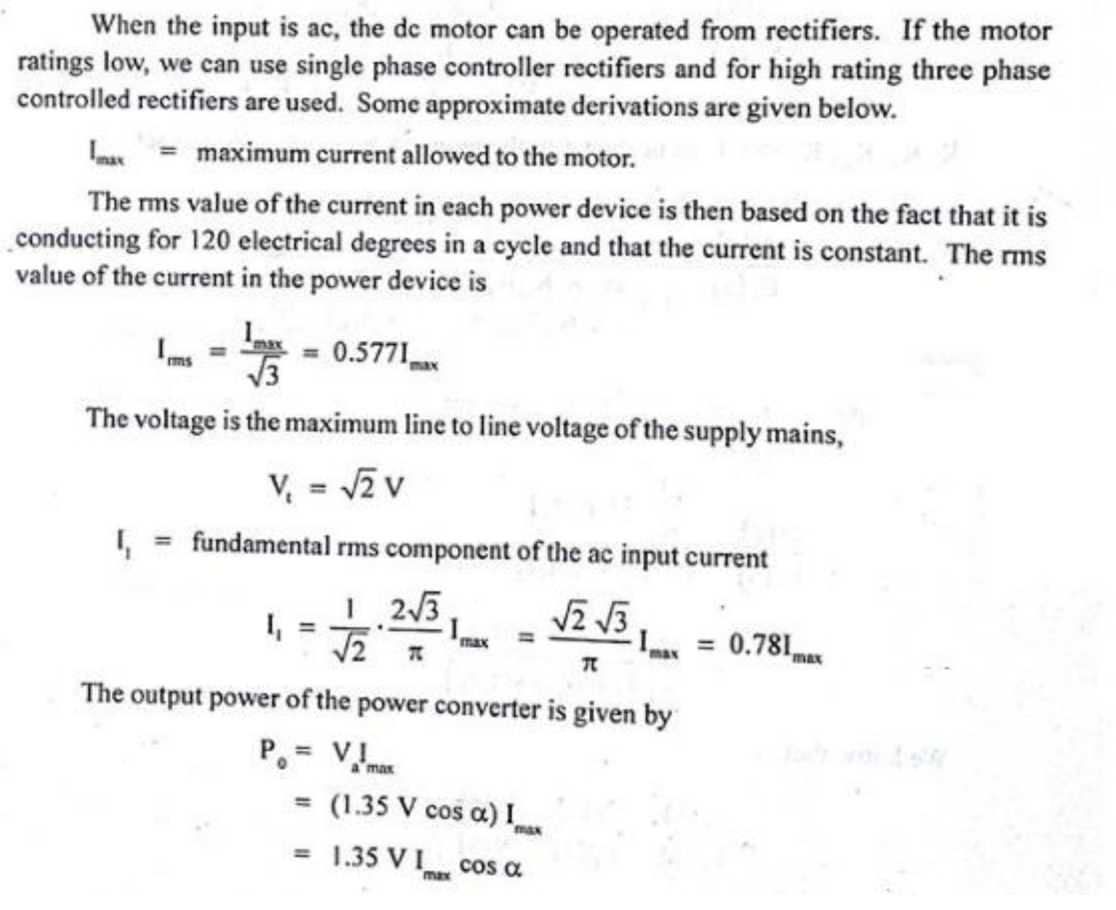
Selection factors (3M)

- Rating of the converter
- Power switches usage
- Motor-load specifications

Dis advantages of phase controlled converters (3M)

- More reactive power consumption
- More expensive
- Due to reactive power consumption, also generate harmonics – which was unacceptable to power utilities.

Controller characteristics and out power (7M)



When the input is ac, the dc motor can be operated from rectifiers. If the motor ratings low, we can use single phase controller rectifiers and for high rating three phase controlled rectifiers are used. Some approximate derivations are given below.

I_{max} = maximum current allowed to the motor.

The rms value of the current in each power device is then based on the fact that it is conducting for 120 electrical degrees in a cycle and that the current is constant. The rms value of the current in the power device is

$$I_{rms} = \frac{I_{max}}{\sqrt{3}} = 0.577I_{max}$$

The voltage is the maximum line to line voltage of the supply mains,

$$V_t = \sqrt{2}\,V$$

I_1 = fundamental rms component of the ac input current

$$I_1 = \frac{1}{\sqrt{2}}\cdot\frac{2\sqrt{3}}{\pi}I_{max} = \frac{\sqrt{2}\,\sqrt{3}}{\pi}I_{max} = 0.78I_{max}$$

The output power of the power converter is given by

$$P_0 = V_a I_{max}$$
$$= (1.35\,V\cos\alpha)\,I_{max}$$
$$= 1.35\,V\,I_{max}\cos\alpha$$

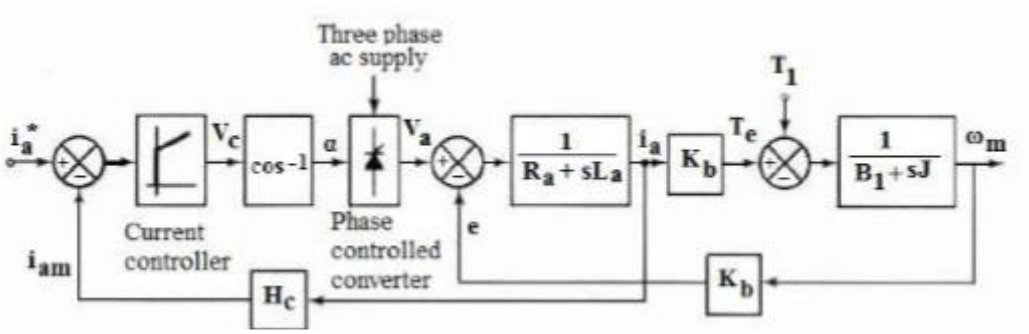
6

Discuss the design procedure for speed controller and current controller of an electrical drive. (13M) (Nov'17'18) BTL 4

Answer Page: 6.30- V.Thiyagarajan

Design procedure of speed controller (7M)

- During the starting of separately excited DC motor, its starting performance is affected by its nonlinear behaviour. The DC machine contains an inner loop due to induced emf. It is not physically seen; it is magnetically coupled. The inner current loop will cross this back emf loop, creating a complexity in development of model



Supply voltage = $V_a(s)$

Back emf of the dc motor = $E_b(s)$

Rotor speed of the motor, rad/sec = $\omega_m(s)$

Armature resistance of the motor = R_a

Armature inductance of the motor = L_a

Total moment of inertia of the motor = J

Design procedure of current controller (6M)

- It is always beneficial to limit the motor current to its maximum allowable value. This objective cannot be achieved by using a simple speed control loop.
- In speed control loop, the motor voltage is controlled by speed error. When speed error is reduced, the applied voltage is changed. But no change in current happens.
- Hence a current limit is implemented using a current control loop by using the speed error to produce current reference.
- It is implemented using both P and P-I controllers.

EE8602 PROTECTION AND SWITCHGEAR

OBJECTIVES:

- To educate the causes of abnormal operating conditions (faults, lightning and switching surges) of the apparatus and system.
- To introduce the characteristics and functions of relays and protection schemes.
- To impart knowledge on apparatus protection
- To introduce static and numerical relays
- To impart knowledge on functioning of circuit breakers

UNIT I PROTECTION SCHEMES 9

Principles and need for protective schemes – nature and causes of faults – types of faults – fault current calculation using symmetrical components – Methods of Neutral grounding – Zones of protection and essential qualities of protection – Protection schemes

UNIT II ELECTROMAGNETIC RELAYS 9

Operating principles of relays - the Universal relay – Torque equation – R-X diagram – Electromagnetic Relays – Overcurrent, Directional, Distance, Differential, Negative sequence and Under frequency relays.

UNIT III APPARATUS PROTECTION 9

Current transformers and Potential transformers and their applications in protection schemes - Protection of transformer, generator, motor, bus bars and transmission line.

UNIT IV STATIC RELAYS AND NUMERICAL PROTECTION 9

Static relays – Phase, Amplitude Comparators – Synthesis of various relays using Static comparators – Block diagram of Numerical relays – Overcurrent protection, transformer differential protection, distant protection of transmission lines.

UNIT V CIRCUIT BREAKERS 9

Physics of arcing phenomenon and arc interruption - DC and AC circuit breaking – re-striking voltage and recovery voltage - rate of rise of recovery voltage - resistance switching - current chopping - interruption of capacitive current - Types of circuit breakers – air blast, air break, oil, SF6 and vacuum circuit breakers – comparison of different circuit breakers – Rating and selection of Circuit breakers.

TOTAL : 45 PERIODS

OUTCOMES:

- Ability to understanding and analyzing power system operation, stability, control and protection.

TEXT BOOKS:

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2. B.Rabindranath and N.Chander, 'Power System Protection and Switchgear', New Age International (P) Ltd., First Edition 2011.
3. M.L.Soni, P.V.Gupta, U.S.Bhatnagar, A.Chakrabarti, 'A Text Book on Power System Engineering', Dhanpat Rai & Co.,1998.

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2. Y.G.Paithankar and S.R.Bhide, 'Fundamentals of power system protection', Second Edition, Prentice Hall of India Pvt. Ltd., New Delhi, 2010.
3. C.L.Wadhwa, 'Electrical Power Systems', 6th Edition, New Age International (P) Ltd., 2010
4. Ravindra P.Singh, ' Switchgear and Power System Protection', PHI Learning Private Ltd., New Delhi, 2009.
5. Bhavesh Bhalja, R.P. Maheshwari, Nilesh G. Chotani,'Protection and Switchgear' Oxford University.

Subject Code: EE 8602 **Year/Semester: III/06**
Subject Name: Protection And Switchgear **Subject Handler: Mrs. Muthukumari T**

UNIT I - PROTECTION SCHEMES

Principles and need for protective schemes – nature and causes of faults – types of faults – fault current calculation using symmetrical components – Methods of Neutral grounding – Zones of protection and essential qualities of protection – Protection schemes.

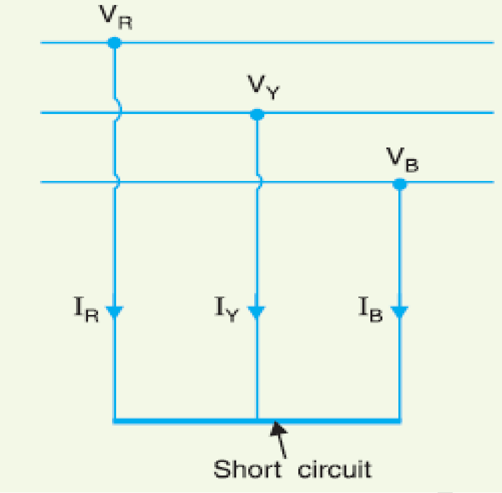
PART * A

Q.No	Questions
1	**State any four functions of protective relaying. (MAY -20 15)** BTL2 ➢ To disconnect the abnormally operating part so as to avoid the damage within effective operation of the rest of the system. ➢ To prevent the subsequent faults arising due to the primary fault. ➢ To disconnect the faulty part as quickly as possible so as to minimize the damage to the faulty part itself. ➢ To improve system performance, reliability and service continuity.
2	**Give the consequences of short circuit.(April/May 2019)** BTL2 Whenever a short-circuit occurs, the current flowing through the coil increases to an enormous value. If protective relays are present , a heavy current also flows through the relay coil, causing it to operate by closing its contacts. The trip circuit is then closed , the circuit breaker opens and the fault is isolated from the rest of the system. Also, a low voltage may be created which may damage systems connected to the supply.
3	**What is protective zone? (MAY -20 15) (April/May 2019)** BTL1 A protective zone is a separate zone which is established around each element of power system remains unprotected. The area of a power system which remains unprotected such that any fault occurring in that area would not be cleared at all is called dead spot or blind spot of a power system.
4	**What are unit system and non unit system?** BTL1 A unit protective system is one in which only faults occurring within its protected zone are isolated. Faults occurring elsewhere in the system have no influence on the operation of a unit system. A non unit system is a protective system which is activated even when the faults are external to its protected zone.
5	**List the basic requirements or essential qualities of protective relaying. (DEC-2008)** BTL1 (i)Reliability (ii) selectivity and discrimination (iii) speed and time (iv)sensitivity (v) stability (vi) adequateness (vii) simplicity and economy.
6	**What is primary protection?** BTL1 Is the protection in which the fault occurring in a line will be cleared by its own relay and circuit breaker. It serves as the first line of defense.
7	**What is back up protection?** BTL1 Is the second line of defense, which operates if the primary protection fails to activate within a definite time delay.
8	**Define energizing quantity.** BTL1 It :s to the current or voltage which is used to activate the relay into operation.
9	**Define operating time of a relay.** BTL1

	It is defined as the time period extended from the occurrence of the fault through the relay detecting the fault to the operation of the relay.
10	**Define resetting time of a relay.** BTL1 It is defined as the time taken by the relay from the instant of isolating the fault to the moment when the fault is removed and the relay can be reset.
11	**What are over and under current relays?** BTL1 Overcurrent relays are those that operate when the current in a line exceeds a predetermined value. (eg: Induction type non-directional/directional overcurrent relay, differential overcurrent relay)whereas undercurrent relays are those which operate whenever the current in a circuit/line drops below a predetermined value.(eg: differential over-voltage relay)
12	**Mention any two applications of differential relay.** BTL2 Protection of generator & generator transformer unit; protection of large motors and bus bars.
13	**What is biased differential bus zone reduction?** BTL2 The biased beam relay is designed to respond to the differential current in terms of its fractional relation to the current flowing through the protected zone. It is essentially an over-current balanced beam relay type with an additional restraining coil. The restraining coil produces a bias force in the opposite direction to the operating force.
14	**Define pickup value and plug setting multiplier.(DEC -201 0)** BTL2 Pickup value: it is the minimum value of an actuating quantity at which relay starts operating. In most of the relays actuating quantity is current in the relay coil and pickup value of current is indicated along with the relay. Plug setting multiplier: the ratio of actual fault current in the relay coil to the pickup current is called plug setting multiplier(P.S.M.).
15	**Why the secondary of the C.T. should not be open?(MAY-2 01 5)** BTL2 If the secondary of the C.T. is kept open then current through the secondary becomes zero hence the ampere turns produced by secondary which generally oppose primary ampere turns becomes zero. As there is no counter m.m.f., unopposed primary m.m.f. produce high flux in the core. This produces excessive core loss heating the core. It also produces heavy e.m.f. on primary and secondary side which may damage the insulation of the winding. This is dangerous from the operator point of view as well. Hence the secondary of C.T. should not be open.
16	**What is pickup current? (DEC -201 4)** BTL1 The minimum value of the actuating current at which the relay starts operating is called pickup current of the relay.
17	**What are the different types of faults in a power system? (May 17) (MAY-2014)** BTL1 Symmetrical faults: the fault which gives rise to equal fault currents in all the lines with displacement of 120° between them. The example is line to line fault i.e. shorting of all three lines. Unsymmetrical faults: The fault which gives rise to unequal fault currents in all the lines with unequal displacement between them. The example is line ground, line to line, line to line to ground faults.
18	**What are the causes of faults in a power system? (DEC -201 3)** BTL2 The various causes are failure of insulation of conductor at one or more places, conducting objects comes in contact with the live part of the system, mechanical failure, excessive internal and external stress, over voltages due to switching surges, lightning strokes, heavy winds and storms, falling of trees on the lines, accidents of vehicles with the towers or poles,

	perching of birds on the lines, accidental short circuits due to snakes, kites, strings etc.
19	**What are the various methods of earthing in substations? (MAY -20 15)** BTL1 ➢ Solid or effective grounding ➢ Resistance grounding ➢ Reactance grounding ➢ Resonant grounding
20	**Why earth wire is provided in overhead transmission lines? (DEC -201 5)** BTL2 ➢ To protect the line conductors from direct lightning strokes. ➢ To reduce the line outages ➢ To reduce the interference on neighbouring installations. ➢ To transmit telecommunication signals.
21	**What is the difference between a short circuit and an overload? (DEC-2015)** BTL2 When there is a short circuit, the impedance at the fault point is almost zero and the voltage at the fault point is zero. The short circuit current is very high. While an overload means the load is higher than the rated load which is specified as the safe load. Thus the current is also higher than the safe load. The overload does not causes damage instantly but if persists for long time, can cause damage to the system.
22	**Differentiate between a fuse and a circuit breaker.** BTL2 Fuse is a low current interrupting device. It is a copper or an aluminium wire. Circuit breaker is a high current interrupting device and it act as a switch under normal operating conditions.
23	**Define auto re-closing.** BTL1 Auto recloser, is a circuit breaker equipped with a mechanism that can automatically close the breaker after it has been opened due to a fault.
24	**Summarize the functions of isolating switch**. BTL2 In sub-stations, it is often desired to disconnect a part of the system for general maintenance and repairs. This is accomplished by an isolating switch or isolator. An isolator is essentially a knife switch and is designed to open a circuit under *no load.* In other words, isolator switches are operated only when the lines in which they are connected carry no current.
25	**Explain surge absorber. Differentiate it from surge diverter.** BTL2 A **surge absorber** is a protective device which reduces the steepness of wave front of a surge by absorbing surge energy. Although both surge diverter and surge absorber eliminate the surge, the manner in which it is done is different in the two devices. The surge diverter diverts the surge to earth but the surge absorber absorbs the surge energy.
	PART * B
1.	(i) **Describe the Essential Qualities of Protective Relaying. (8 M) (MAY-2014) .(April/May 2019)** BTL 2 **Answer: Page: 1.2 - Thiagarajan** **Three main functions/duties:** 1. Safeguard the entire system to maintain continuity of supply 2. Minimize damage and repair costs where it senses fault 3. Ensure safety of personnel. (2 M) **Necessity:** Necessary for early detection and localization of faults, prompt removal of faulty equipment from service. ➢ **Selectivity**: detect, isolate, the faulty item. ➢ **Stability**: leave all healthy circuits, intact to ensure continuity or supply.

	➢ **Sensitivity**: Detect even the smallest fault, current or system abnormalities and operate correctly at its setting before the fault, irreparable damage. ➢ **Speed**: operate speedily, when it is called upon to do so, minimizing damage to the surroundings and ensuring safety to personnel. ➢ meet all of the above requirements, protection must be reliable. ➢ **Dependable**: must trip when called upon to do so. ➢ **Secure**: must not trip when it is not supposed to. (6 M) **(ii) Discuss the Nature and Causes of Faults in a power system. (7M) (DEC-2007)** BTL1 **Answer :Page 1.5 – Thiagarajan** **Various causes of faults**: ➢ Breaking of conductors or failure of insulation. (1 M) ➢ Mechanical failure, accidents, excessive internal and external stresses, affects the supply to the neighbouring zone.(1 M) ➢ The maximum possibility of fault occurrence, transmission lines, greater lengths, exposure to atmospheric conditions. (1 M) ➢ Deterioration of insulation, perching of birds, accidental short circuiting by snakes, kite strings, three branches etc. (1 M) ➢ Switching surges or surges caused by lighting.(1 M) ➢ Fire which destroys the equipment, spreads up in the system and causes total failure.(1 M)
2.	**Explain the overlapping of protective zones with neat sketch. (13M) (DEC -201 5) (April/May 2019)** BTL2 **Answer :Page 1.11- Thiagarajan** **Protective Zones**: Protective relaying scheme, the circuit breakers , appropriate points, power system can be disconnected for repairing work, usual operation and maintenance requirements, under abnormal conditions like short circuits. ➢ overlapped, no chance of existence of a dead spot in a system. No part of the system is left unprotected. (3 M) ➢ **Primary and Backup Protection**: ➢ The backup protection, main protection can fail, reasons : Failure in circuit breaker, Failure in protective relay, Failure in tripping circuit, Failure in d.c tripping voltage.(5 M) ➢ Diagram: (3 M) **Various components in protective zone:** Generators, transformers, transmission lines, bus bars, cables, capacitors etc. (2 M)
3.	**Classify and analyse the different faults in power system. Which of these are more frequent? (13M) (April/May 2019)** BTL 2 **Answer :Page 1.8 - Thiagarajan** ➢ **Types of faults**: Symmetrical and unsymmetrical faults, Open circuited phases, winding faults, simultaneous faults, cross country earth fault.(3 M) ➢ **Symmetrical faults** Gives rise to symmetrical fault currents, also known as balanced faults, two types: line to line to line to ground (L-L-L-G) and line to line to line (L-L-L). (3 M)



- **Unsymmetrical faults:** gives rise to unsymmetrical currents, the magnitude of fault currents in the three lines are different having unequal phase displacement.

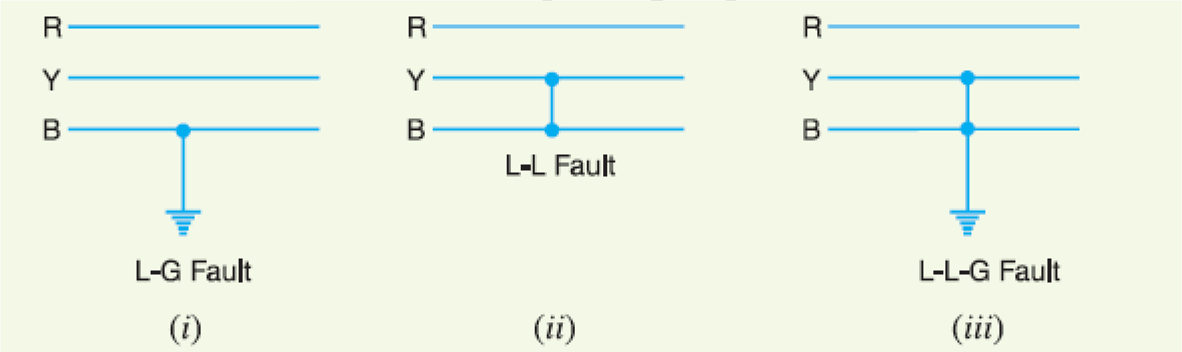
Very common and less severe than symmetrical faults. (7 M)

Three types: Line to ground (L-G), line to line (L-L) and double line to ground (LL-G) faults.

(*i*) Single line-to-ground fault (*L* — *G*): Between a line and ground. Most common type of fault.

(*ii*) Line-to-line fault (*L* — *L*): Between two lines

(*iii*) Doube line-to-ground fault (*L* — *L* — *G*): Between two lines and ground.



(*i*) (*ii*) (*iii*)

4. **Explain the fault current calculation using symmetrical components.(13M)** BTL3

Answer :Page 423 - V.K.Mehta

Symmetrical components:

The positive, negative and zero phase sequence components are called the symmetrical components of the original unbalanced system (Definition- 2 M)

Operator 'a':

The operator 'a' is one, which when multiplied to a vector rotates the vector through 120° in the anticlockwise direction. (operator 'a' explanation- 3 M)

$$
\begin{aligned}
\overrightarrow{I_R} &= \overrightarrow{I_{R1}} + \overrightarrow{I_{R2}} + \overrightarrow{I_{R0}} \\
\overrightarrow{I_Y} &= \overrightarrow{I_{Y1}} + \overrightarrow{I_{Y2}} + \overrightarrow{I_{Y0}} \\
&= a^2\,\overrightarrow{I_{R1}} + a\,\overrightarrow{I_{R2}} + \overrightarrow{I_{R0}} \\
\overrightarrow{I_B} &= \overrightarrow{I_{B1}} + \overrightarrow{I_{B2}} + \overrightarrow{I_{B0}} \\
&= a\,\overrightarrow{I_{R1}} + a^2\,\overrightarrow{I_{R2}} + \overrightarrow{I_{R0}}
\end{aligned}
$$

(8 M)

5. **Define the terms pick-up current, Plug setting multiplier and auto reclosure. (6M)** BTL1

Pick up current:

The deflecting force, controlling force, the moving parts, initiate to move, to change the position of the contacts in the relay. The current which the relay initiates its operation.(2 M)

Plug setting multiplier:

Ratio of fault current in the relay to its pick up current.

$$PSM = \frac{Fault\ current\ in\ relay\ coil}{Pick\ up\ current}$$

$$= \frac{Fault\ current\ in\ relay\ coil}{Rated\ CT\ secondary\ current \times Current\ setting}$$

(2 M)

Auto reclosure:

Relay receives the fault initiation from the protection relay, triggers the auto reclose function. After tripping the circuit breaker (CB), the Auto reclose function reclose the CB.(2 M)

6. **Explain in detail about surge absorbers. (13M)** BTL2

Answer :Page 3.38- Bakshi

Surge absorber: Reduce the steepness of wave front, absorbs energy containing in travelling wave. Eliminate the surge, Surge diverter- diverts the surge to earth. (3 M)

Surge absorber using capacitor: Impedance of capacitor inversely proportional to frequency. Used for protection of transformer winding, free from very high stresses. Series combination of resistor and capacitor. Diagram. (4 M)

Parallel combination of resistance and inductance.

Ferranti surge absorber: Inductive coil magnetically coupled, not electrically to a metal shield and steel tank containing it. Filter effect, high frequency currents, prevented from passing freely through the absorber. Energy transferred through mutual induction, heat dissipation. Diagram. (4 M)

Field of application: Near rotating machines or switchgear, across series reactors. (2 M)

PART*C

1. **Explain the various methods of earthing the neutral point of the power system. (15 M) (DEC-2015) (May 2017) (April/May 2019)** BTL 2

Answer :Page 1.15- Thiagarajan

Grounding:

- Connecting the metallic frame of electrical equipment or some electrical part of the system (e.g. neutral point in a star-connected system) to earth (i.e. soil) (2 M)

Classifications: ***(i)*** Equipment grounding ***(ii)*** System grounding.

Equipment Grounding:

Connecting non-current-carrying metal parts (i.e. metallic enclosure) of the electrical equipment to earth (i.e. soil) ,insulation failure, the enclosure remains at earth potential. (1 M)

System grounding:

Connecting some electrical part of the power system (e.g. neutral point of a star connected system, one conductor of the secondary of a transformer etc.) to earth (i.e. soil)(1 M)

Advantages of Neutral Grounding: (3 M)

(i) Voltages of the healthy phases do not exceed line to ground voltages *i.e.* they remain nearly constant.

(ii) The high voltages due to arcing grounds are eliminated.

(iii) The protective relays can be used to provide protection against earth faults. In case earth fault occurs on any line, the protective relay will operate to isolate the faulty line.

(iv) The overvoltages due to lightning are discharged to earth.

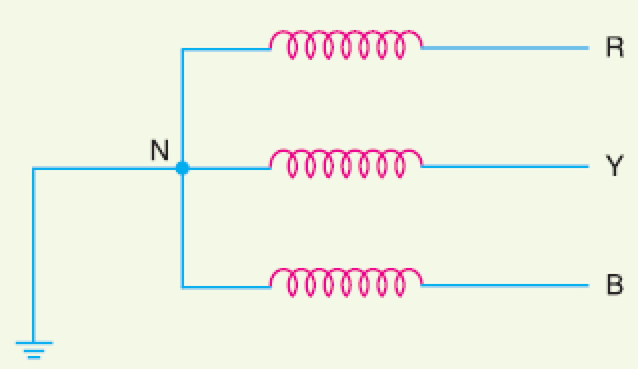
(v) Provides greater safety to personnel and equipment.

(vi) Provides improved service reliability.

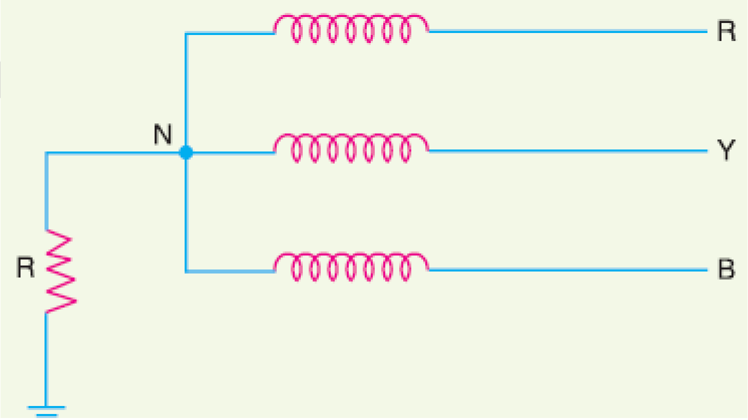
(vii) Operating and maintenance expenditures are reduced.

➢ **Methods of Neutral Grounding**

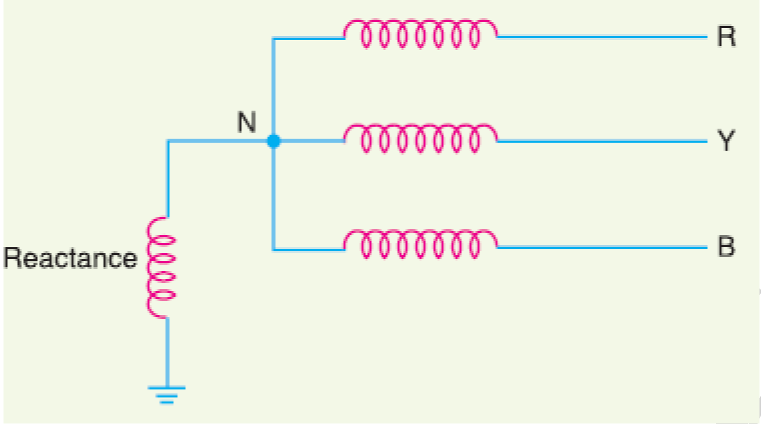
- **Solid Grounding:** When the neutral point of a 3-phase system (e.g. 3- phase generator, 3-phase transformer etc.) is directly connected to earth (i.e. soil) through a wire of negligible resistance and reactance, it is called solid grounding or effective grounding. (2 M)



- **Resistance Grounding:** When the neutral point of a 3-phase system (e.g. 3-phase generator, 3-phase transformer etc.) is connected to earth (i.e. soil) through a resistor, it is called resistance grounding. (2 M)

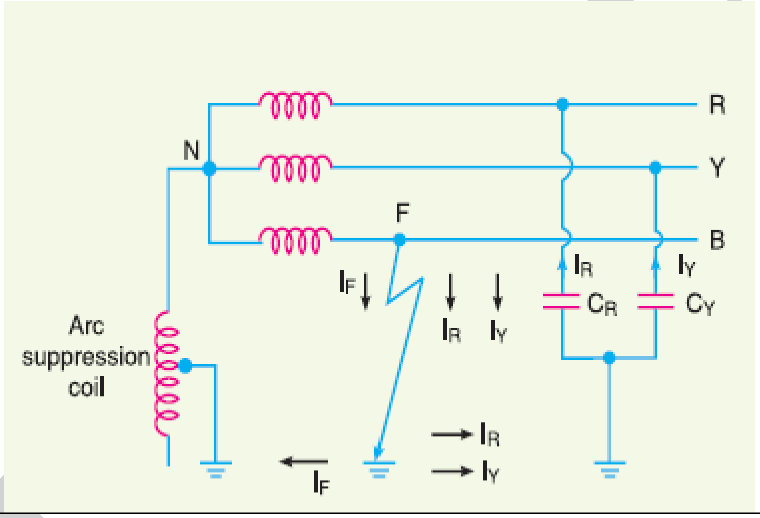


- **Reactance Grounding:**In this system, a reactance is inserted between the neutral and ground. (2 M)



- **Resonant Groundings/Peterson coil Groundings**

When the value of L of arc suppression coil is such that the fault current I_F exactly balances the capacitive current I_C, it is called resonant grounding. (2 M)



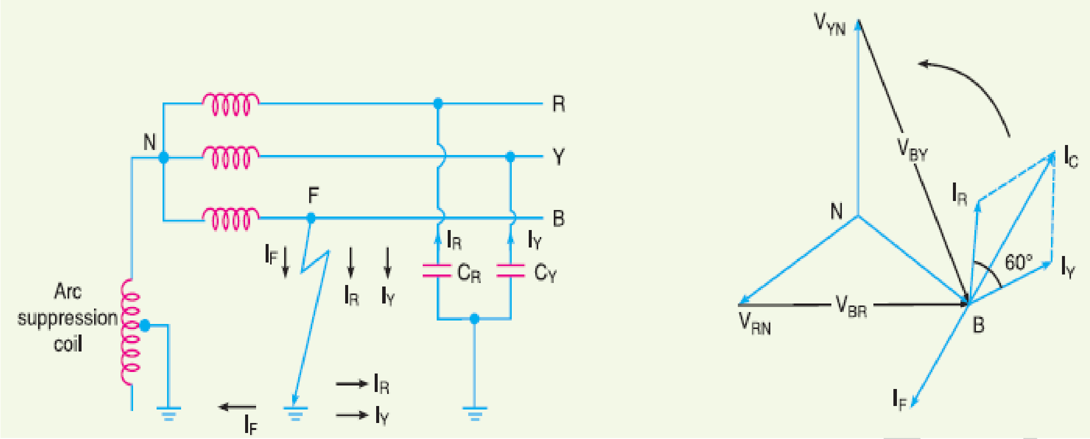
2. **Write a note on RESONANT GROUNDING (OR) ARC SUPPRESSION COIL GROUNDING (OR) PETERSON COIL (8 M) (May 2017) (MAY -20 15)** BTL3

Answer :Page: 1.21 - Thiagarajan

- Capacitive currents, responsible for producing arcing grounds, capacitive currents flow, capacitance exists between each line and earth (3 M)
- value of L of arc suppression coil ,fault current I_f exactly balances the capacitive current IC, resonant grounding.

$$L = \frac{1}{3\omega^2 C}$$

(Derivation: 3 M)



Advantages:

1. The Peterson coil has the advantages of ungrounded neutral system.
2. The Peterson coil is completely effective in preventing any damage by an arcing ground.

Disadvantages.

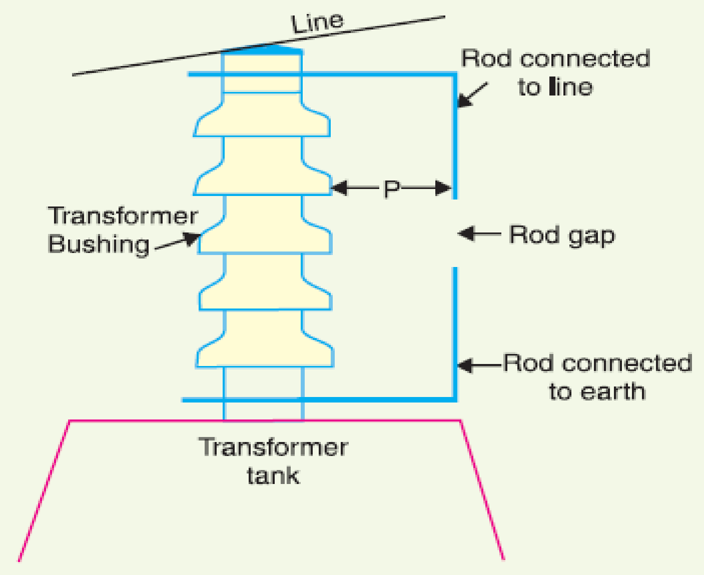
(*i*) Due to varying operational conditions, the capacitance of the network changes from time to time. Therefore, inductance *L* of Peterson coil requires readjustment.

(*ii*) The lines should be transposed. (2 M)

3. **Analyse the various types of lightning arrestors and working Principle of Lightning arresters. (15 M) (May 2017)** BTL4

Answer :Page: 560 - V.K.Mehta

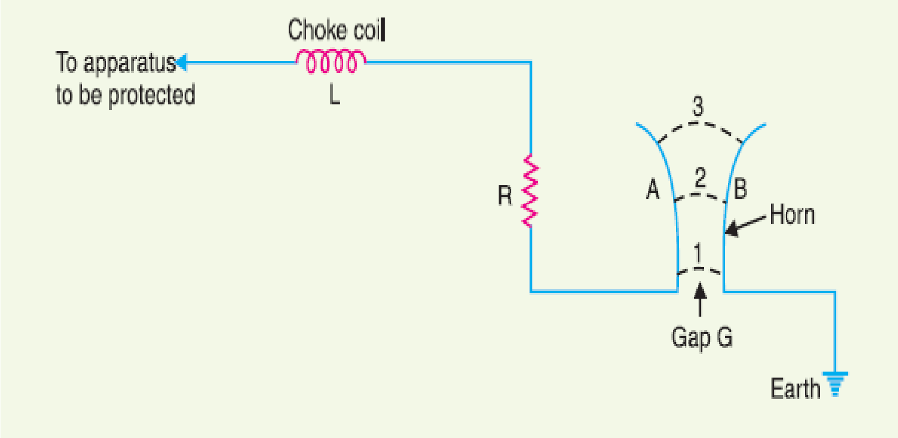
- A lightning arrester or a surge diverted is a protective device, which conducts the high voltage surges on the power system to the ground. (2 M)
- **Rod arrester** : Under normal operating conditions, the gap remains non-conducting. On the occurrence of a high voltage surge on the line, the gap sparks over and the surge current is conducted to earth. In this way, excess charge on the line due to the surge is harmlessly conducted to earth. (2 M)



(1 M)

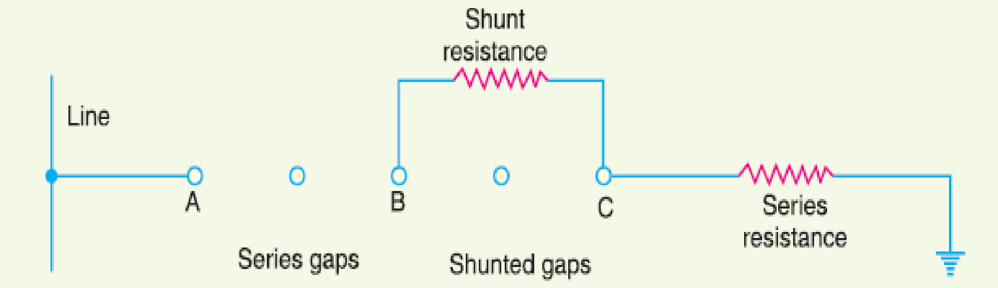
- **Horn gap arrester:** Two horn shaped metal rods *A* and *B* separated by a small air gap. One end of horn is connected to the line through a resistance *R* and choke coil

L while the other end is effectively grounded. (2 M)



(1 M)

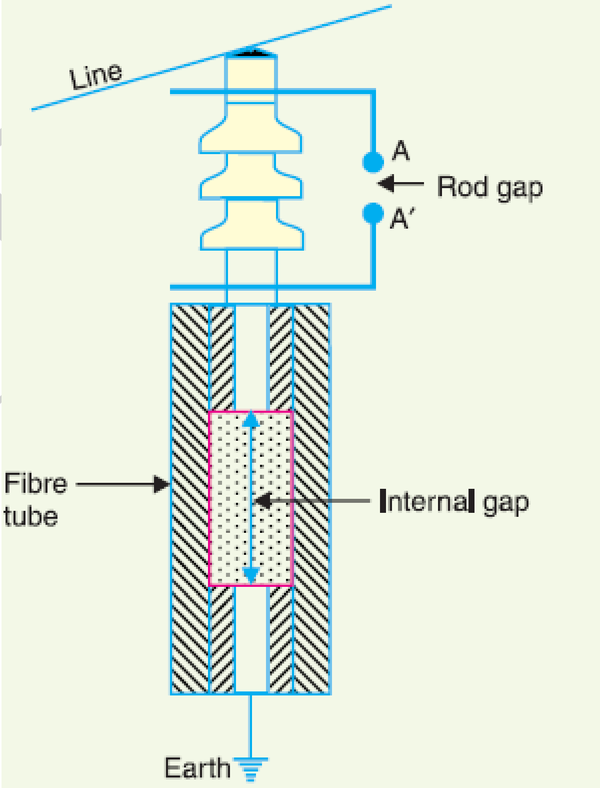
- **Multi gap arrester**



(1 M)

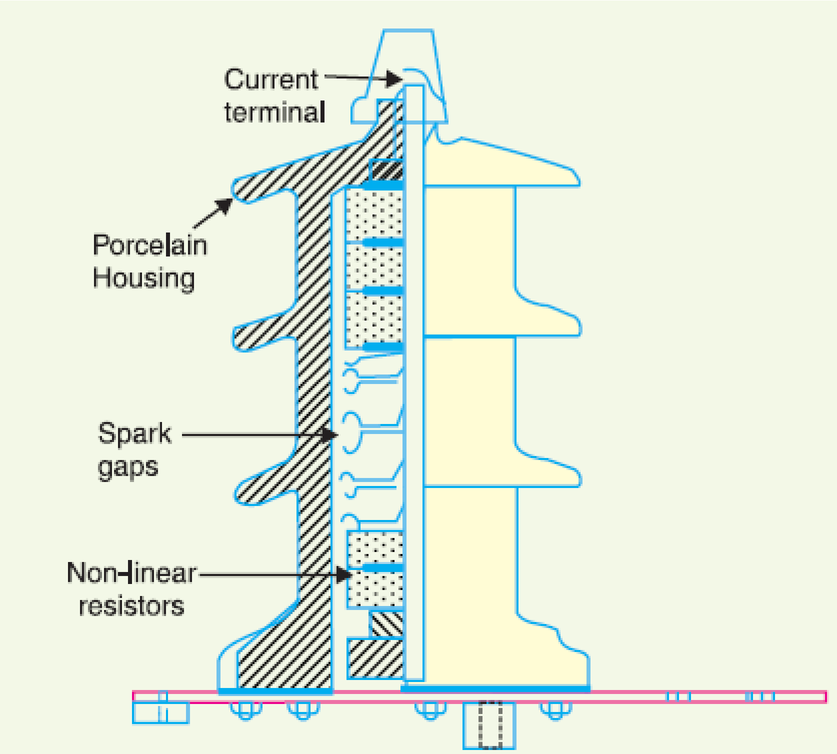
Employed where system voltage does not exceed 33 kV.(2 M)

- **Expulsion type lightning arrester**



(1 M)

- **Valve type lightning arrester:** Two assemblies (*i*) series spark gaps and (*ii*) non-linear resistor discs (made of material such as thyrite or metrosil) in series. The non-linear elements are connected in series with the spark gaps.(2 M)



4. **A balanced 3 phase star connected load is supplied from 3 phase unbalanced supply with negligible internal impedance. Three identical star connected resistors rated for 3300 V, 500 KVA are used as a three phase load. The neutral point is not available. The line voltages of supply are $E_R= 3960<0^0$ V, $E_Y= 3300<-138.6^0$ V, $E_R= 2640<124.2^0$ V. Find the current in R line by the method of symmetrical components. (15 M)** BTL3

Answer :Page 2.23- Bakshi

$E_{R1}= 3252.48<-5.05^0$V (2 M)

$E_{R2}= 774.18<21.674^0$ V(2 M)

Converting all line to phase components- (2 M)

R= 21.78 Ω (3M)

$I_R= 68.5119<-102.879^0$ V (6 M)

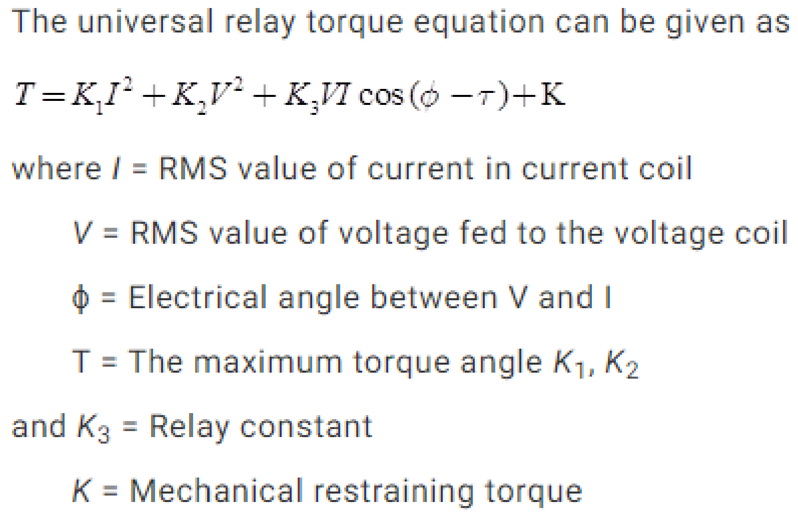
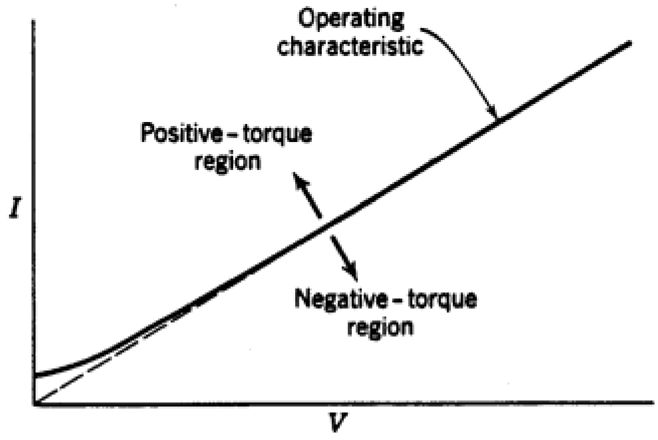
UNIT II ELECTROMAGNETIC RELAY

Operating principles of relays - the Universal relay – Torque equation – R-X diagram – Electromagnetic Relays – Over current, Directional, Distance, Differential, Negative sequence and Under frequency relays.

PART * A

Q.No.	Questions
1	**Identify the need of relay coordination.** BTL2 The operation of a relay should be fast and selective, ie, it should isolate the fault in the shortest possible time causing minimum disturbance to the system. Also, if a relay fails to operate, there should be sufficiently quick backup protection so that the rest of the system is protected. By coordinating relays, faults can always be isolated quickly without serious disturbance to the rest of the system.
2	**Mention the short comings of Merz Price scheme of protection applied to apower transformer.** BTL2 In a power transformer, currents in the primary and secondary are to be compared. As these two currents are usually different, the use of identical transformers will give differential current, and operate the relay under no-load condition. Also, there is usually a phase difference between the primary and secondary currents of three phase transformers. Even CT's of proper turn-ratio are used, the differential current may flow through the relay under normal condition.
3	**What are the various faults to which a turbo alternator is likely to be subjected?** BTL1 Failure of steam supply; failure of speed; over current; over voltage; unbalanced loading; stator winding fault .
4	**Define under frequency relay. (Nov/Dec 2014).(April/May 2019)** BTL1 An under frequency relay is one which operates when the frequency of the system (usually an alternator or transformer) falls below a certain value.
5	**Define the term pilot to power line protection.** BTL1 Pilot wires to the wires that connect the CT's placed at the ends of a power transmission line as part of its protection scheme. The resistance of the pilot wires is usually less than 500ohms.
6	**Mention any two disadvantage of carrier current scheme for transmission line only**. BTL1 The program time (ie, the time taken by the carrier to reach the other end-upto .1% mile); the response time of band pass filter; capacitance phase-shift of the transmission line
7	**List the features of directional relay.** BTL2 High speed operation; high sensitivity; ability to operate at low voltages; adequate short-time thermal ratio; burden must not be excessive.
8	**What are the causes of over speed and how alternators are protected fromit?** BTL2 Sudden loss of all or major part of the load causes over-speeding in alternators. Modernalternatorsareprovidedwithmechanicalcentrifugaldevicesmountedontheir driving

	shafts to trip the main valve of the prime mover when a dangerous over-speed occurs.
9	**Explain the main types of stator winding faults?** BTL1 Fault between phase and ground; fault between phases and inter-turn fault involving turns of the same phase winding.
10	**Give the limitations of Merz Price protection**. BTL2 Since neutral earthing resistances are often used to protect circuit from earth-fault currents, it becomes impossible to protect the whole of a star-connected alternator. If an earth-fault occurs near the neutral point, the voltage may be insufficient to operate the relay. Also it is extremely difficult to find two identical CT's. In addition to this, there always an inherent phase difference between the primary and the secondary quantities and a possibility of current through the relay even when there is no fault.
11	**State the uses of Buchholz's relay.** BTL1 Bucholz relay is used to give an alarm in case of incipient(slow-developing) faults in the transformer and to connect the transformer from the supply in the event of severe internal faults. It is usually used in oil immersion transformers with a rating over 750KVA.
12	**Mention any two applications of differential relay.** BTL1 Protection of generator & generator transformer unit; protection of large motors and bus bars.
13	**Define differential relay. (April / May 2015)&(May / June 20 13)** BTL1 A differential relay is defined as the relay that operates when the phasor difference of two or more similar electrical quantities exceeds a predetermined value. Thus a current differential relay operates on the result of comparison between the phase angle and magnitudes of the currents entering and leaving the system to be protected.
14	**What is biased differential bus zone reduction? (April / May 2015)** BTL1 The biased beam relay is designed to respond to the differential current in terms of its fractional relation to the current flowing through the protected zone. It is essentially an over-current balanced beam relay type with an additional restraining coil. The restraining coil produces a bias force in the opposite direction to the operating force.
15	**What is meant by directional relay?(May / June 2012)** BTL1 The directional power relay is not suitable to use as a protective relay under short circuit conditions. This is because under short circuit conditions the voltage fril is drastically and such a reduced voltage may not be sufficient to produce the driving torque required for the relay operation.
16	**Describe the features of directional relay.** BTL2 High speed operation; high sensitivity; ability to operate at low voltages; adequate short-time thermal ratio; burden must not be excessive.
17	**Define Positive Sequence Components.** BTL1 Positive sequence components have three vectors equal in magnitude and displaced from each other by an angle 120˚ and having the phase sequence as original vectors.
18	**Define Negative Sequence Component. (Nov/Dec 2015)** BTL1 It has three vectors and equal in magnitude displaced from each other by an angle 120˚and the phase sequence in opposite to its original phasor.
19	**List the types of electromagnetic relay.** BTL1 Electromagnetic attraction Attracted armature type relay Solenoid type relay Balanced type relay Electromagnetic Induction

	Shaded pole structure Watt – hour meter Induction cup
20	**A relay is connected to 400/5 ratio current transformer with current setting of 150%. Formulate the Plug Setting Multiplier when circuit carries a fault current of 4000A.** BTL 3 Pick-up value = Rated secondary CT current × current setting = 5 × 1.5 = 7.5A Fault current in relay coil = 2400 x 5/ 400 = 30 A P.S.M = Fault current in relay coil / Pick up current = 30/ 7.5= 4
21	**Write down the universal torque equation of overcurrent relay.** BTL3  The universal relay torque equation can be given as $T = K_1 I^2 + K_2 V^2 + K_3 VI \cos(\phi - \tau) + \mathrm{K}$ where I = RMS value of current in current coil V = RMS value of voltage fed to the voltage coil ϕ = Electrical angle between V and I T = The maximum torque angle K_1, K_2 and K_3 = Relay constant K = Mechanical restraining torque
22	**Draw the operating characteristics of impedance relay.** BTL3 
23	**Draw the R-X diagram of impedance relay.(April/May 2019)** (BTL 3)

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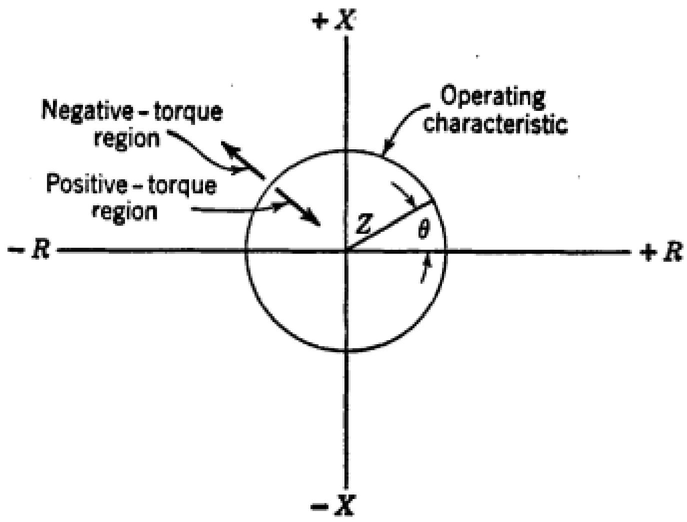
<tr><td></td><td>
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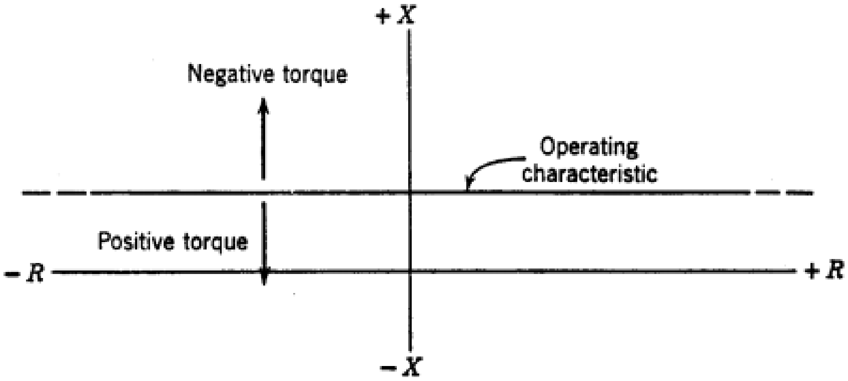
<tr><td>24</td><td>Illustrate with a diagram on the operating characteristics of reactance relay BTL3

</td></tr>
<tr><td>25</td><td>Write down the torque equation of voltage restrained distance relay. BTL3
$T = K_1VI \cos (\theta - \tau) - K_2V^{2} - K_3$</td></tr>
<tr><td></td><td>PART * B</td></tr>
<tr><td>1.</td><td>With neat Diagram explain the construction and operation of Non Directional over current relay. (13M) BTL 2
Answer : Page 508 - V.K.Mehta
Construction: (5 M)</td></tr>
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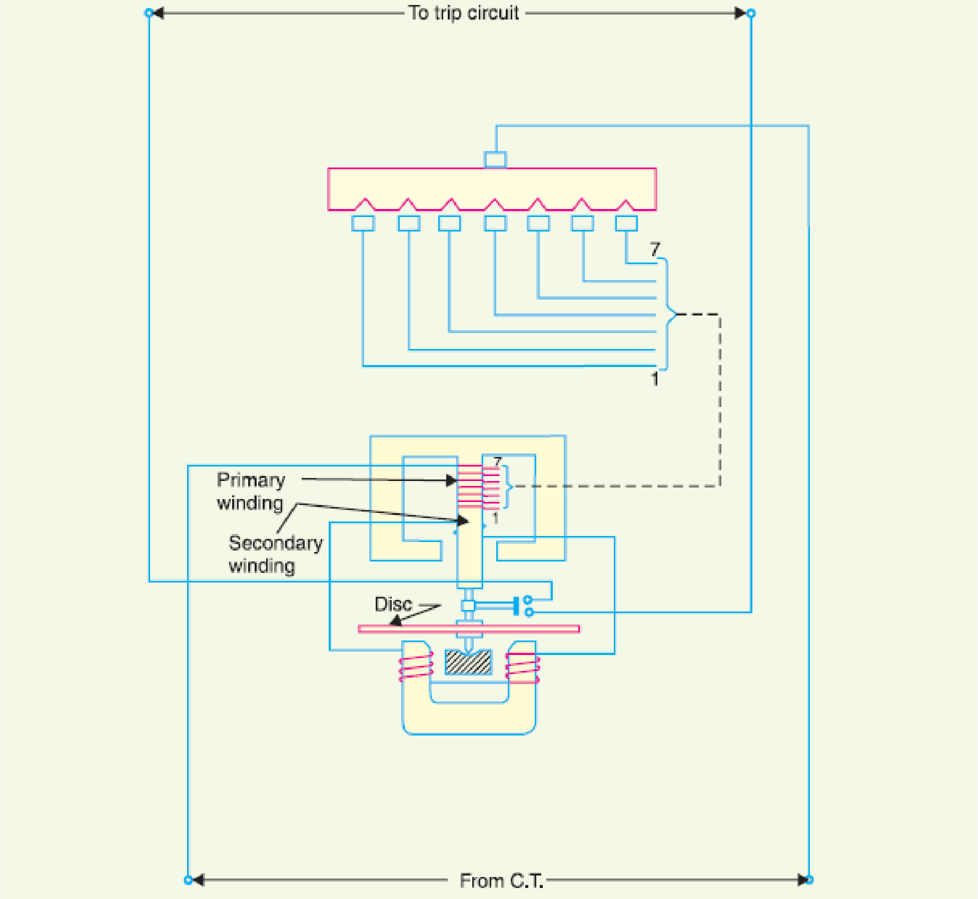


- Metallic (aluminium) disc, free to rotate in between the poles of two electromagnets. The upper electromagnet, primary and a secondary winding.
- The primary connected to the secondary of a C.T. in the line to be protected, tapped at intervals. plug-setting bridge, relay operating coil, desired current setting.
- The secondary winding, energised by induction from primary series connection with winding on the lower magnet.
- The controlling torque, spiral spring, Spindle of the disc, moving contact, bridges two fixed contacts (connected to trip circuit) , disc rotates through a pre-set angle.

Working: (8 M)

- earth leakage induction type relay .
- The driving torque on the aluminium disc, induction principle.
- This torque, opposed by the restraining torque, provided by the spring.
- Under normal operating conditions, restraining torque is greater than the driving torque, the aluminium disc remains stationary.

- If the current in the protected circuit exceeds the pre-set value, the driving torque becomes greater than the restraining torque.
- The disc rotates, moving contact bridges the fixed contacts when the disc has rotated through a pre-set angle.
- The trip circuit operates the circuit breaker which isolates the faulty section.

2.

With neat Diagram explain the construction and operation of Directional over current relay. (13M) (Nov / Dec 2015) .(April/May 2019) BTL 2

Answer : Page 2.20- V.Thiagarajan

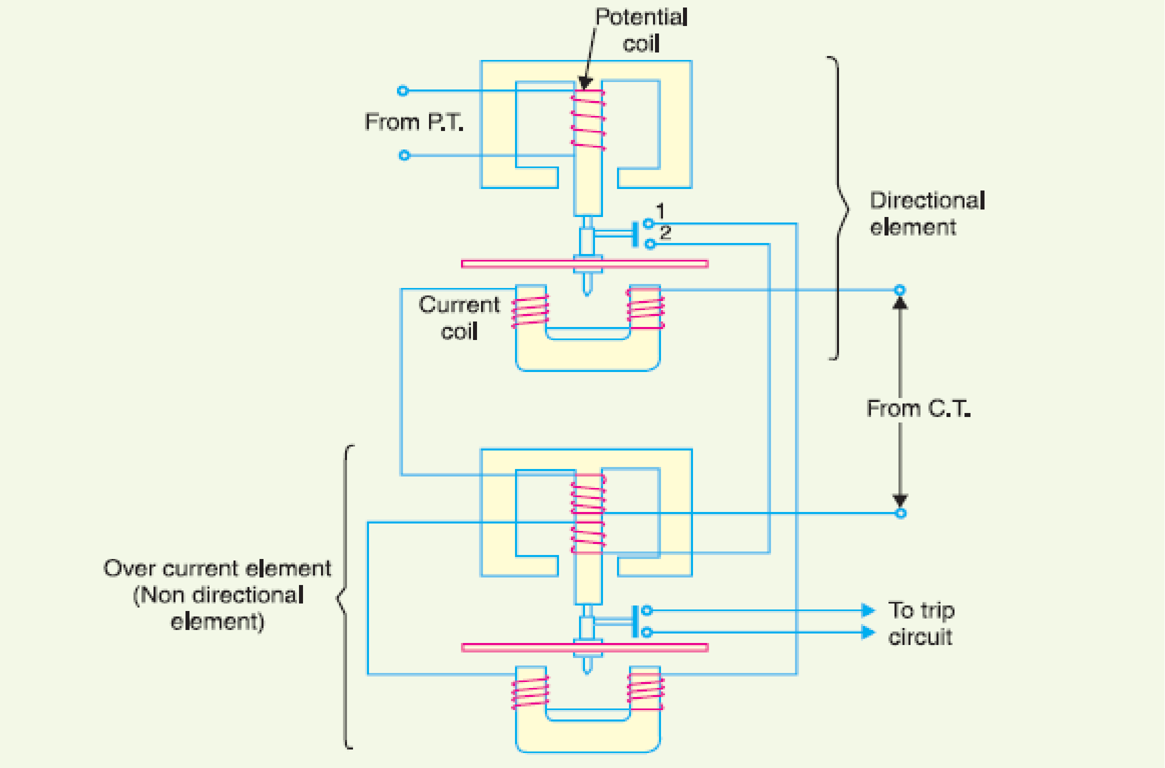


Diagram: (4 M)

Construction: (4 M)

- Independent of system voltage and power factor
- They elements are,

1. Directional element, directional power relay
2. Non directional element, non directional over current relay.

Directional element.

- Directional power relay which operates when power flows in a specific direction.
- The potential coil of this element connected through a potential transformer (P.T.) to the system voltage.

- The current coil energised through a C.T. by the circuit current.
- This winding carried over the upper magnet of the non-directional element.
- The trip contacts (1 and 2) of the directional element, series with the secondary circuit of the overcurrent element, the latter element cannot start to operate , secondary circuit is completed.

Non-directional element.

- The spindle of the disc, moving contact, closes the fixed contacts (trip circuit contacts) after the operation of directional element.
- Plug-setting bridge, relay for current setting, tappings, upper magnet of over current element, connected to the bridge.

Operation: (5 M)

- Under normal operating conditions, power flows in the normal direction directional power relay (upper element) does not operate, over current element (lower element) unenergised.
- When a short-circuit occurs, current or power flow in the reverse direction, the disc of the upper element rotates to bridge the fixed contacts 1 and 2. Completes the circuit for over current element.
- The disc of this element rotates and the moving contact attached to it closes the trip circuit. This operates the circuit breaker which isolates the faulty section.

Condition for final tripping of current:

- Current flows in a direction such as to operate the directional element.
- Current in the reverse direction exceeds the pre-set value.
- Excessive current persists for a period corresponding to the time setting of over current element.

3. **Illustrate with a diagram about differential relay. (10M) (April / May 2015 & 12)** BTL 2

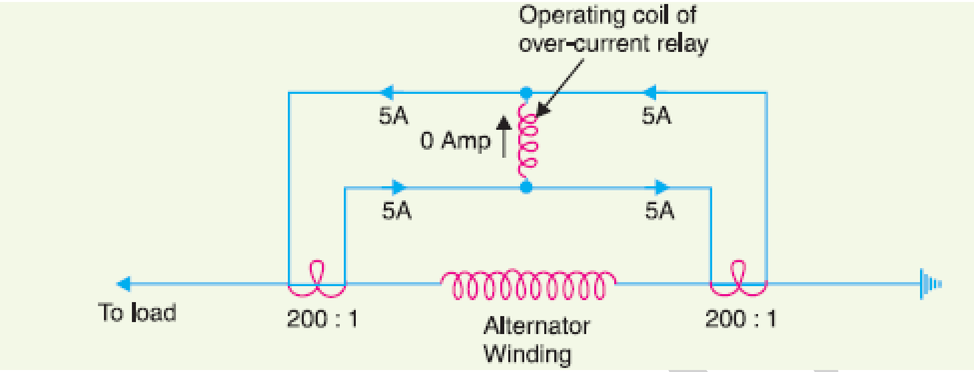
Answer : Page 2.40- V.Thiagarajan

- A differential relay, operates when the phasor difference of two or more similar electrical quantities exceeds a predetermined value. current differential relay operates on the result of comparison between the phase angle and magnitudes of the currents entering and leaving the system to be protected. (2 M)
- Under normal conditions, the two currents, equal in phase and magnitude, inoperative.
- If difference current exceeds a preset value then the relay operates, opens the circuit

breaker. (2 M)

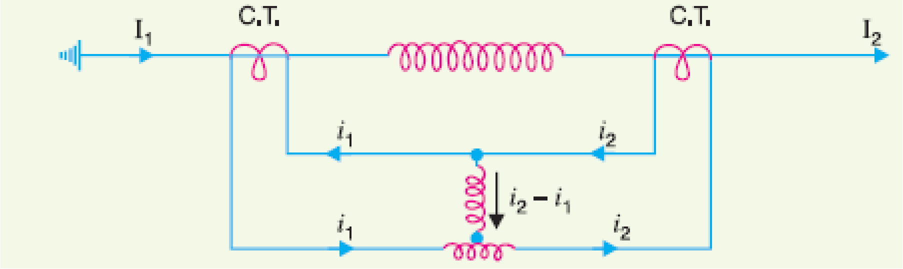
- Types of Differential Relays:

Current differential relay (2 M)



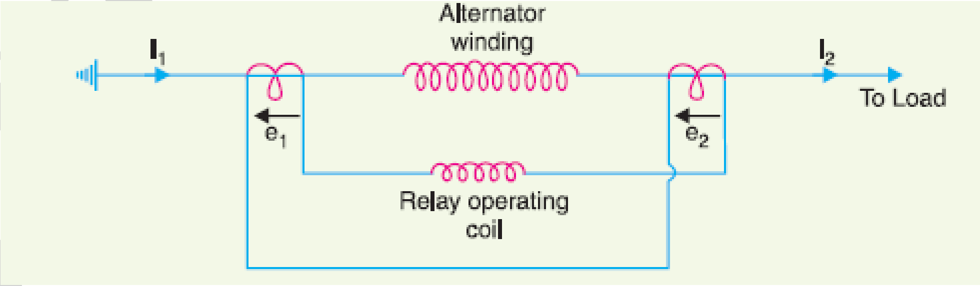
- Secondary currents of CT not equal- relay operate.

Biased beam relay or percentage differential relay (2 M)



- Operating coil proportional to $i_2 - i_1$, restraining coil proportional to (i_1+i_2)/2.
- Operating current required to trip, percentage of load current.

Voltage balance differential relay (2 M)



- Under normal condition, Currents equal, secondary voltage balanced
- Voltage difference, current to flow through the operating coil of the relay, closes the trip circuit.
- Translay system- modified form of voltage balance system.

4. **Explain the working principle of under frequency relay. (8 M)** BTL 2
Answer : Page 2.47- V.Thiagarajan

	Need for Frequency relay- (2 M) Frequency Equation: $N_s=\frac{120f}{P}$: (2 M) Working principle and diagram : (4 M) ➢ The frequency of induced e.m.f. of synchronous generator, maintained constant by constant speed. ➢ Over speeding of the generator occurs due to loss of load and under speeding occurs due to increase in load. ➢ In both the cases, the frequency varies from normal value. In order to avoid damage to the generator under the above two conditions, frequency relays are used. ➢ Under frequency relay trips the feeder on load at set value of frequency, so as to give relief to the generator, thereby saving the unit. ➢ Under frequency relay thus aids load shedding programme to save the grid.
5.	**Explain the working principle of Negative sequence relay. (8M).(April/May 2019)** BTL 2 **Answer : Page 2.49- V.Thiagarajan** ➢ Negative sequence relays are used to protect electrical machines against overheating due to unbalance currents in stator. (Definition: 2 M) ➢ Working principle and diagram: (6 M) ➢ Inverse square law characteristics.
6.	**Derive the Universal relay torque equation. (5 M)** BTL 3 ➢ The universal torque equation explains the working of an electrical relay. ➢ The relay, electromagnetic. ➢ These electromagnetic consists current and voltage windings. ➢ The current through the winding produces magnetic flux. torque, produced by the interaction of the flux of the same winding or between the flux of both the windings. (2 M) $\text{Torque Developed by curent windings} = K_1I^2$ $\text{Torque developed by voltage winding} = K_1V^2$ $T = K_1I^2 + K_2V^2 + K_3VIcos(\theta - \tau) + K_4$ (3 M)
7.	**List the detailed classification of relays based on various parameters. (8 M)** BTL 2 **Answer : Page 2.4- V.Thiagarajan**

	According to construction: (2 M) ➢ Electromagnetic relays ➢ Induction relays ➢ Electrothermal relays ➢ Physico-electric relay ➢ Electro-dynamic relay ➢ Static relay ➢ Microprocessor relay According to application: (2 M) ➢ Falls below specific limit or value ➢ Directional or reverse current relay ➢ Directional or reverse power relay According to time of operation (2 M) ➢ Instantaneous relay ➢ Definite time lag relay ➢ Inverse time lag relay ➢ Inverse definite minimum time lag relay According to connectivity of circuit: (2 M) ➢ Primary relay ➢ Secondary relay ➢ Auxillary relay ➢ Back up relay ➢ Reinforcing relay
	PART*C
1.	**Explain the working principle of impedance relays. (15 M) (April/May 13)(Nov/Dec 2012 &15)** BTL 2 **Answer : Page 2.26- V.Thiagarajan** Distance relay general definition: (3 M) Working principle of impedance relay: (5 M)

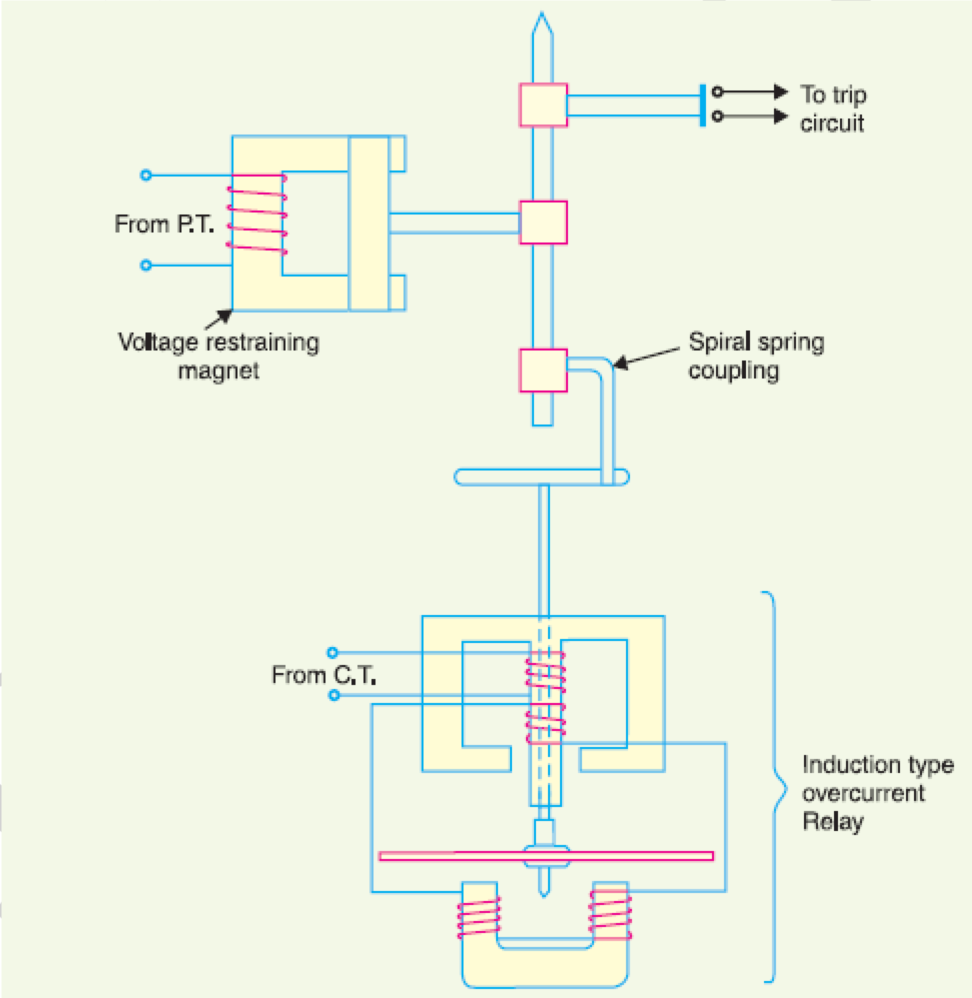
- Dependent on the ratio of V and I there are three types of distance relays which are, impedance relay, mho relay and reactance relay.
- Impedance relay which is based on measurement of impedance

Torque equation: (3 M)
R-X Diagram: (2 M)
Explanation- (1 M)

2. **With neat sketch, investigate how impedance relay is used as Time Distance. (13 M) (May 2017)** BTL 6

Answer : Page 2.27- V.Thiagarajan

Operating time, $T \propto V/I$
$\propto$ Z
$\propto$ distance (2 M)



(4 M)

Construction. (3 M)

- Current driven induction element, spindle carrying the disc, spiral spring coupling to a second spindle, bridging piece of the relay trip contacts.
- The bridge- open position by an armature, pole face of an electromagnet

excited by the voltage of the circuit to be protected.

Operation. (4 M)

- Under normal load conditions, the pull of the armature , induction element, trip circuit contacts remain open.
- On the occurence of a short-circuit, the disc of the induction current element , rotate at a speed depending upon the operating current. the spiral spring coupling wound up till the tension of the spring , sufficient to pull the armature away from the pole face of the voltage-excited magnet.
- the spindle carrying the armature and bridging piece moves rapidly in response to the tension of the spring and trip contacts are closed.
- This opens the circuit breaker to isolate the faulty section.
- The speed of rotation of the disc proportional to the operating current,
- Neglecting the effect of control spring. time of operation of the relay , directly proportional to the pull of the voltage-excited magnet , line voltage *V* at the point where the relay is connected.
- The time of operation of relay would vary as *V/I i.e.* as *Z* or distance.

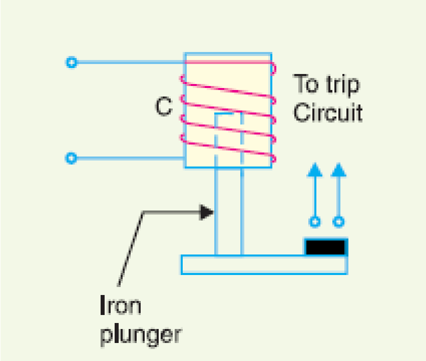
3. **What are the Classification of Electromagnetic Relays? Explain about Electromagnetic Attraction Type Relays. (Nov2013, May2012) (May 2017) (15 M)** BTL 2

Answer : Page 2.7- V.Thiagarajan

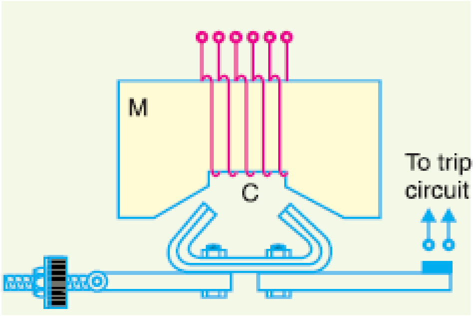
- All the relays consist of one or more elements which gets energized and actuated by the electrical quantities of the circuit.
- On-no-mechanical type which work on the principles of electromagnetic attraction and electromagnetic induction

The various types of these relays are,

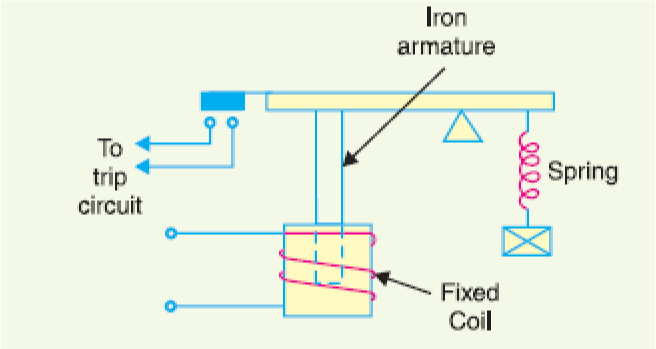
- Solenoid Type



- Attracted armature type



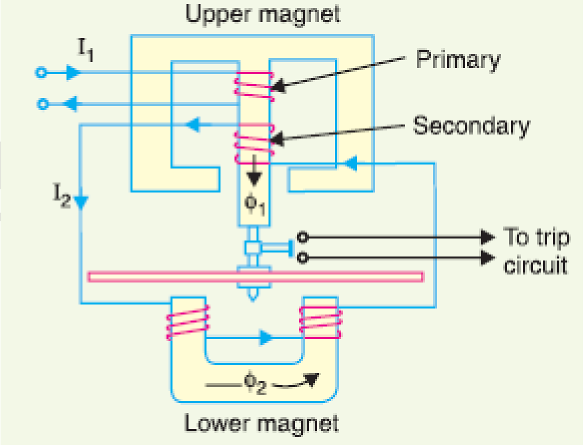
- Balanced beam type relay:



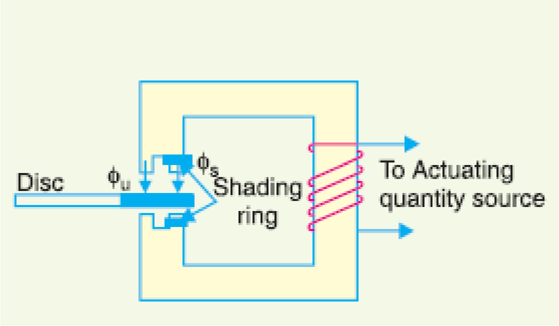
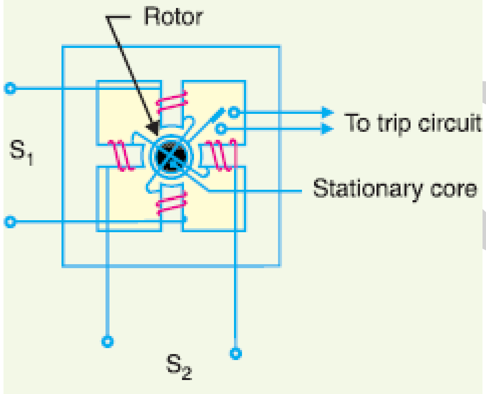
4\. **Explain the types of Electromagnetic induction type relays. (15 M)** BTL 2

Answer : Page 2.15- V.Thiagarajan

Wattmeter type: (5 M)



Shaded pole type: (5 M)

	 Induction cup type relay: (5 M) 

UNIT III APPARATUS PROTECTION

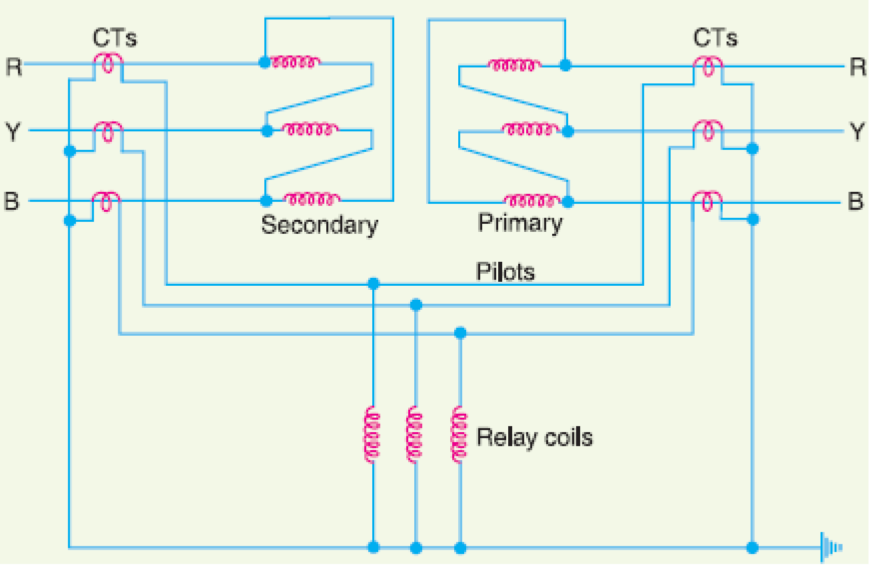
Current transformers and Potential transformers and their applications in protection schemes - Protection of transformer, generator, motor, busbars and transmission line.

PART * A

Q.No.	Questions
1	**What are the types of graded used in line of radial relay feeder?** BTL 2 Definite time relay and inverse-definite time relay.
2	**What are the various faults that would affect an alternator?** BTL 2 a) Stator faults 1. Phase to phase faults 2. Phase to earth faults 3. Inter turn faults b) 1. Earth faults 2. Fault between turns 3. Loss of excitation due to fuel failure c) 1. Over speed 2. Loss of drive 3. Vacuum failure resulting in condenser pressure rise, resulting in shattering of the turbine low pressure casing d) 1. Fault on lines 2. Fault on busbars
3	**Why neutral resistor is added between neutral and earth of an alternator?** BTL 2 In order to limit the flow of current through neutral and earth a resistor is introduced between them.
4	**What is the backup protection available for an alternator?** BTL 1 Over current and earth fault protection is the backup protections.
5	**What are faults associated with an alternator?** BTL 1 External fault or through fault Internal fault 1, Short circuit in transformer winding and connection 2, Incipient or slow developing faults

6	**What are the main safety devices available with transformer?** BTL 1 Oil level guage, sudden pressure delay, oil temperature indicator, winding temperature indicator .
7	**What are the limitations of Buchholz relay?** BTL 2 Only fault below the oil level are detected. Mercury switch setting should be very accurate, otherwise even for vibration, there can be a false operation. The relay is of slow operating type, which is unsatisfactory.
8	**What are the problems arising in differential protection in power transformer and how are they overcome?** BTL 2 Difference in lengths of pilot wires on either sides of the relay. This is overcome by connecting adjustable resistors to pilot wires to get equipotential points on the pilot wires. Difference in CT ratio error difference at high values of short circuit currents that makes the relay to operate even for external or through faults. This is overcome by introducing bias coil. Tap changing alters the ratio of voltage and currents between HV and LV sides and the relay will sense this and act. Bias coil will solve this. Magnetizing inrush current appears wherever a transformer is energized on its primary side producing harmonics. No current will be seen by the secondary. CT's as there is no load in the circuit. This difference in current will actuate the differential relay. A harmonic restraining unit is added to the relay which will block it when the transformer is energized.
9	**What is REF relay?** BTL 1 It is restricted earth fault relay. When the fault occurs very near to the neutral point of the transformer, the voltage available to drive the earth circuit is very small, which may not be sufficient to activate the relay, unless the relay is set for a very low current. Hence the zone of protection in the winding of the transformer is restricted to cover only around 85%. Hence the relay is called REF relay.
10	**What is over fluxing protection in transformer?** BTL 1 If the turns ratio of the transformer is more than 1:1, there will be higher core loss and the capability of the transformer to withstand this is limited to a few minutes only. This phenomenon is called over fluxing.
11	**What are the uses of Buchholz's relay?** BTL 1 Buchholz relay is used to give an alarm in case of incipient(slow-developing) faults in the transformer and to connect the transformer from the supply in the event of severe internal faults. It is usually used in oil immersion transformers with a rating over 750KVA.
12	**Why busbar protection is needed?.(April/May 2019)** BTL 2 Fault level at busbar is high b) The stability of the system is affected by the faults in the bus zone. (c) A fault in the bus bar causes interruption of supply to a large portion of the system network.
13	**What are the merits of carrier current protection?** BTL 2 Fast operation, auto re-closing possible, easy discrimination of simultaneous faults .
14	**What is field suppression?** BTL 2 When a fault occurs in an alternator winding even though the generator circuit breaker is tripped, the fault continues to fed because EMF is induced in the generator itself. Hence the field circuit breaker is opened and stored energy in the field winding is discharged through

	another resistor. This method is known as field suppression.
15	**What are the causes of bus zone faults?** BTL 2 Failure of support insulator resulting in earth fault Flashover across support insulator during over voltage Heavily polluted insulator causing flashover Earthquake, mechanical damage etc.
16	**What are the problems in bus zone differential protection?** BTL 2 Large number of circuits, different current levels for different circuits for external faults. Saturation of CT cores due to dc component and ac component in short circuit currents. The saturation introduces ratio error. Sectionalizing of the bus makes circuit complicated. Setting of relays need a change with large load changes.
17	**What is meant by relay operating time?(Nov 2012)** BTL 1 It is defined as the time period extending from the occurrence of the fault through the relay detecting the fault to the operation of the relay.
18	**Give the limitations of Merz Price protection. (May 2017)** BTL 1 Since neutral earthing resistances are often used to protect circuit from earth- fault currents, it becomes impossible to protect the whole of a star-connected alternator. If an earth-fault occurs near the neutral point, the voltage may be insufficient to operate the relay. Also it is extremely difficult to find two identical CT‟s. In addition to this, there always an inherent phase difference between the primary and the secondary quantities and a possibility of current through the relay even when there is no fault.
19	**List the different faults that may occur in transformer.** BTL 1 External fault Internal fault Short circuit in transformer winding and connection. Incipient or slow developing fault.
20	**What are the uses of Buchholz's relay?(May 2009) (May 2017)** BTL 1 Buchholz relay is used to give an alarm in case of incipient(slow-developing) faults in the transformer and to connect the transformer from the supply in the event of severe internal faults. It is usually used in oil immersion transformers with a rating over 750KVA.
21	**Discuss the most severe fault in transmission line.** BTL 2 The most severe fault is L-L-L-G fault . (Symmetrical fault)
22	**Why secondary of CT should not be left open?** BTL 2 During normal operation of CT, the primary and secondary winding produces mmf which by lenze's law opposes each other. As the secondary mmf is slightly less than the primary mmf, the net mmf is small. This net mmf is the working / magnetizing mmf of the core of CT. Now, in case secondary winding is kept open then secondary current will be zero while the primary current of CT will remain same. Therefore the opposing mmf of secondary will no longer exist. Hence the net mmf is due to primary current only i.e. N_1I_1 which is very large. This large mmf will produce large flux in the core and will saturate the core. Again, due to large flux in the core the flux linkage of secondary winding will be large which in turn will produce a large voltage across the secondary terminals of the CT. This large voltage across the secondary terminals will be very dangerous and will lead to the insulation failure and there is a good chance that the person who is opening the CT secondary while primary is energized will die due to shock.

23	**Define the term pilot with reference to power line protection** BTL 1 Pilot wire is a communication cable between DC and primary substation, a communication cable between two relays whenever a transmission line or equipment is to be protected by using distance relay or by differential relay or price protection. A wire is connected between the CT which is located in different ends of the protection zone. This wire provides the path for the circulating current produce in abnormal condition, which is sensed by the relay and therefore is tripped.
24	**What is burden in Current Transformer?** BTL 1 The actual burden is formed by the resistance of the pilot conductors and the protection relay(s).
25	**Define feeder protection.** BTL 1 Feeder protection is defined as the protection of the feeder from the fault so that the power grid continually supply the energy. The feeder injects the electrical energy from the substation to the load end. So it is essential to protect the feeder from the various type of fault.
	PART * B
1.	**Briefly explain about transformer protection using Differential protection scheme (Merz-price protection scheme) (13M) (May june 2014, May 2017, Nov Dec 2013) .(April/May 2019)** BTL 2 **Answer: Page 3.5- Thiagarajan** ➢ **Differential protection** Differential protection, compares currents entering and leaving the protected zone and operates when the differential current between these currents exceed a pre-determined level. (3 M) ➢ Under internal fault conditions (i.e. faults between the CTs) the relay operates, since both the CT secondary currents add up and pass through the relay. ➢ This protection is also called unit protection, as it only operates for faults on the unit it is protecting, which is situated between the CTs. **Diagram-** (5 M) **and explanation-** (5 M)  ➢ Difference in magnitude of currents in the primary and secondary of power transformer is compensated by different turns ratio of CTs.

2\. **What is meant by Buchholz Relay? Explain its operation with neat sketch. (13M)** BTL 2

Answer: Page 3.36- Thiagarajan

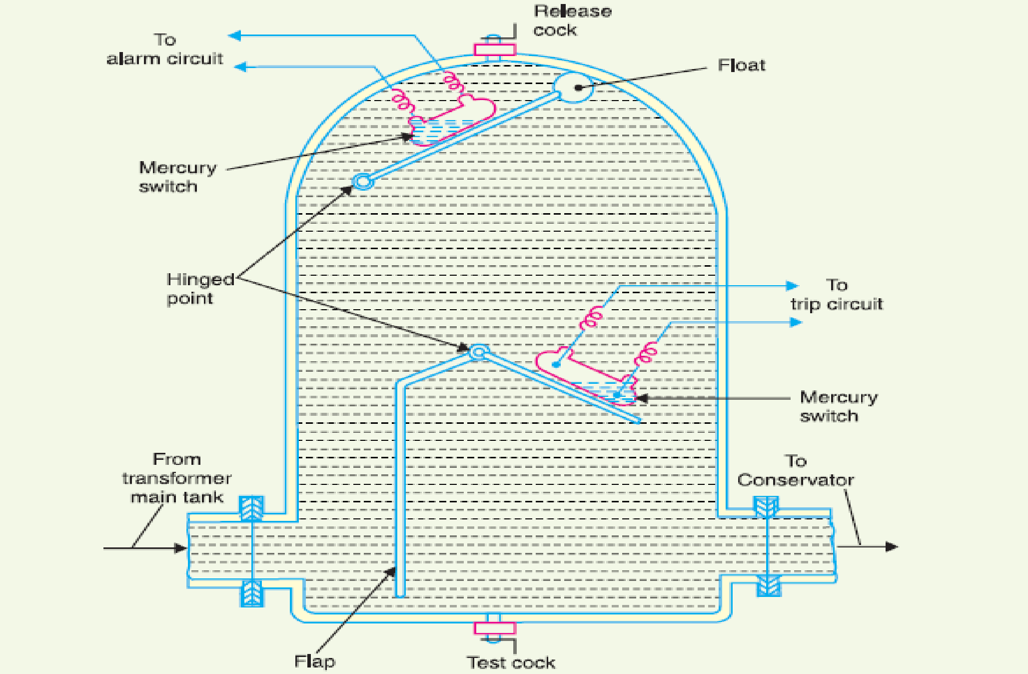
Construction: (4 M)

Alarm circuit, conservator, main tank, float, hinge, mercury switch.

Working: (5 M)

- Failure of the winding insulation will result in some form of arcing, which can decompose the oil into hydrogen, acetylene, methane, etc. Localized heating can also precipitate a breakdown of oil into gas.
- Severe arcing will cause a rapid release of a large volume of gas as well as oil vapor. The action can be so violent that the build-up of pressure can cause an oil surge from the tank to the conservator.

Diagram: (4 M)



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3\. **Explain about the faults occuring in generator (13M) (Apr 2015 ,May 2014, Nov 2012)** BTL 3

Answer: Page 3.6- Thiagarajan

- The various faults which can occur associated with a generator can be classified as,
- Stator faults: The faults associated with the stator of the generator
- Rotor faults: The faults associated with the rotor of the generator.
- Abnormal running conditions: This includes number of abnormal conditions which may occur in practice, from which the generator must be protected. (3 M)
- Stator Faults

The main types of stator faults are.

Phase to phase faults

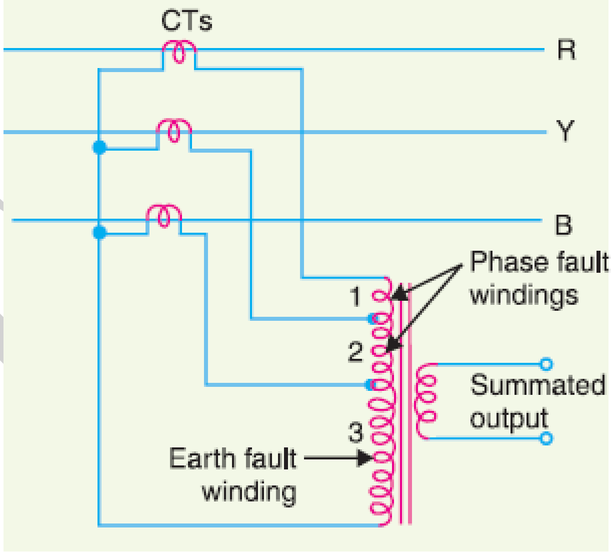
Phase to Earth Faults

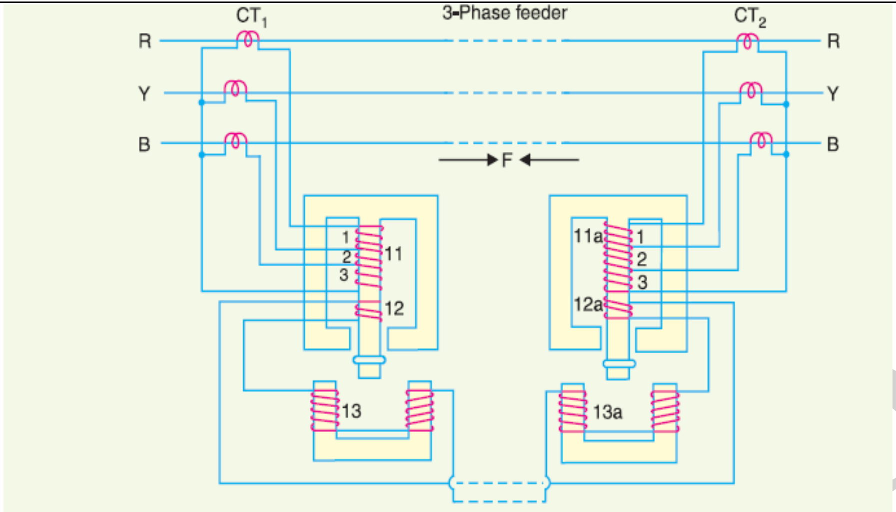
Stator Inter-Turn Faults

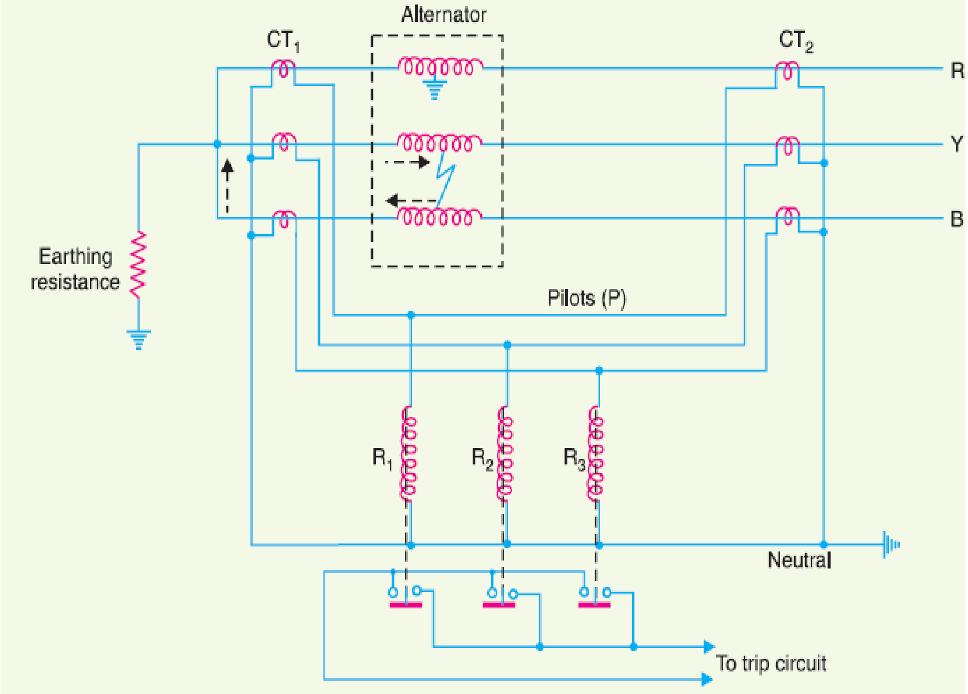
Rotor Faults

Abnormal Running Conditions

	These abnormal conditions include, I. Overloading 2. Over speeding 3. Unbalanced loading 4. Over voltage 5. Failure of prime mover (Arc of excitation (Field failure) 7. Cooling system failure (Explanation: Each 2 M) **Failure of prime-mover.** Input, prime-mover fails, the alternator runs as a synchronous motor draws some current from the supply system, "inverted running". **Failure of field:** No immediate damage , permitting the alternator to run without a field for a short-period, rely on the control room attendant to disconnect the faulty alternator manually from the system bus-bars. **Over current.** Due to partial breakdown of winding insulation or due to overload on the supply system. Reasons. **Over speed.** Sudden loss of all or the major part of load on the alternator. **Over-voltage.** Speed of the prime-mover increases due to sudden loss of the alternator load. relays are so arranged that when the generated voltage rises 20% above the normal value, they operate to ➢ trip the main circuit breaker to disconnect the faulty alternator from the system ➢ disconnect the alternator field circuit **Unbalanced loading.** There are different phase currents in the alternator. Unbalanced loading arises from faults to earth or faults between phases on the circuit external to the alternator. The unbalanced currents, if allowed to persist, may either severely burn the mechanical fixings of the rotor core or damage the field winding. **(*vii*) Stator winding faults.** These faults occur mainly due to the insulation failure of the stator windings. The main types of stator winding faults, in order of importance are : **(*a*)** fault between phase and ground **(*b*)** fault between phases **(*c*)** inter-turn fault involving turns of the same phase winding The stator winding faults- most dangerous- cause considerable damage to the expensive machinery. Differential method of protection (also knows as Merz-Price system)- due to its greater sensitivity and reliability.
4.	**A star-connected, 3-phase, 10-MVA, 6·6 kV alternator has a per phase reactance of 10%. It is protected by Merz-Price circulating-current principle which is set to operate for fault currents not less than 175 A. Calculate the value of earthing resistance to be provided in order to ensure that only 10% of the alternator winding remains unprotected. (10 M)** BTL 3 **Answer: Page 529- V.K. Mehta** Voltage per phase, Vph= 3810 V Full-load current, I= 875 A (2 M) Reactance per phase x = 0·436 Ω (3 M) r = 2·171Ω (5 M)
5.	**A star-connected, 3-phase, 10 MVA, 6·6 kV alternator is protected by Merz- Price circulating-current principle using 1000/5 amperes current transformers. The star point of the alternator is earthed through a resistance of 7·5 Ω . If the minimum operating current for the relay is 0·5 A, calculate the percentage of each phase of the stator winding which is unprotected against earth-faults when the machine is operating at normal voltage. (8 M)** BTL 3 **Answer: Page 530- V.K. Mehta**

	Voltage per phase, Vph= 3810 V Minimum fault current which will operate the relay = 1000/5 * 0.5 = 100 A (2 M) E.M.F. induced in x% winding = 38·1 x volts (2 M) 19·69% of alternator winding is left unprotected. (4 M)
6	**A 3-phase transformer of 220/11,000 line volts is connected in star/delta. The protective transformers on 220 V side have a current ratio of 600/5. What should be the CT ratio on 11,000 V side ? (8 M)** BTL 3 **Answer: Page 538- V.K. Mehta** Phase current of star connected *CT*s on 11,000 V side = $5\sqrt{3}$ A (2 M) Diagram: (2 M) Primary apparent power = Secondary apparent power I= 12A (2 M) Turn-ratio of *CT*s on 11000 V side= 12 : 5√ 3 = **1·385 : 1** (2 M)
7.	**Explain differential pilot wire protection using translay scheme. (13 M) (BTL 3)** **Answer: Page 548- V.K. Mehta** ➢ Similar to voltage balance system except balance or opposition is between the voltages induced in the secondary windings wound on the relay magnets and not between the secondary voltages of the line current transformers. ➢ This permits to use current transformers of normal design and eliminates one of the most serious limitations of original voltage balance system, namely; its limitation to the system operating at voltages not exceeding 33 kV. (3 M) ➢ Diagram: (3 M)  ➢ Construction and working: (7 M) Summation transformer, poly phase quantity into single phase quantity. Three CTs connected to tapped primary of summation transformer. Advantages: ➢ primary windings 1 and 2 can be used for phase faults whereas winding 3 can be used for earth fault ➢ The number of pilot wires required is only two.

	
	PART*C
1.	**Breifly explain about Merz-price protection of a generator with neat sketch. (15 M)** BTL 3 **Answer: Page 3.6- Thiagarajan** Diagram- (4 M) Merz-price protection- (3 M) Working: (4 M) Advantages and disadvantages: (4 M) ➢ In this method, the currents at the two ends of the protected section are sensed using current transformers. ➢ The wires connecting relay coils to the current transformer secondary's arc called pilot wires. ➢ Under normal conditions, when there is no fault in the windings, the currents in the pilot wires fed C.T. secondary are equal. ➢ When fault occurs inside the protected section to the stator windings, the differential current I, flows through the operating coils of the relay.



2. **Explain about Motor protection (15 M)** BTL 3

Answer: Page 3.24- Thiagarajan

Ground fault protection : (8 M)

- Phase Fault Protection (**7 M)**

This protection is also called short circuit protection.

- Attracted armature type relay

Main requirements

- In the event of fault, or short circuit the breaker close to the fault should open and all other breakers are to remain in closed position, except in case of grid lines.
- In case the nearest breaker to the fault to open, back-up protection should be provided by the adjacent breakers.
- The relay operating time should be as short as possible in order to pressure system stability.
- Protection of transmission line has quite a different problem, compared to protection of generators, transformers, motors etc.

3. **Explain transmission system protection schemes with neat sketch. (15 M) .(April/May 2019)** BTL 4

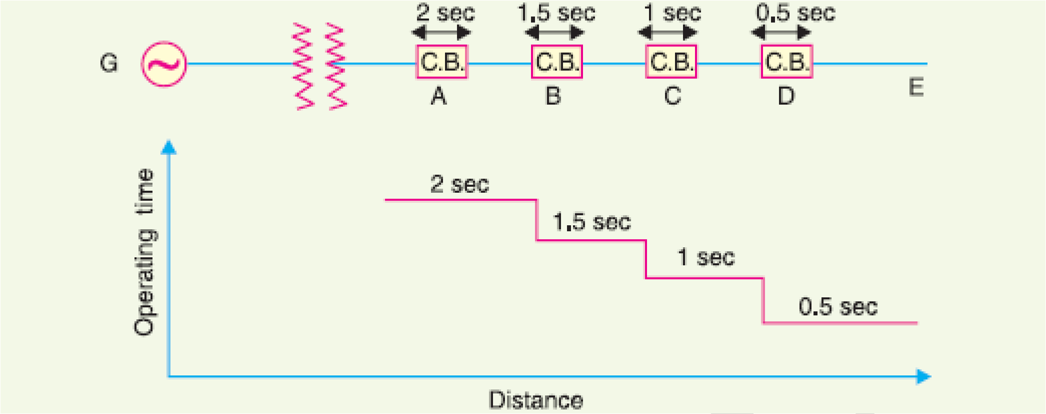
Answer: Page 3.57- Thiagarajan

- A transmission system may use one or more of the following types of protection.
- Over current protection non directional time and current graded scheme (3M)
- Directional time and current graded scheme (3M)
- Distance protection using high speed distance relays. (3M)
- Pilot wire protection (3M)
- Carrier current pilot protection
- Micro wave pilot protection
- Distance protection of lines (3M)

4. **Discuss with neat diagram, time graded overcurrent protection and distance protection of transmission lines. (13 M)** BTL 2

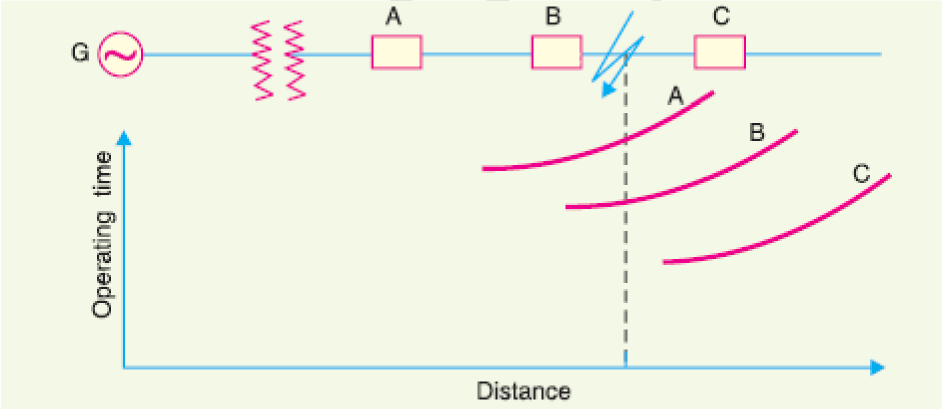
Answer: Page 544-V.K.Mehta

Definite Time relay: (4 M)



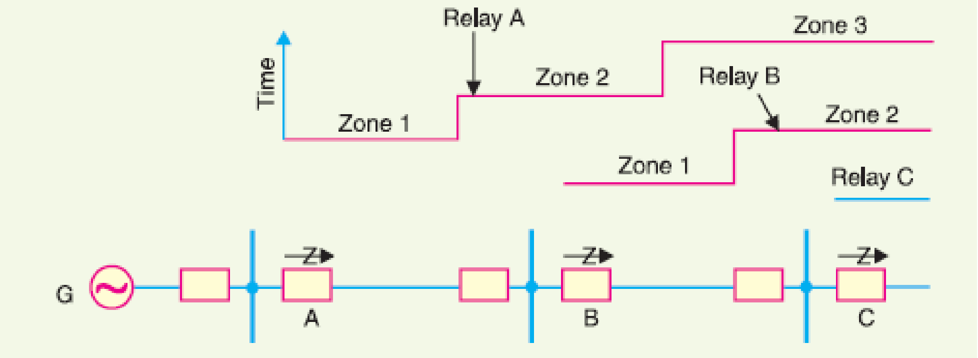
- Time of operation is fixed.
- Is independent of the operating current.
- Disadvantage: If there are a number of feeders in series, the tripping time for faults near the supply end becomes high.

Inverse Time relay: (4 M)



- Inverse time characteristics.

Distance Protection of transmission lines: (13 M)



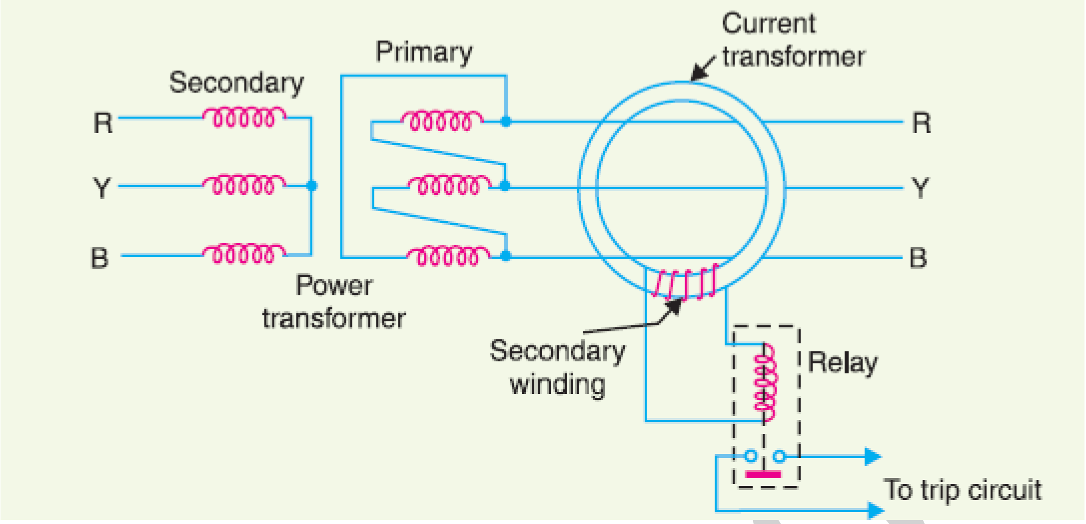
- Zone 1 covers 90% of the line and is arranged to trip instantaneously for faults in this portion.

- Zone 2 element trips the fault in the remaining 10 % of the line.
- Zone 3- back up protection.

4. **Differentiate between CT and PT. (6). (May June 2012) (May 2017)** BTL 2

S. No	Current Transformers (CT)	Potential/Voltage Transformers (PT/VT)
1	The Primary winding of a C.T have smaller number of turns than secondary.	The Primary winding of a P.T have larger number of turns than secondary.
2	The secondary of a C.T cannot be open circuited on any circumstance when it is under service.	The secondary of a P.T can be open circuited without any damage being caused either to the operator or the transformer.
3	A CT may be considered as a series transformer.	P.T may be considered as a parallel transformer.
4	The primary current in a C.T is independent of the secondary circuit conditions (burden/load).	The primary current of a P.T depends upon the secondary circuit conditions (burden/load).
5	The primary winding of the CT is connected in series with the line carrying the current to be measured. Hence it carries of the full line current.	The primary winding P.T is connected across the line of voltage to be measured. Hence the full line voltage is impressed across its terminal.
6	With the help of CT, a 5A ammeter can be used measure a high current like 200A.	With the help of P.T, a 120V voltmeter can be used to measure very high voltages like 11KV.

5. **Explain earth fault protection of transformers. (8 M)** BTL 3
Answer: Page 535- V.K.Mehta



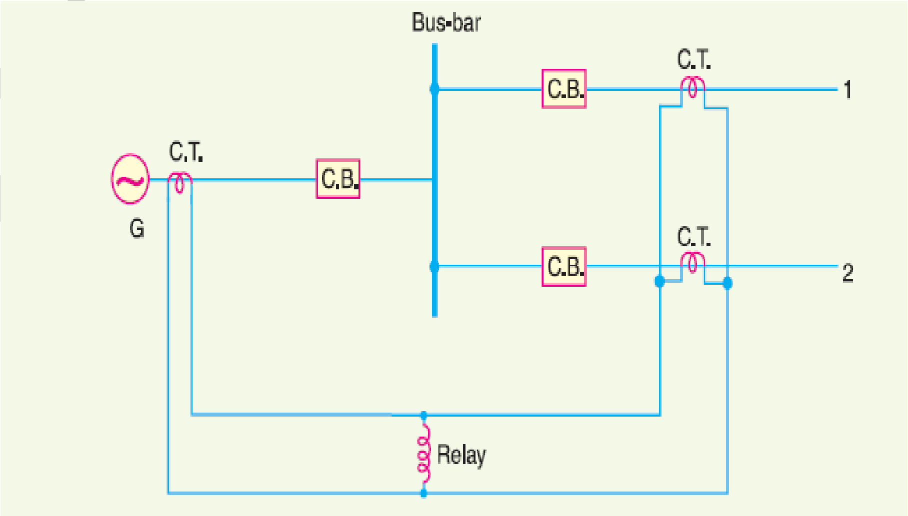
(4 M)

- ➢ The three leads of the primary winding of power transformer are taken through the core of a current transformer which carries a single secondary winding.
- ➢ The operating coil of a relay- connected to this secondary.
- ➢ Under normal conditions (i.e. no fault to earth), the vector sum of the three phase currents is zero and there is no resultant flux in the core of current transformer
- ➢ No current flows through the relay and it remains inoperative.
- ➢ Occurrence of an earth-fault, the vector sum of three phase currents - no longer zero. The resultant current sets up flux in the core of the C.T. which induces e.m.f. in the secondary winding.
- ➢ Energizes the relay to trip the circuit breaker and disconnect the faulty transformer from the system. (4 M)

6. **Briefly explain about busbar protection schemes with neat diagram. (15 M)** BTL 3

Answer: Page 542- V.K. Mehta

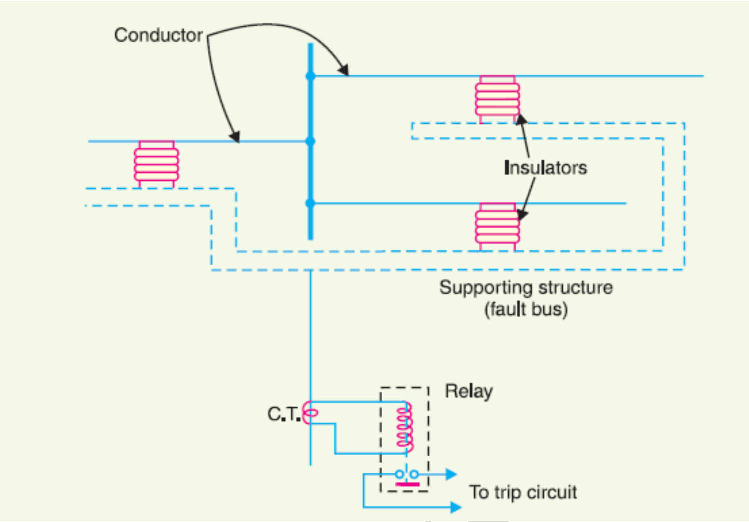
Differential Protection: (7 M)



- ➢ All CTs must be of same ratio.
- ➢ Under normal condition or during external fault condition- the sum of current entering the bus is equal to sum of current leaving it.
- ➢ Fault condition- difference current flows and cause opening of generator circuit

breaker and each of the line circuit breakers.

Fault Bus Protection: (8 M)



- It is possible to design a station so that the faults that develop are mostly earth-faults.
- This can be achieved by providing earthed metal barrier (known as *fault bus*) surrounding each conductor throughout its entire length in the bus structure.
- Every fault that might occur must involve a connection between a conductor and an earthed metal part.
- By directing the flow of earth-fault current, it is possible to detect the faults and determine their location. This type of protection is known as fault bus protection.

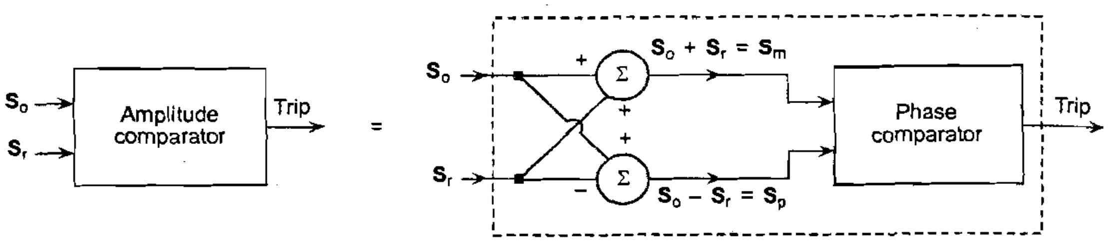
UNIT IV STATIC RELAYS AND NUMERICAL PROTECTION

Static relays – Phase, Amplitude Comparators – Synthesis of various relays using Static comparators – Block diagram of Numerical relays – Over current protection, transformer differential protection, distant protection of transmission lines.

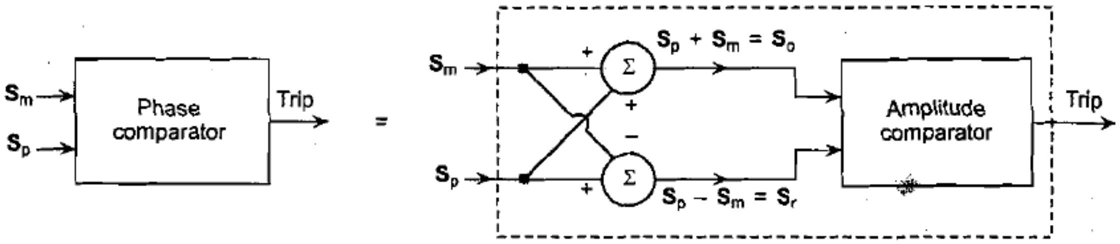
PART * A

Q.No.	Questions
1	**What is a programmable relay?** BTL 1 A static relay may have one or more programmable units such as microprocessors or microcomputers in its circuit.
2	**What is CPMC?** BTL 1 It is combined protection, monitoring and control system incorporated in the static system.
3	**What are the advantages of static relay over electromagnetic relay? (Nov 2013) .(April/May 2019)** BTL 1 Low power consumption as low as 1mW No moving contacts; hence associated problems of arcing, contact bounce, erosion, replacement of contacts No gravity effect on operation of static relays. Hence can be used in vessels i.e., ships, aircrafts etc. A single relay can perform several functions like over current, under voltage, single phasing protection by incorporating respective functional blocks. This is not possible in electromagnetic relays. Static relay is compact Superior operating characteristics and accuracy Static relay can think , programmable operation is possible with static relay Effect of vibration is nil, hence can be used in earthquake-prone areas Simplified testing and servicing. Can convert even non-electrical quantities to electrical in conjunction with transducers.
4	**Define static relay.(April/May 2019)** BTL 1 A static relays to a relay in which measurement or comparison of electrical quantities is done in a static network which is designed to give an output signal, when a threshold condition is passed, which operates a tripping device.
5	**List the types of static relays.** BTL 1 Electronic relays 2. Transducer relays 3. Rectifier bridge relays 4.Transistor relays 5. Hall effect relays 6. Guass effect relays
6	**What are the limitations of a static relay?** BTL 1 ➢ Auxiliary voltage requirement for Relay Operation. ➢ Static relays are sensitive to voltage transients which are caused by operation of breaker and isolator in the primary circuit of CTs and PTs. ➢ Serious over voltage is also caused by breaking of control circuit, relay contacts etc. ➢ Temperature dependence of static relays: The characteristics of semiconductor devices are affected by ambient temperature. Highly reliable power supply circuits

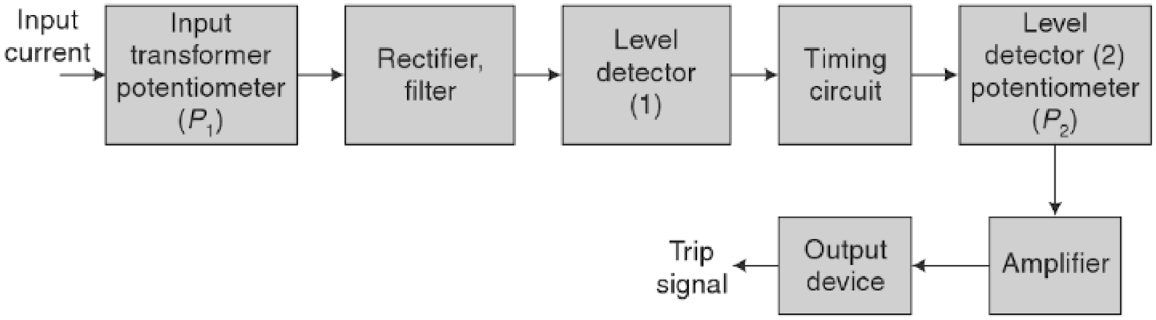
	are required.
7	**Define comparator.** BTL 3 Comparator is a part of a static relay which receives two inputs to be compared and gives output based on comparison. Types are amplitude comparator, phase comparator, Hybrid comparator.
9	**What are the types of electronic circuits used in a static protection system?** BTL 1 Analog circuits – For simple functions Digital circuits – For complex functions Hybrid circuits – For highly complex functions
10	**How does a numerical over current relay work? (May 2017)** BTL 1 Numerical over current protection algorithm first reads all the setting such as the type of characteristics to be implemented, the pickup value $I_{perunit}$, the time multiplier setting in case of inverse time over current relay or the time delay in case of DTOC relay. Using a multiplexer, the microprocessor can sense the faults currents. If fault current exceeds a pickup value, microprocessor sends a tripping signal to the C.B of the faulty circuit.
11	**Define hybrid comparator.** BTL 1 It is a comparator which compares both magnitude and phase of the input quantities. Hence amplitude and phase comparators are used. Inputs are given to phase comparator and output of phase comparator is given to amplitude comparator.
12	**What is digital filtering?** BTL 1 Digital filtering is performed using analog filters consisting of RLC circuits and active filters using operational amplifiers which is the most needed operation in numerical relaying
13	**Define sampling theorem. (May 2017)** BTL 1 It states that in order to preserve the information contained in a signal of frequency it must be sampled at a frequency at least equal to or greater than twice the signal frequency. $\varpi_{\text{sampling,min}} \geq 2\varpi\text{signal}$
14	**What are the Limitations of Numerical Relay?** BTL 1 ➢ Numerical Relay offers more functionality, and greater precision. Numerical Relay can make faster decisions. Numerical Relay protection often relies on non-proprietary software, exposing the system to potential risk of hacking. ➢ Numerical Relay protection sometimes has exposure to externally-sourced transient interference that would not affect conventional technology. ➢ Numerical Relay protection shares common functions. This means that there are common failure modes that can affect multiple elements of protection.
15	**What are the two types of Phase comparators?** BTL 1 Phase comparators are of two types: the cosine type and the sine type.
16	**What is the trip condition for Sine comparators?** BTL 1 If $0^0 < \text{Arg}(S_m/S_p) < 180^0$ then trip; else restrain where S_m and S_p are the inputs to the sine comparator.
17	**What is the trip condition for Cosine comparators?** BTL 1 If $-90^0 < \text{Arg}(S_m/S_p) < +90°$ then trip; else restrain where Sm and Sp are the inputs to the cosine comparator.
18	**Draw the duality between amplitude and phase comparators.** BTL 3



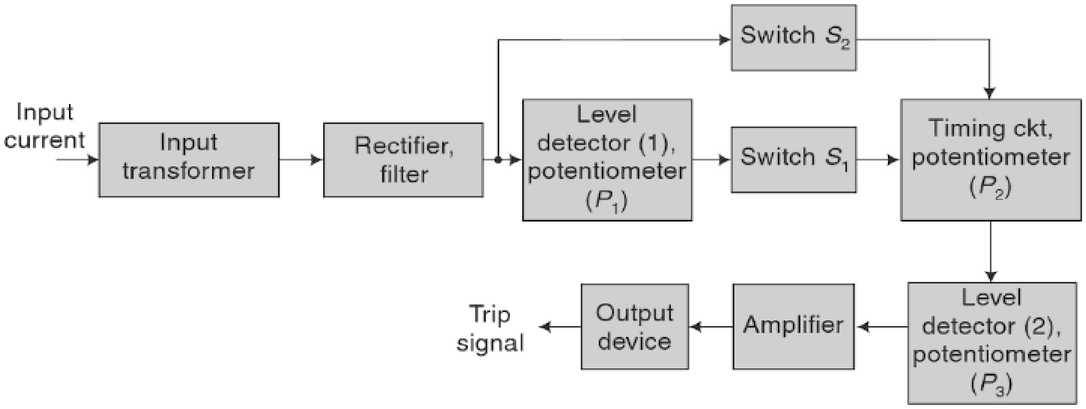
19 **Draw the duality between phase and amplitude comparators.** BTL 3



20 **Draw the block diagram of static instantaneous over current relay.** BTL 3

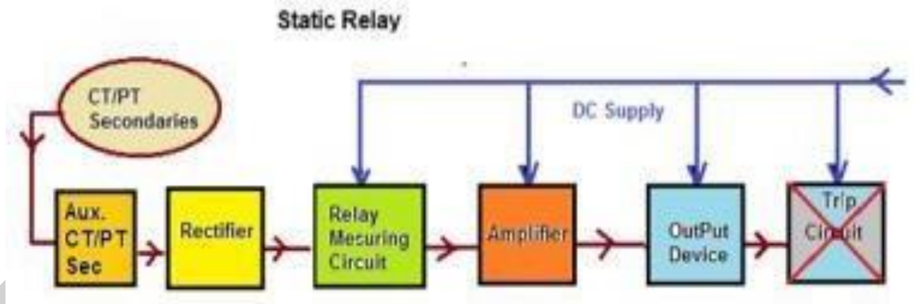


21 **Draw the block diagram of static inverse time over current relay.** BTL 3



22 **What are the types of Numerical Over current relays?** BTL 1

- Microprocessor based over current relays
- Microcontroller based over current relays
- Digital Signal Processor based over current relays

	➢ FPGA based over current relays ➢ ANN over current relays
23	**What is meant by under reach of distance relay?** BTL 1 A distance relay is said to under reach when the impedance seen by relay due to fault is more than the relay setting value even though the fault point is within the protected zone of line. This means that reach of relay has decreased from the setting value.
24	**What is meant by over reach of distance relay?** BTL 1 The tendency of a distance relay to operate eve when the fault is beyond its preset reach is known as over reach.
25	**State the reason for overreach of distance relays.** BTL 1 Presence of DC offset in the fault current wave.
	PART * B
1	**Explain with neat block diagram of the solid state relays. (13M)(Nov 2013)** BTL 1 **Answer: Page 98 - Notes** **Static relay introduction:** (3 M) ➢ Measurement or comparison of electrical quantities is done in a static network which is designed to give an output signal, when a threshold condition is passed, which operates a tripping device. **Block diagram:** (4 M)  **Working:** (6 M) ➢ A relay using combination of both static and electro-magnetic units is also called a static relay provided that static units accomplish the response. ➢ The performance of static relay is better than electromagnetic relays as they are fast acting and accuracy of measurement is better than electromagnetic relay. ➢ The rectified output supplied to a measuring unit comprising of comparators, level detectors, filters, logic circuits. Output - actuated when the dynamic input (i.e., the relaying quantity) attains the threshold value. ➢ This output of the measuring unit amplified by amplifier and fed to the output unit device, which is usually an electro-magnetic one. The output unit energizes the trip coil only when relay operates.

2

Explain the block diagram of numerical relay with neat sketch. (13M) (May 2017)
BTL 1
Answer: Page: 85: Notes

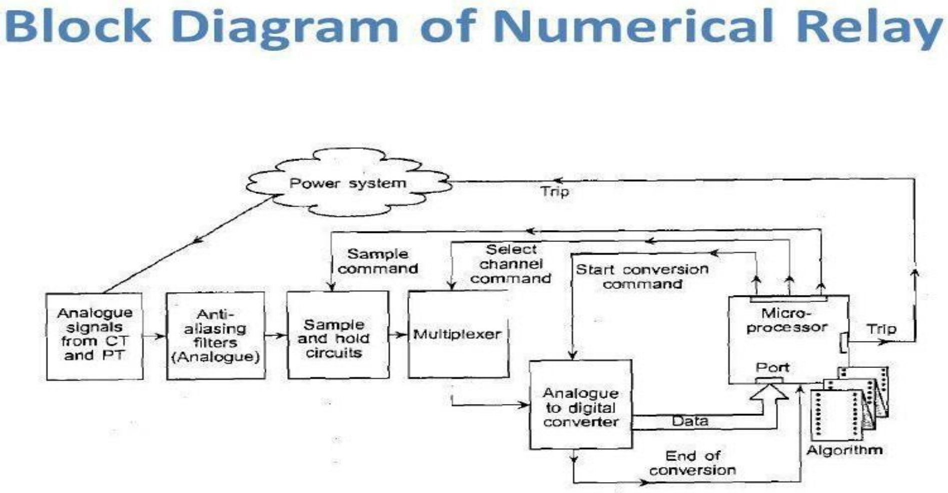
Numerical relay introduction (3 M)

Numeric relays are programmable relays. The characteristics and behavior of the relay can be programmed.

First generation numerical relays to meet the static relay protection characteristic, modern numeric protection devices capable of providing complete protection with added functions like control and monitoring.

Numerical protection devices offer several advantages in terms of protection, reliability, and trouble shooting and fault information.

Block diagram: (4 M)



Block Diagram of Numerical Relay

Working: (6 M)

- ➢ These are microprocessor - based relays in contrast to other relays that are electromechanically controlled.
- ➢ Function of Relay: Modern power system protection devices are built with integrated functions. Multifunction like protection, control, monitoring and measuring are available today in numeric power system protection devices. Also, the communication capability of these devices facilitates remote control, monitoring and data transfer.
- ➢ Numerical protection devices are available for generation, transmission and distribution systems
- ➢ Numerical relays are micro processor based relays

- These relays provide great precision and convenience in application in the sophisticated electronic products.

Advantages of Numerical relays:

- Compact Size
- Flexibility:
- Reliability
- Multi Function Capability
- Modular frame:
- Low burden.
- Sensitivity:
- Speed & Fast Resetting

3 **Describe with neat block diagram about the working of numerical over current protection. (13M).(April/May 2019)** BTL 3

Answer: Page:89 - Notes

Diagram (5 M)

C. Block Schematic Diagram of proposed NPR for Over Current Protection

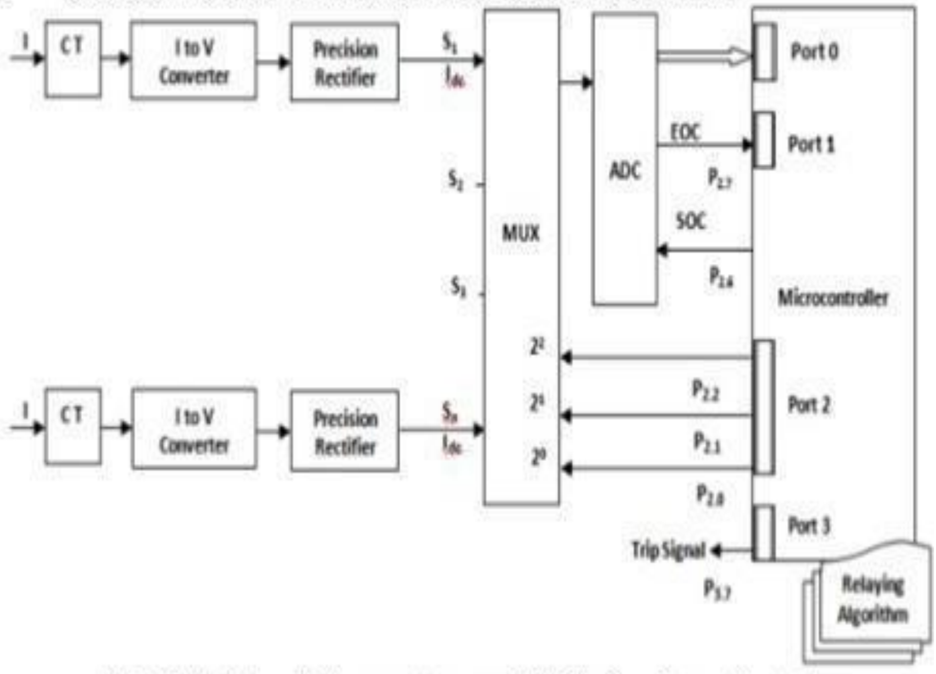


Fig.1: Block Schematic Diagram of proposed NPR for Over Current Protection

Working: (8 M)

	➢ The output of the rectifier fed to the multiplexer. ➢ The microcomputer sends a command to switch on desired channel of the multiplexer to obtain the rectified voltage proportional to the current in a particular circuit. ➢ The output of the multiplexer is fed to the A/D converter to obtain the signal in digital form. ➢ The A/D converter ADC 0800 has been used for this purpose. ➢ The microcomputer reads the end of conversion signal to examine whether the conversion is over or not. ➢ As soon as the conversion is over, the microcomputer reads the current signal in digital form and then compares it with the pickup value.
4	**Explain about amplitude comparators and phase comparators in detail. (13 M)** BTL 1 **Answer: Page: 96 - Notes** Amplitude comparators- (3 M) Amplitude comparator compares the magnitude of two input quantities irrespective of the angle between them. One – operating quantity, Two- restraining quantity. Amplitude of operating quantity greater than the restraining quantity, relay trips. Phase comparators- (3 M) Compares two input quantities in phase angle, irrespective of their magnitudes and operates if the phase angle between them is <=90^0 Synthesis of relays using static comparators- (7 M)
5	**Draw the flowchart for numerical over current relay. (8 M)** BTL 4 **Answer: Page 99 - Notes** **Flowchart:** (5 M)

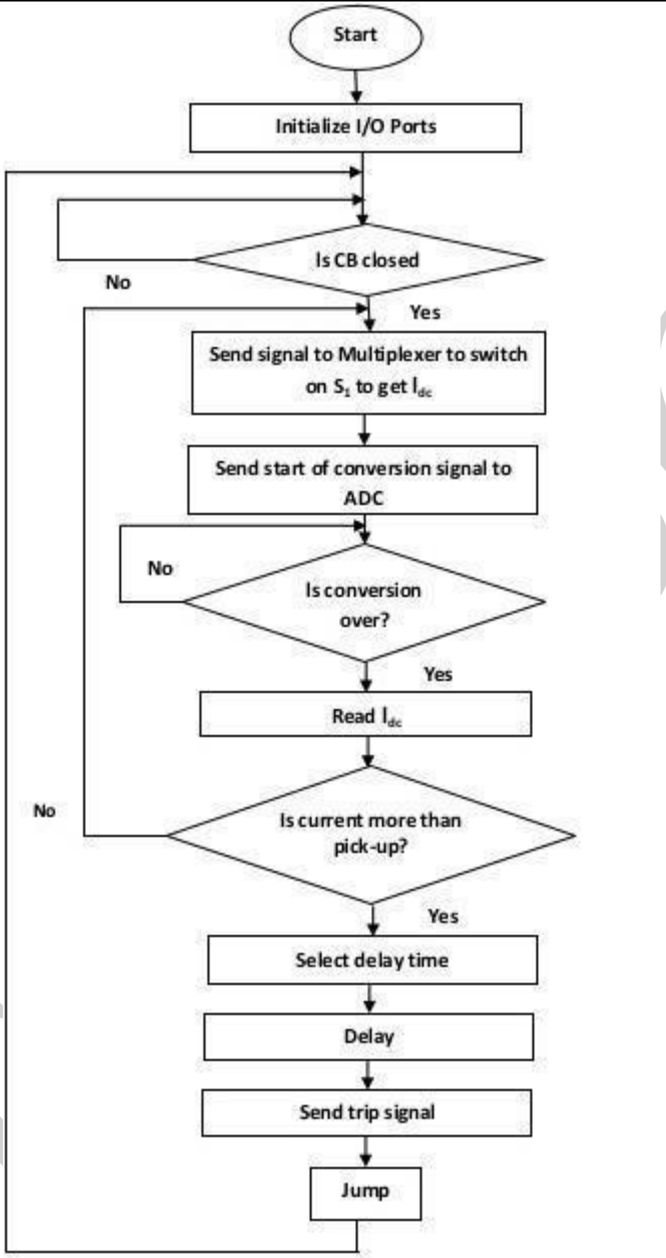


Fig.2: Flow Chart of NPR Algorithm for Over Current Protection

Explanation: (3 M)

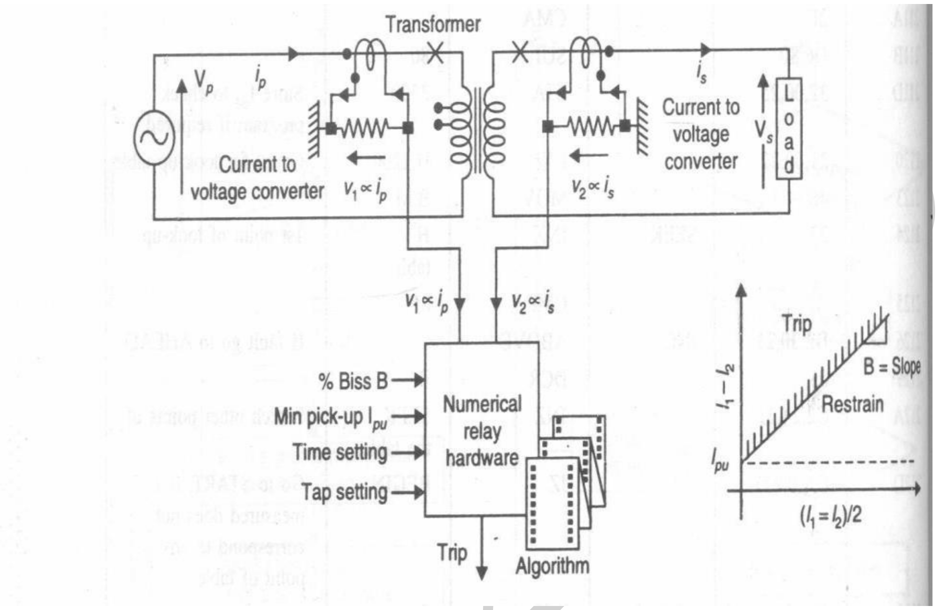
- When the fault current exceeds the pickup value, the fault current - measured once again by the microprocessor to confirm whether - fault current or transient.
- In case of any transient of short duration, the measured current above pick up value will not appear in the second measurement.
- But if there is an actual fault, it will again appear in the second measurement also and then the microprocessor will issue the tripping signal to disconnect the faulty part of the system.

PART*C

1 **Describe with neat block diagram, the working of numerical transformer differential protection. (15 M)** BTL 3

Answer: Page 102 - Notes

Diagram (5 M)



Working: (5 M)

The idea is to estimate the phasor value of the current on both sides of the transformer and find the phasor difference between the two. If magnitude of this difference -substantial, internal fault indicated and the trip signal should be issued.

Algorithm for percentage differential relay: (5 M)

- Read percentage bias B and the minimum pick up I_{pu}.
- Read i_p samples. Estimate phasor I_p using any technique.
- Read is samples. Estimate phasor Is using any technique.
- Compute spill current $I_{spill} = I_p - I_s$.
- Compute circulating current $I_{circulating} = (I_p + I_s) / 2$
- If $I_{spill} > (BI_{circulating} + I_{pu})$ then trip, else restrain.

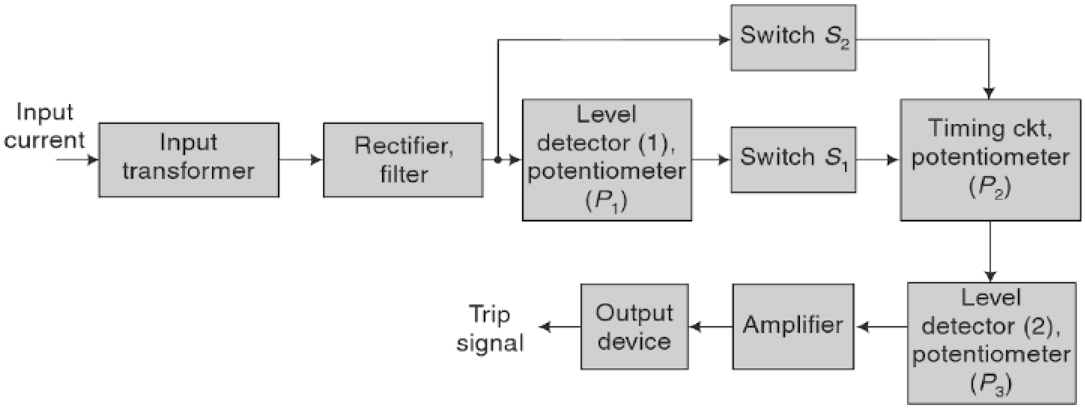
2 **Describe with neat block diagram, the working of static instantaneous over current protection relay.(15 M)** BTL 3

Answer: Page 99 - Notes

Over current relay- (3 M)

Numerical over current protection algorithm first reads all the setting such as the type of characteristics to be implemented, the pickup value $I_{perunit}$, the time multiplier setting in case of inverse time over current relay or the time delay in case of DTOC relay. Using a multiplexer,, the microprocessor can sense the faults currents. If fault current exceeds a pickup value,, microprocessor sends a tripping signal to the C.B of the faulty circuit.

Block diagram: (4 M)



Explanation: (8 M)

- The current derived from the C.T is fed to the input transformer which gives a proportional output voltage.
- The input transformer has an air gap in the iron core and is provided with tappings on its secondary winding to obtain different current settings.
- The output voltage of the transformer is rectified through a rectifier and then filtered at a single stage.
- A fixed portion of the rectified and filtered voltage (through a potential divider) is compared against a preset pick up by a level detector and if it exceeds the pickup value, a signal through an amplifier is given to the output device which issues the trip signal.
- The output may either be a static thyristor circuit or an electromagnetic slave relay.

3

Explain the types of amplitude comparators in detail. (15 M) BTL 3

Answer: Page: 66- Badri Ram

Types: (2 M)

- Circulating current type rectifier bridge comparators
- Phase splitting type comparators
- Sampling comparators

Circulating current type rectifier bridge comparators- used for over current and distance relay characteristics. Operating and restraining quantities are rectified and then applied to a slave relay or thyristor circuit. Two full wave rectifiers- one for operating quantity and the other for restraining quantity.

Bridges- DC polarized relay.

Operating quantity exceeds restraining quantity, relay operates. Diagram. (5 M)

Phase splitting type comparators- Input split into six components 60^0 apart, output after

	rectification smoothens within 5%, a continuous output signal is obtained. The operating time depends on the time constant. Diagram. (5 M) **Sampling comparators-** One of the inputs is rectified and it is compared with the other input at the particular moment. Diagram. (3 M)

UNIT V CIRCUIT BREAKERS

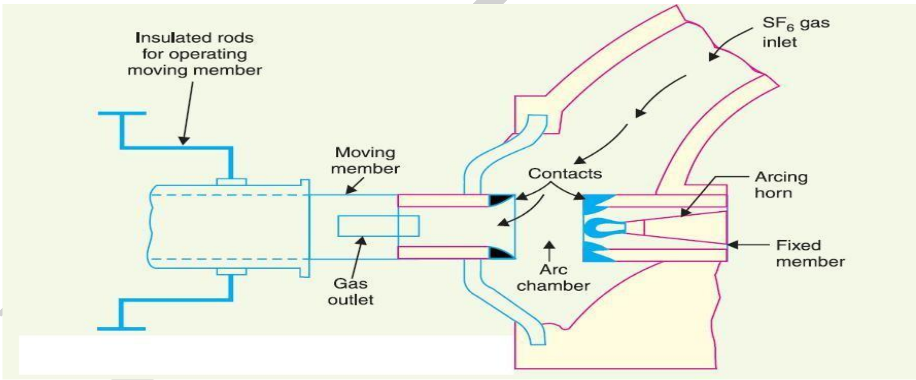
Physics of arcing phenomenon and arc interruption - DC and AC circuit breaking – re-striking voltage and recovery voltage - rate of rise of recovery voltage - resistance switching - current chopping - interruption of capacitive current - Types of circuit breakers – air blast, air break, oil, SF6 and vacuum circuit breakers – comparison of different circuit breakers – Rating and selection of Circuit breakers.

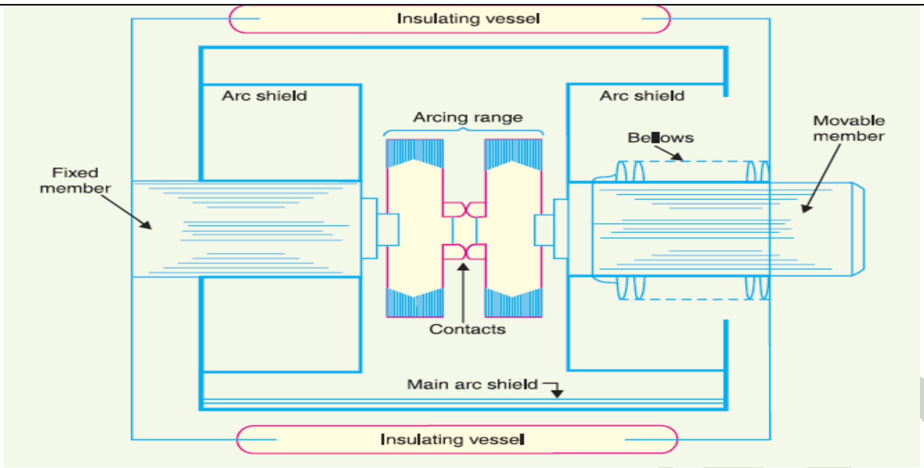
PART * A

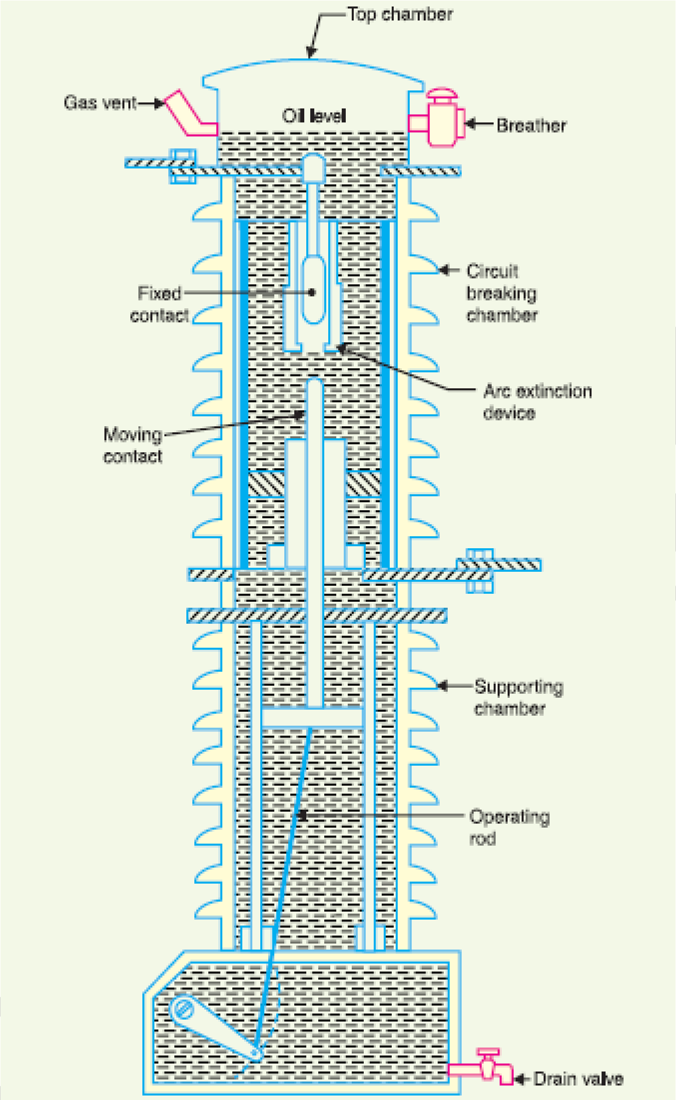
Q.No.	Questions
1	**What is resistance switching?** BTL 2 It is the method of connecting a resistance in parallel with the contact space(arc). The resistance reduces the restriking voltage frequency and it diverts part of the arc current. It assists the circuit breaker in interrupting the magnetizing current and capacity current.
2	**What do you mean by current chopping? (April/May 2019)** BTL 2 When interrupting low inductive currents such as magnetizing currents of the transformer, shunt reactor, the rapid deionization of the contact space and blast effect may cause the current to be interrupted before the natural current zero. This phenomenon of interruption of the current before its natural zero is called current chopping.
3	**What are the methods of capacitive switching?** BTL 2 Opening of single capacitor bank Closing of one capacitor bank against another
4	**What is an arc?** BTL 1 Arc is a phenomenon occurring when the two contacts of a circuit breaker separate under heavy load or fault or short circuit condition.
5	**Give the two methods of arc interruption.** BTL 1 High resistance interruption:-the arc resistance is increased by elongating, and splitting the arc so that the arc is fully extinguished _ Current zero method:-The arc is interrupted at current zero position that occurs100 times a second in case of 50Hz power system frequency in ac.
6	**What is restriking voltage?** BTL 1 It is the transient voltage appearing across the breaker contacts at the instant of arc being extinguished.
7	**What is meant by recovery voltage?** BTL 2 The power frequency rms voltage appearing across the breaker contacts after the arc is extinguished and transient oscillations die out is called recovery voltage.
8	**What is RRRV?** BTL 2 RRRV is the rate of rise of restriking voltage, expressed in volts per microsecond. It is closely associated with natural frequency of oscillation.
9	**What is circuitbreaker?** BTL 1 Circuit breaker is a piece of equipment used to break a circuit automatically under fault conditions. It breaks a circuit either manually or by remote control under normal conditions and under fault conditions.

10	**Write the classification of circuit breakers based on the medium used for arc extinction.** BTL 1 - Air break circuit breaker - Oil circuit breaker - Minimum oil circuit breaker - Air blast circuit breaker - SF6 circuit breaker - Vacuum circuit breaker
11	**What is the main problem of the circuitbreaker?** BTL 2 When the contacts of the breaker are separated, an arc is struck between them. This arc delays the current interruption process and also generates enormous heat which may cause damage to the system or to the breaker itself. This is the main problem.
12	**Write the demerits ofMOCB.** BTL 2 - Short contact life - Frequent maintenance - Possibility of explosion - Larger arcing time for small currents - Prone to restricts
13	**What are the advantages of oil as arc quenching medium? (April/May 2019)** BTL 2 • It absorbs the arc energy to decompose the oil into gases, which have excellent cooling properties • It acts as an insulator and permits smaller clearance between line conductors and earthed components
14	**What are the hazards imposed by oil when it is used as an arc quenching medium?** BTL 2 There is a risk of fire since it is inflammable. It may form an explosive mixture with arc. So oil is p:red as an arc quenching medium.
15	**What are the advantages of MOCB over a bulk oil circuit breaker?** BTL 2 • It requires lesser quantity of oil • It requires smaller space • There is a reduced risk offire • Maintenance problem are reduced
16	**What are the disadvantages of MOCB over a bulk oil circuit breaker?** BTL 2 The degree of carbonization is increased due to smaller quantity of oil There is difficulty of

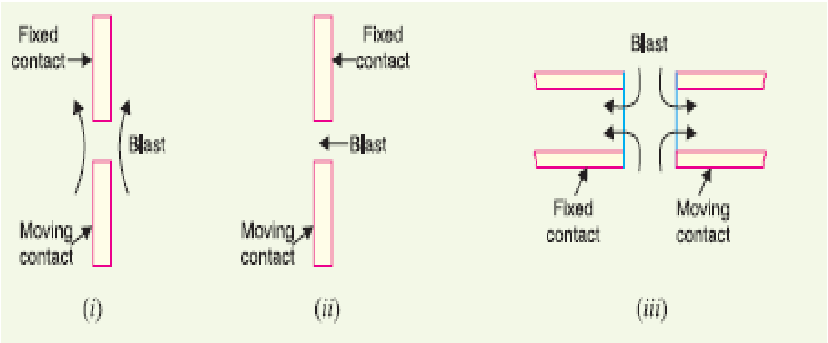
	removing the gases from the contact space in time The dielectric strength of the oil deteriorates rapidly due to high degree of carbonization
17	**What are the types of air blast circuit breaker?** BTL 1 Arial-blast type Cross blast Radial-blast
18	**What are the advantages of air blast circuit breaker over oil circuit breaker?** BTL 2 • The risk of fire is diminished • The arcing time is very small due to rapid buildup of dielectric strength between contacts • The arcing products are completely removed by the blast whereas oil deteriorates with successive operations.
19	**What are the demerits of using oil as an arc quenching medium?** BTL 2 • The air has relatively inferior arc quenching properties • The air blast circuit breakers are very sensitive to variations in the rate of rise of restriking voltage • Maintenance is required for the compression plant which supplies the airblast
20	**What is meant by electro negativity of SF6gas?** BTL 2 SF6 has high affinity for electrons. When a free electron comes and collides with a neutral gas molecule, the electron is absorbed by the neutral gas molecule and negative ion is formed. This is called as electro negativity of SF6 gas.
21	**What are the characteristic of SF6gas?** BTL 2 It has good dielectric strength and excellent arc quenching property. It is inert, non- toxic, noninflammable and heavy. At atmospheric pressure, its dielectric strength is 2.5 times that of air. At three times atmospheric pressure, its dielectric strength is equal to that of the transformer oil.
22	**Write the classifications of test conducted on circuit breakers.** BTL 1 • Type test • Routine test • Reliability test • Commissioning test
23	**What are the indirect methods of circuit breaker testing?** BTL 1 • Unit test • Synthetic test • Substitution testing

	- Compensation testing - Capacitance testing
24	**What are the advantages of synthetic testing methods?** BTL 2 • The breaker can be tested for desired transient recovery voltage and RRRV. • Both test current and test voltage can be independently varied. This gives flexibility to the test • The method is simple • With this method a breaker capacity (MVA) of five time of that of the capacity of the test plant can be tested.
25	**How does the over voltage surge affect the power system?** BTL 2 The over voltage of the power system leads to insulation breakdown of the equipment's. It causes the line insulation to flash over and may also damage the nearby transformer, generators and the other equipment connected to the line.
	PART * B
1.	**Explain about the SF6 circuit breaker in detail. (13M) (Nov 2015,2014,2012)** (BTL 3) **Answer: Page 5.25- V.Thiagarajan** **Diagram: (5 M)** **Explanation: (8 M)** ➢ SF6 gas has high dielectric strength which is the most important quality of a material for use in electrical equipments and in particular for breaker it is one of the most desired properties. It has high Rate of Rise of dielectric strength after arc extinction. 
2.	**Explain about the vacuum circuit breaker in detail. (13M) (Apr 2015)** (BTL 3) **Answer: Page 5.23- V.Thiagarajan** **Diagram: (5 M)** **Explanation: (8 M)**

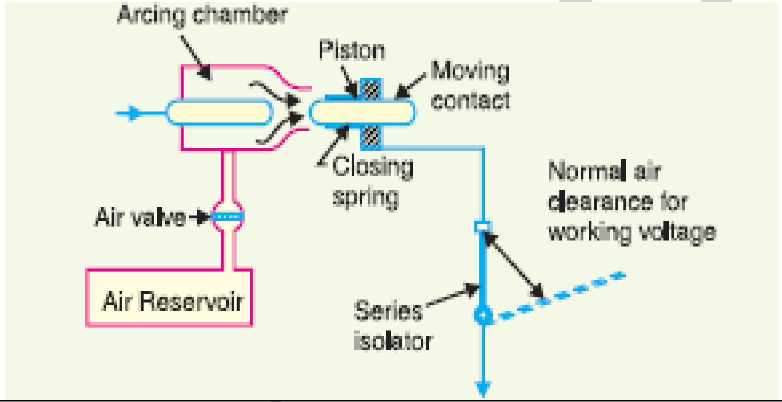
	 **Principle.** The arc is quickly extinguished because the metallic vapours, electrons and ions produced during arc rapidly condense on the surfaces of the circuit breaker contacts, resulting in quick recovery of dielectric strength.
3.	**Explain about the oil circuit breakers in detail.(13M)(Nov 2013,Nov 2015)** (BTL 3) **Answer: Page 5.9- V.Thiagarajan** **Costruction: (5 M)** There are two compartments separated from each other but both filled with oil. The upper chamber is the circuit breaking chamber while the lower one is the supporting chamber. *Circuit-breaking chamber.* It is filled with oil and has the following parts **(*a*)** upper and lower fixed contacts **(*b*)** moving contact **(*c*)** turbulator

	 **Diagram: (5 M)** Top chamber. It is a metal chamber and is mounted on the circuit-breaking chamber. **Operation: (5 M)** Under normal operating conditions, the moving contact remains engaged with the upper fixed contact. When a fault occurs, the moving contact is pulled down by the tripping springs and an arc is struck. The arc energy vaporises the oil and produces gases under high pressure.
	PART*C
1.	**Explain about the air blast circuit breakers in detail. (15M)(Apr 2015) (May 2017) (April/May 2019)** BTL 3 **Answer: Page 5.19- V.Thiagarajan** **Principle: (3 M)** **Construction with diagram: (7 M)** **Working: (5 M)** Depending upon the direction of air-blast in relation to the arc, air-blast circuit breakers are classified into :

(*i*) Axial-blast typein which the air-blast is directed along the arc path



Cross-blast typein which the air-blast is directed at right angles to the arc path.
Radial-blast typein which the air-blast is directed radially.

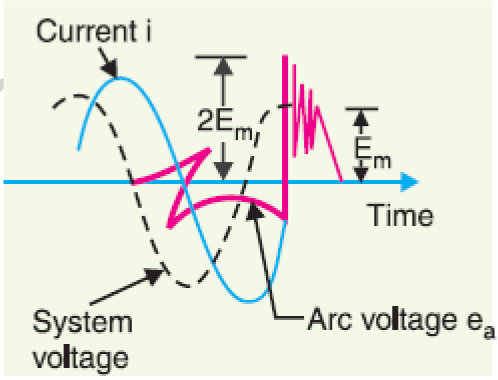


2. **Explain about Rate of rise of recovery voltage (15M)** BTL4

Answer: Page 4.17- V.Thiagarajan

Diagram: (4 M)

Explanation: (6 M)

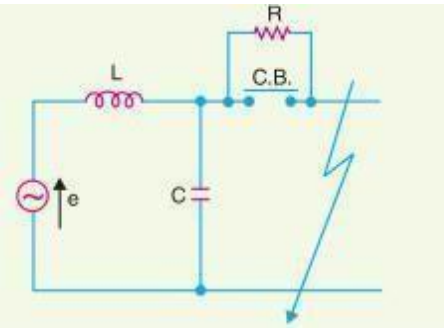


Before current interruption, the capacitance *C* is short-circuited by the fault and the short-circui current through the breaker is limited by inductance *L* of the system only

When the contacts are opened and the arc finally extinguishes at some current zero, the generato voltage *e* is suddenly applied to the inductance and capacitance in series.

Transient frequency :$fn = 1/2\ \pi\sqrt{\ LC}$

The value of R.R.R.V. depends upon :

	(*a*) recovery voltage **(*b*)** natural frequency of oscillations (**3 M**) For a short-circuit occuring near the power station bus-bars, *C* being small, the natura frequency f_n(= 1/ 2 π $\sqrt{LC}$) will be high. Consequently, R.R.R.V. will attain a large value. Thus the worst condition for a circuit breaker would be that when the fault takes place near th bus-bars.
3.	**Write short notes on Resistance switching (15M) (Nov 2015,May 2013)** (BTL 4) **Answer: Page:4.22- V.Thiagarajan** **Resistance switching: (4 M)** **Diagram: (4 M)** **Derivation: (4 M)** **Explanation: (3 M)** To reduce the restriking voltage, RRRV and severity of the transient oscillations, a resistance is connected across the contacts of the circuit breaker.  This is known as resistance switching. The analysis of resistance switching can be made to find out the critical value of the shunt resistance to obtain complete damping of transient oscillations.

EE8691 EMBEDDED SYSTEMS LT P C 3 0 0 3

OBJECTIVES:

- To introduce the Building Blocks of Embedded System
- To Educate in Various Embedded Development Strategies
- To Introduce Bus Communication in processors, Input/output interfacing.
- To impart knowledge in Various processor scheduling algorithms.
- To introduce Basics of Real time operating system and example tutorials to discuss on one real time operating system tool

UNIT I INTRODUCTION TO EMBEDDED SYSTEMS 9

Introduction to Embedded Systems – The build process for embedded systems- Structural units in Embedded processor , selection of processor & memory devices- DMA – Memory management methods- Timer and Counting devices, Watchdog Timer, Real Time Clock, In circuit emulator, Target Hardware Debugging.

UNIT II EMBEDDED NETWORKING 9

Embedded Networking: Introduction, I/O Device Ports & Buses– Serial Bus communication protocols RS232 standard – RS422 – RS485 - CAN Bus -Serial Peripheral Interface (SPI) – Inter Integrated Circuits (I2C) –need for device drivers.

UNIT III EMBEDDED FIRMWARE DEVELOPMENT ENVIRONMENT 9

Embedded Product Development Life Cycle- objectives, different phases of EDLC, Modelling of EDLC; issues in Hardware-software Co-design, Data Flow Graph, state machine model, Sequential Program Model, concurrent Model, object oriented Model.

UNIT IV RTOS BASED EMBEDDED SYSTEM DESIGN 9

Introduction to basic concepts of RTOS- Task, process & threads, interrupt routines in RTOS, Multiprocessing and Multitasking, Preemptive and non-preemptive scheduling, Task communication shared memory, message passing-, Inter process Communication – synchronization between processes-semaphores, Mailbox, pipes, priority inversion, priority inheritance, comparison of Real time Operating systems: VxWorks, чC/OS-II, RT Linux.

UNIT V EMBEDDED SYSTEM APPLICATION DEVELOPMENT 9

Case Study of Washing Machine- Automotive Application- Smart card System Application,.

OUTCOMES:

- Ability to understand and analyze, linear and digital electronic circuits.

TEXT BOOKS:

1. Rajkamal, ‘Embedded System-Architecture, Programming, Design’, Mc Graw Hill, 2013.

2. Peckol, “Embedded system Design”, JohnWiley & Sons,2010

3. Lyla B Das,” Embedded Systems-An Integrated Approach”, Pearson, 2013

REFERENCES:

1. Shibu. K.V, “Introduction to Embedded Systems”, Tata Mcgraw Hill,2009.
2. EliciaWhite,” Making Embedded Systems”, O’ Reilly Series,SPD,2011.
3. Tammy Noergaard, “Embedded Systems Architecture”, Elsevier, 2006.
4. Han-Way Huang, ”Embedded system DesignUsing C8051”, Cengage Learning,2009.
5. Rajib Mall “Real-Time systems Theory and Practice” Pearson Education, 2007.

Subject Code:EE8691 **Year/Semester: III /06**
Subject Name: EMBEDDED SYSTEMS **Subject Handler: ANTONY CHARLES A**

UNIT I

Introduction to Embedded Systems – The build process for embedded systems-Structural units in Embedded Processor , selection of processor & memory devices - DMA – Memory management methods-Timer and Counting devices, Watchdog Timer, Real Time Clock, In circuit emulator, Target Hardware Debugging.

Part*A

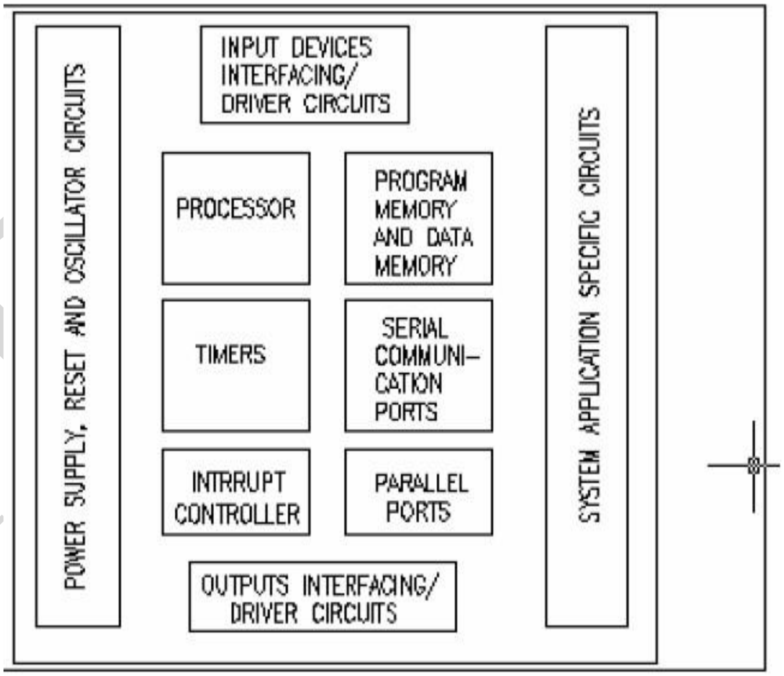
Q.No	Question
1.	**List out the challenges in building embedded system.(May/June 2016, Nov/Dec 2016)** BTL1 • Clock rate reduction • Voltage reduction • Wait • Stop & cache
2.	**What is the need of Watch Dog timer? .(May June 2016) (APR/MAY 2019)**BTL1 A Watch dog timer is an additional timer that does a monitoring job and resets the system, if necessary. Most embedded systems are expected to self- reliant, when the software is detected to be malfunctioning the best way is to reset and start again.
3.	**What are the steps involved in build processor? (Nov/Dec 2016)(April/May 2017)** BTL1 • Processor in an embedded system • Microprocessor • Micro controller • Special purpose processor
4.	**What is an embedded system?** BTL1 An embedded system employs a combination of hardware & software (a "computational engine") to perform a specific function; is part of a larger system that may not be a "computer" works in a reactive and time-constrained environment.

.5.	**What are the typical characteristics of an embedded system? (April/May 2017**) BTL1 Typical characteristics: Perform a single or tightly knit set of functions. Increasingly high-performance & real-time constrained, Power, cost and reliability are often important attributes That influence design. Application specific processor design can be a significant component of some embedded systems. Other characteristics: • Application specific • Digital signal processing in ECS • Reactive • Real-time • Distributed
6.	**What are the advantages of embedded system?** BTL1 • User friendly environment. • Customization yields lower area • Power • Cost
7.	**What are the disadvantages of embedded system**? BTL1 Disadvantages: Higher HW/software development overhead design, compilers, debuggers, etc., may result in delayed time to market.
8.	**What are the complicating factors in embedded design?** BTL1 • Complicating factors in the design of embedded systems • Many of the subtasks in design are intertwined. • Allocation depends on the partitioning, and scheduling presumes a certain allocation. • Predicting the time for implementing the modules in hardware or software is not very easy, Particularly for tasks that have not been performed before.
9.	**What are the applications of an embedded system? (APR/MAY 2019)** BTL1 **Embedded Systems: Applications:** • Consumer electronics, e.g., cameras, camcorders. • Consumer products, e.g., washers, microwave ovens. • Automobiles (anti-lock braking, engine control. • Industrial process controllers & avionics/defense applications. • Computer/Communication products, e.g., printers, FAX machines. • Emerging multimedia applications & consumer electronics.
10.	**What are the real-time requirements of an embedded system?** BTL1 Hard-real time systems: where there is a high penalty for missing a deadline e.g., control systems for aircraft/space probes/nuclear reactors; refresh rates for video, or DRAM. Soft real time systems: where there is a steadily increasing penalty if a deadline is missed. e.g., laser printer: rated by pages-per-minute, but can take differing times to print a page (depending on the \"complexity\" of the page) without harming the machine or the customer.
11.	**What are the functional requirements of embedded system?** BTL1

	• Data Collection • Sensor requirements • Signal conditioning • Alarm monitoring
12.	**What are the main components of an embedded system?** BTL1 Three main components of embedded systems: • Hardware • Application Software • RTOS
13.	**Define embedded microcontroller.** BTL2 An embedded microcontroller is particularly suited for embedded applications to perform dedicated task or operation. Example: 68HC11xx, 8051, PIC, 16F877.
14.	**Explain digital signal processing in embedded system continued digitization of signals increasing the role of DSP in ES.** BTL2 • Signals are represented digitally as sequence of "samples" • ADC's are moving closer to signals
15.	**What are the various classifications of embedded systems?** BTL1 • Small scale embedded systems • Medium scale embedded systems • Sophisticated embedded systems
16.	**What are the two essential units of a processor on an embedded system?(APR/MAY 2019)**BTL1 • Program flow control unit (CU) • Execution unit (EU)
17.	**Give examples for general purpose processor.** (APR/MAY 2019BTL1 • Microprocessor • Microcontroller • Embedded processor • Digital Signal Processor • Media Processor
18.	**Define microprocessor.** BTL2 A microprocessor fetches and processes the set of general-purpose instructions such as data transfer, ALU operations, stack operations , I/O operations and other program control operations.
19.	**When is Application Specific System processors (ASSPs) used in an embedded system?** BTL2 An ASSP is dedicated to real-time video processing applications such as video conferencing ,video compression and decompression systems. It is used as an additional processing unit for running application specific tasks in the place of processing using embedded software.
20.	**What is the need for LCD and LED displays?** BTL1 Uses of LCD and LED display: • It is used for displaying and messaging. • Example: Traffic light status indicator, remote controls, signals, etc.,

	The system must provide necessary circuit and software for the output to LCD controller
21.	**Explain distributed systems.** BTL2 • Consist of components that may necessarily be physically distributed. • Consist of communicating processes on multiple processors and/or dedicated hardware **Motivation:** • Economical multiple processors to handle multiple time critical tasks physically distributed • Devices under control may be physically distributed.
22.	**What are the temporal requirements?** BTL1 • Tasks may have deadlines • Minimal latency jitter • Minimal error detection latency • Timing requirements due to tight software control loops • Human interface requirements

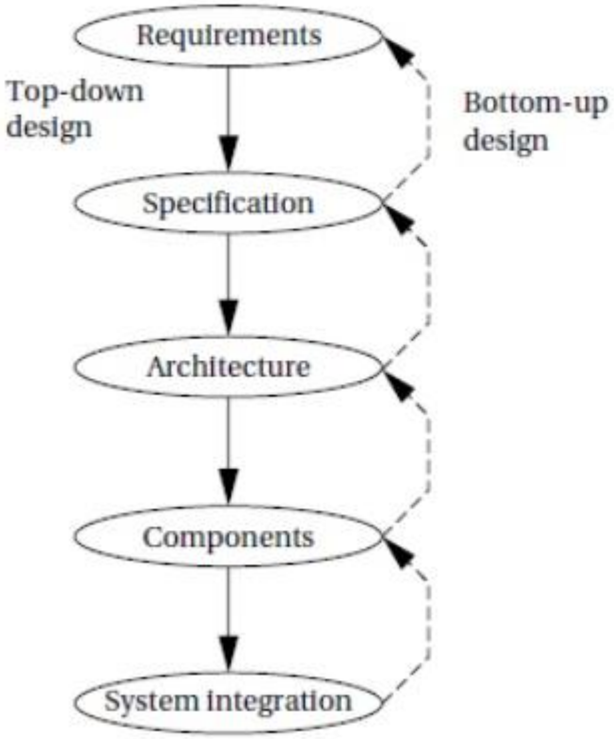
Part*B

Q.No	Question
1.	**Explain in detail about the build process for embedded systems. (May/June 2016, Nov/Dec 2016, April/May 2017)** BTL1 (13M) **Answer: Page No.1.3 – Dr.G. Ramprabu** • Heart of the embedded system – important unit  • Two units – Program Flow unit and Execution unit • Program Flow unit – Fetch unit -----(6M) • Execution unit – implementing instruction – ALU Types of Embedded system Processor • General purpose processor – Microprocessor and embedded processor • Application Specific instruction processor – Micro controller , DSP , Network processor

- Single purpose processor as additional processor – coprocessor, Accelerator , controllers
- Programable logic device
- Application Specific system processor
- Multicore processor or multiprocessor-----(7M)

2. **Explain the Design processor for Embedded system. (APR/MAY 2019**BTL1 (13M)

Answer: Page No.1.14 – Dr.G. Ramprabu



Requirements :

- General description – idea od product – list of ideas

Types

- functional requirement - input and out put devices
- non-functional requirement – cost, performance, physical size and weight, power conception

Specifications

- Behavior of product
- Global characteristics

Architecture design-----(6M)

- Plan for overall product
- Design the components first phase
- Refining the hardware

Design software and hardware design

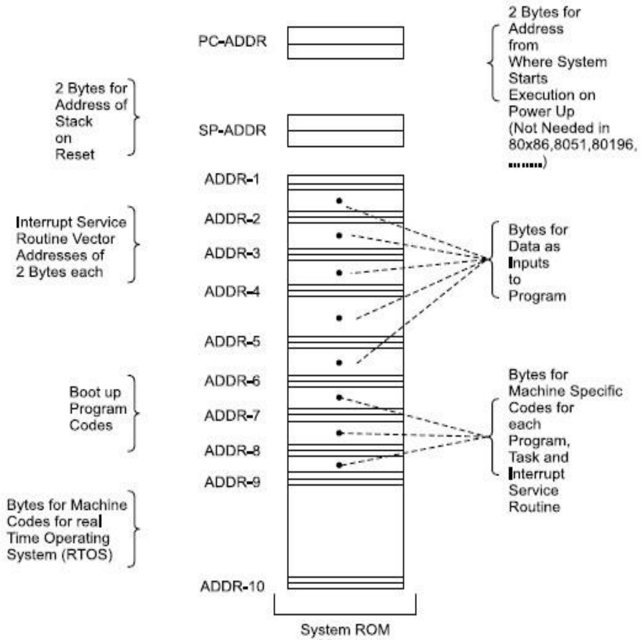
	• Architectural design tells the components • Components include both hardware and software • Components – ready made System Integration • Plugging everything together – software and hardware • Debug modules at that time • Good planning will help the system integration • Make – user friendly-----(7M)
3.	**Discuss in detail about the timer and counter devices in Embedded System .** BTL4 (13M) **Answer: Page No. 1.30 – Dr.G. Ramprabu** TIMING AND COUNTING DEVICES TIMER • Timer - which counts the input at regular interval (δT) using clock pulses- inputs • The counts increment on each pulse and store in a register, called count register • Evaluation of Time- counts multiplied by the interval δT give the time. • The (present counts −initial counts) ×δT interval gives the time interval between two instances when present count bits are read and initial counts were read or set. • Has an input pin (or a control bit in control register) for resetting it for all count bits = 0s. • Has an output pin (or a status bit in status register) for output when all count bits = 0s • after reaching the maximum value, which also means after timeout or overflow**-----(6M)** Counter • A device, which counts the input due to the events at irregular or regular intervals. • The counts gives the number of input events or pulses since it was last read. • Has a register to enable read of present counts • Functions - timer when counting regular interval clock pulses**-----(7M)** • Has an input pin (or a control bit in control register) for resetting it for all count bits = 0s. • Has an output pin (or a status bit in status register) for output when all count bits = 0s .
4.	**Explain the following Embedded Hardware Units** **(13M)** **(i) Watch Dog Timer (5M)** **(ii) Memory (4M)** (iii) **Input/ Output-Port (4M). (April/May 2017)** BTL2 **Answer: Page No. 1.32, 1.29 – Dr.G. Ramprabu** (i) Watchdog timer. • Baud or Bit Rate Control for serial communication on a line or network. • Timer timeout interrupts define the time of each baud • Input pulse counting when using a timer, which is ticked by giving non periodic inputs instead of the clock inputs. • The timer acts as a counter if, in place of clock inputs, the inputs are given to the

timer for each instance to be counted.

- Scheduling of various tasks.
- A chain of software-timers interrupt and RTOS uses these interrupts to schedule the tasks.
- Time slicing of various tasks.
- A multitasking - multi-programmed operating system presents the illusion that multiple tasks
- programs are running simultaneously by switching between programs very rapidly, for example, after every 16.6 ms. **-----(6M)**

(ii) Memory

- ROM - read only memory - is non-volatile memory used for program information - permanent data.
- The microcontroller uses ROM memory space to store program instructions it will execute when it is started or reset.
- Program instructions must be saved in non-volatile memory so that they are not affected by loss of power.
- The microcontroller usually cannot write data to program memory space.
- RAM - random access memory - used to write and read data values as a program runs.
- RAM - volatile: if you remove the power supply its contents are lost.
- Any variables used in a program are allocated from RAM. -----(7M)



System ROM memory embedding the software, RTOS, data, and vector addresses

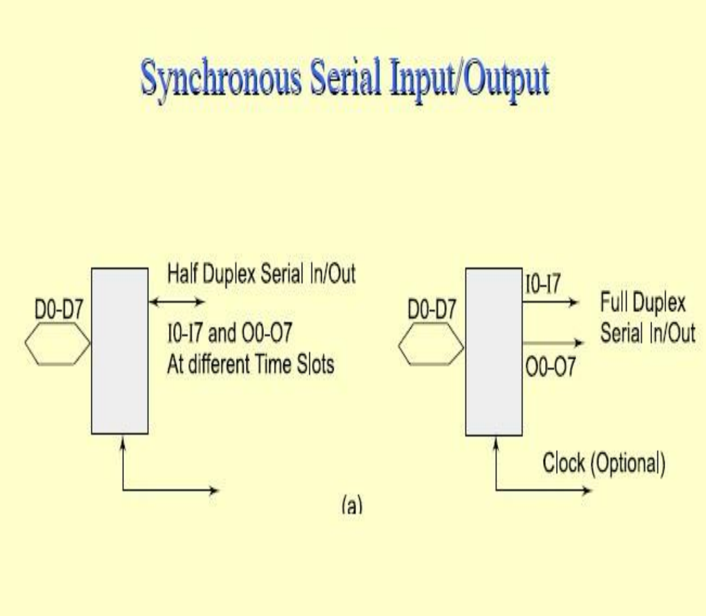
- Arrangement at each ROM address of bytes for instructions and data.
- Bytes at each address defined for creating the ROM image.
- the same hardware plat form work differently

- Can be used for entirely different applications or for new upgrades of the same system.
- Hardware elements between the distinct systems can be identical.
- Software that makes a system unique and distinct from the other..
- Compressed Codes and Data ROM image may alternatively be compressed software. **-----(7M)**

(iii) IO Port Types

Types of Serial ports

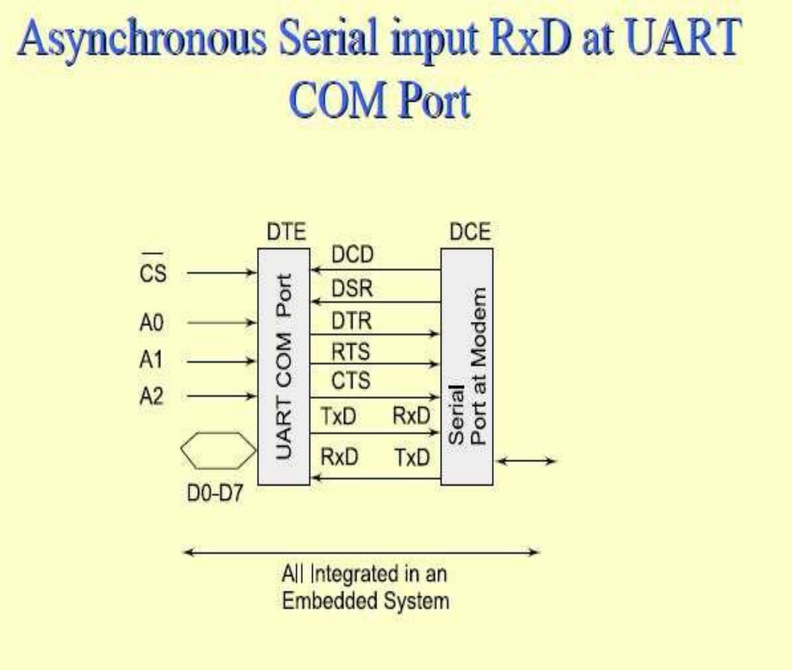
- Synchronous Serial Input
- Synchronous Serial Output



- Each bit in each byte is in synchronization at input
- Each bit in each byte is in synchronization at output with the master clock output.

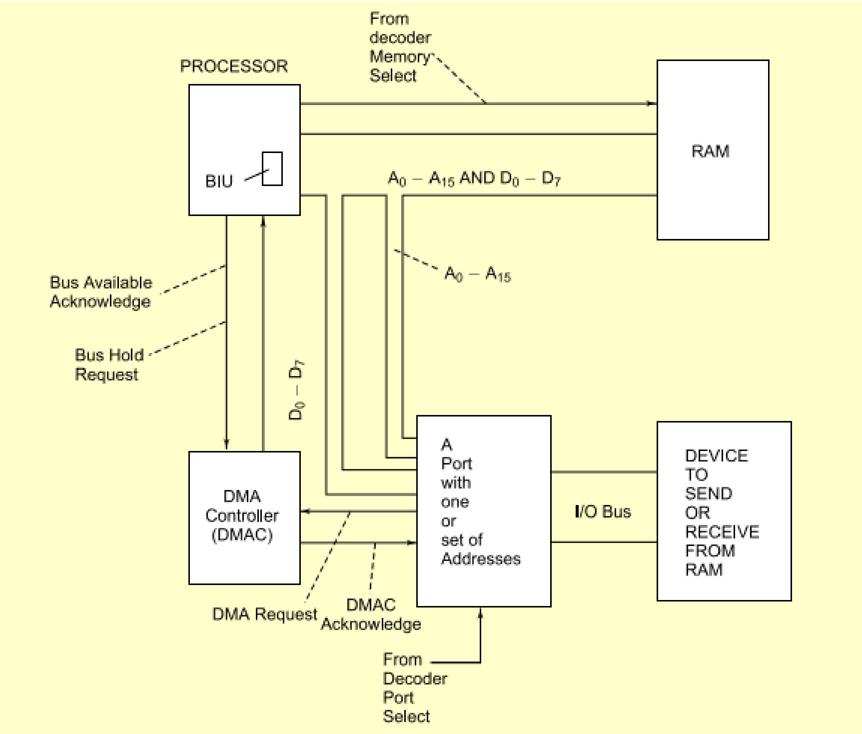
- Asynchronous Serial UART input

- Asynchronous Serial UART output (both as input and as output, for example ,modem.)

	 Asynchronous Serial input RxD at UART COM Port • Does not receive the clock pulses or clock information along with the bits. • Each bit is received in each byte at fixed intervals but each received byte - not in synchronization. • Bytes separate by the variable intervals or phase differences. • Asynchronous serial input also called UART input if serial input - according to UART protocol
5.	**Define Real Time Clock .** BTL1 (13 M) **Answer: Page No. 1.34 – Dr.G. Ramprabu** • which is based on the interrupts at preset intervals. • interrupt service routine executes on each timeout. • once started never resets or never reloaded with another value. • Used in a system to save the time and date. -----(6M) • each tick (interrupt) a service routine runs and updates at a memory location. • Within 256 days there will be 232 ticks • A battery is used to protect the memory for long period. • Interrupt service routine can generate a port bit output after every time it runs. • RTC disabled or enabled by the I bit in the CC (clock control) register-----(7M)
Part*C	
Q.No	**Question**
1.	**With a neat diagram explain the working of Direct Memory Access (DMA) with architecture and timing diagram. (May/June 2016, Nov/Dec 2016, April/May 2017)** BTL2 (15 M) **Answer: Page No.1.23 – Dr.G. Ramprabu** • required when a multi-byte data set or a burst of data. • a block of data is to be transferred between the external device and system or two

systems.

- A device facilitates DMA transfer with a processing element
- Repeatedly interrupting the processor for transfer of every byte during bulk transfer of data. -----(6M)
- System performance improves by separate processing of the transfers from and to the peripherals.



- DMAC hold request - After an ISR initiates - DMAC sends a hold request to the CPU
- CPU acknowledges that if the system memory buses are free to use
- Three modes - Single transfer at a time- Burst transfer at a time- Bulk transfer and then release of the hold-----(6M)
- DMA proceeds without the CPU intervening.
- An ISR is called only at the beginning of the transfer to program the controller (DMAC)
- Another ISR is called only at the end of the transfer.
- Separate set of registers for programming each channel.
- Separate interrupt signals in the case of a multi-channel DMAC.
  system memory with the least processor intervention using DMAC. **-----(7M)**

2.

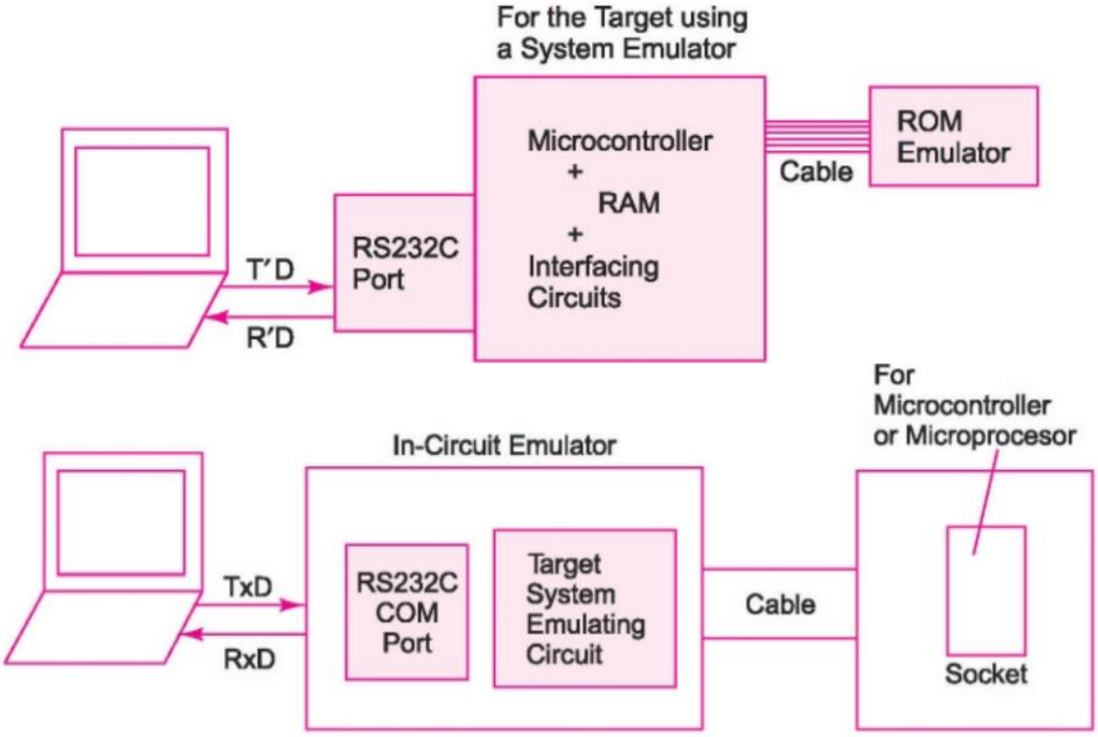
Explain (i) In circuit Emulator (8M)
(ii)Target Hardware Debugging. (7M) BTL2
Answer: Page No.1.35, 1.37 – Dr.G. Ramprabu

In-Circuit Emulator

- Circuit for emulating target system remains independent of a particular targeted system and processor
- emulating target system remains independent of a particular targeted system and

processor-----(8M)

- ICE provides great flexibility
- ease for developing various applications on a single system in place of testing that multiple targeted systems



- Emulates controlled outputs for the peripheral interfaces/systems.

Target Hardware Debugging

- A Debugger or debugging tool - a computer program that is used to test and debug other programs.
- should be running on an instruction set simulator to identify the fault.
- The debugger can be used to identify if the program is running correctly
- a source-level debugger, the debugger can show the actual position in the original code
- the run time errors as in general software development
- Real-time analysis is following code flow in real time with real-time trace analysis
- Memory substitution is replacing ROM-based memory with RAM for rapid and easy code download, debug, and repair cycles

  -----(7M)

3.

Discuss about the structural units in embedded processor and how a processor is selected for an embedded system application. (May/June 2016, Nov/Dec 2016) BTL4 (15M)

Answer: Page No. 1.11, 1.19 – Dr.G. Ramprabu

Selection of the processor

	• Can operate at higher speed • More instruction per second • High computing performance • Context switching with multi tasking system • Burst mode accesses external memories fast, reads fast and write fast • Special programming skills-----(8M) Selection of memory devices • Actual memory requirement – known after the design • ROM and RAM allocation for various segments • Prior estimation of the memory • Available memory are 1 KB , 4KB ,, 16 KB, 32KB etc • 100KB needed 128 KB is choosen-----(7M)

UNIT II

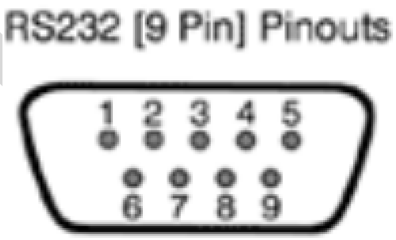
Embedded Networking: Introduction, I/O Device Ports & Buses– Serial Bus communication protocols - RS232 standard – RS422 – RS485 -CAN Bus -Serial Peripheral Interface (SPI) – Inter Integrated Circuits (I2C) –need for device drivers.

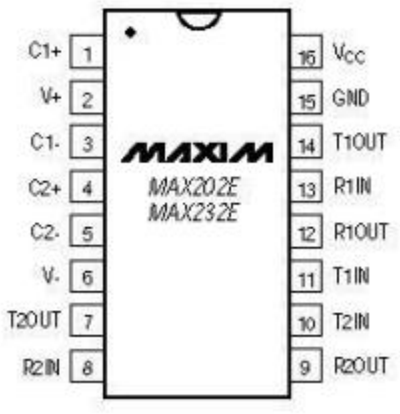
Part*A

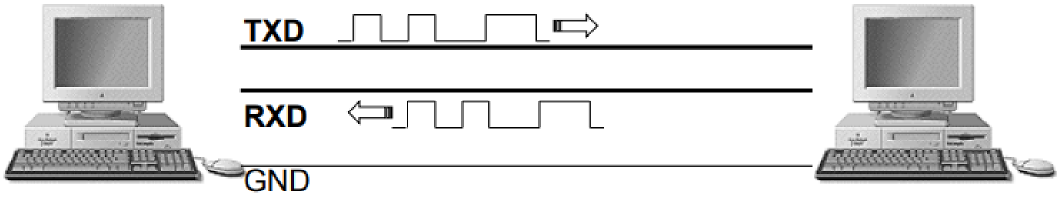
Q.No	Question
1.	**How SPI is differed from other serial interfaces ?(May/June 2016)** BTL1 • The master sends a bit on the MOSI line which the slave reads from the same line. • The slave sends a bit on MISO line and the master reads it from that same line.
2.	**What is the need of Device drivers?(May/June 2016, Nov/Dec 2016)** BTL1 • It is a software interface to hardware device that handle request from the kernel regarding the use of the particular I/O devices • There is a well defined interface for the kernel to make these request, because of this adding new device is easy.
3.	**Mention the features of CAN.(Nov/Dec 2016, April/May 2017)** BTL1 • When common mode signals, usually noise appear on the bus they are subtracted OOF and this makes the CAN bus resistance to noise. • In CAN and most other modern serial protocols differential signaling with NRZ coding ids used to reduce the effect of noise.
4.	**Mention some serial bus communication protocols.(April/May 2017)** BTL1 • I^2 C Bus • CAN Bus • Universal serial Bus
5.	**Define bus.** BTL1 Buses: The exchange of information. Information is transferred between units of the microcomputer by collections of conductors

	called buses. There will be one conductor for each bit of information to be passed, e.g., 161ines for a 16 bit address bus. There will be address, control, and data buses.
6.	**What are the classifications of 110 devices? (APR/MAY 2019** BTL1 • Synchronous serial input and output • Asynchronous serial UART input and output • Parallel one bit input and output • .Parallel port input and output
7.	**Give the steps for accomplishing input output data transfer .** BTL1 -Accomplishing input/output data transfer There are three main methods used to perform/control input/output data transfers. They are, • Software programming (scanning or polling) • interrupt controlled • Direct memory access (DMA)
8.	**Give the limitations of polling technique.** BTL1 The polling technique, however, has limitations. It is wasteful of the processors time, as it needlessly checks the status of all devices all the time. It is inherently slow, as it checks the status of all I/O devices before it comes back to check any given one again. When fast devices are connected to a system, polling may simply not be fast enough to satisfy the minimum service requirements. Priority of the device is determined.
9.	**What do you meant by bus arbitration?** BTL1 Bus Arbitration Most processors use special control lines for bus arbitration, ie, controlling the use of the address and data bus, • An input which the DMAC uses to request the bus • An output(s) indicating the bus status • An output indicating acceptance of the DMAC\'s bus request
10.	**What are the two characteristics of synchronous communication?** BTL1 Bytes/frames maintain constant phase difference and should not be sent at random time intervals. No handshaking signals are provided during the communication. Clock pulse is required to transmit a byte or frame serially. Clock rate information is transmitted by the transmitter.
11.	**What do you mean by asynchronous communication?** BTL1 The most basic way of sharing data is by copying the data in question to each server. This will only work if the data is changed infrequently and always by someone with administrative access to all the servers in the cluster.
12.	**What are the characteristics of asynchronous communication? (APR/MAY 2019(APR/MAY 2019** BTL1 • Variable bit rate - need not maintain constant phase difference • Handshaking method is used • Transmitter need not transmit clock information along with data bit stream
13.	**What are the three ways of communication for a device?** BTL1 • Separate clock pulse along with data bits • Data bits modulated with clock information • Embedded clock information with data bits before transmitting
14.	**What are the features of SPI?(Nov/Dec 2016)** BTL1 • SPI has programmable clock rates

	• Full-duplex mode • Crystal clock frequency is 8MHz • Open drain or totem pole output from master to slave
15.	**Define software timer.** BTL1 A software timer is software that executes the increase/decrease count value on an interrupt from timer or RTC. Software timer is used as virtual timing device.
16.	**What are the forms of timer?** BTL1 • Hardware interrupt timer • Software timer • User software controlled hardware timer • RTOS controlled hardware timer • UP/DOWN count action timer • One-shot timer (No reload after overflow and finished states)
17.	**Define RTC.** BTL1 RTC Stands for Real Time Systems. Once the system starts, do not stop/reset and the count value cannot be reloaded.
18.	**What are the features of the USB protocol?** BTL1 A device can be attached, configured and used, reset, reconfigured and used, detached and reattached, share the bandwidth with other devices.
19.	**What are the four types of data transfer used in USB?** BTL1 • Controlled transfer • Bulk transfer • Interrupt driven data transfer • Iso-synchronous transfer
20.	**What are the function of PCI and PCI/X buses?** BTL1 • Used for most PC based interfacing. • Provides superior throughput than EISA • Platform-independent • Clock rate is nearest to sub-multiples of system clock
21.	**Mention any two advantage of bus standard protocols.** BTL2 • GMII (Gigabit Ethernet MAC Interchange Interface) • XGMI (10 Gigabit Ethernet MAC Interchange Interface)
22.	**What do you meant by high speed device interfaces?** BTL1 Fail-over clustering would not be practical without some way for the redundant servers to access remote storage devices without taking a large performance hit, as would occur if these devices were simply living on the local network. Two common solutions to this problem are double-ended SCSI and fibre-channel.
23.	**Mention some I/O standard interfaces.** BTL2 HSTL - High Speed Transceiver Logic (Used in high speed operations) SSTL - Stub Series Terminated Logic (Used when the buses are needed to isolate from the large no. of stubs)
24.	**Give some examples for serial input I/O devices.** BTL1 Audio input, video input, dial tone, transceiver input, scanner, serial IO bus input, etc.,
Part*B	

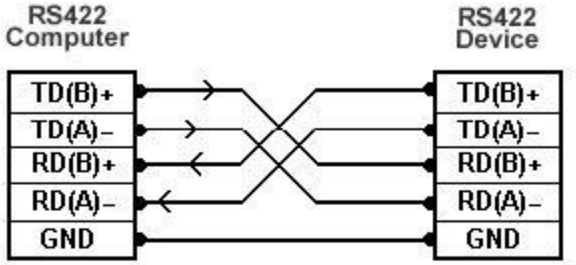
Q.No	Question
1.	**Describe one type of serial communication bus with its communication protocol. (APR/MAY 2019** BTL2 (13M) **Answer: Page No.2.7 – Dr.G. Ramprabu** SERIAL BUSCOMMUNICATION PROTOCOLS– USB Three types • Simplex connection – data flow in only one direction – computer to printer • Half duplex connection – data flow in one direction or other but not in same time – walkie talkie • Full duplex connection – data travel – both direction simultaneously – mobile phone • Transmission rate - unit – bits per second bps • Synchronous bus – clocked -very fast – interface logic small • Asynchronous bus – not clocked – lengthened • USB Host Applications Connecting • flash memory cards, • pen-like memory devices, • digital camera, **-----(6M)** • printer, • mouse-device, • Pocket PC, • video games, Universal Serial Bus (USB) • Serial transmission and reception between host and serial devices • The data transfer - four types: (a)Controlled data transfer, (b) Bulk data transfer, (c) Interrupt driven data transfer, (d) Iso-synchronous transfer • A bus between the host system and interconnected number of peripheral devices-----**(7M)**
2.	**Explain the RS 232, RS 422 and RS 485 protocol. (May/June 2016, April/May 2017)** (13M) **Answer: Page No. 2.8 – Dr.G. Ramprabu**  • Signals between +25V and -25V; some say ±15V usually +12V to -12V





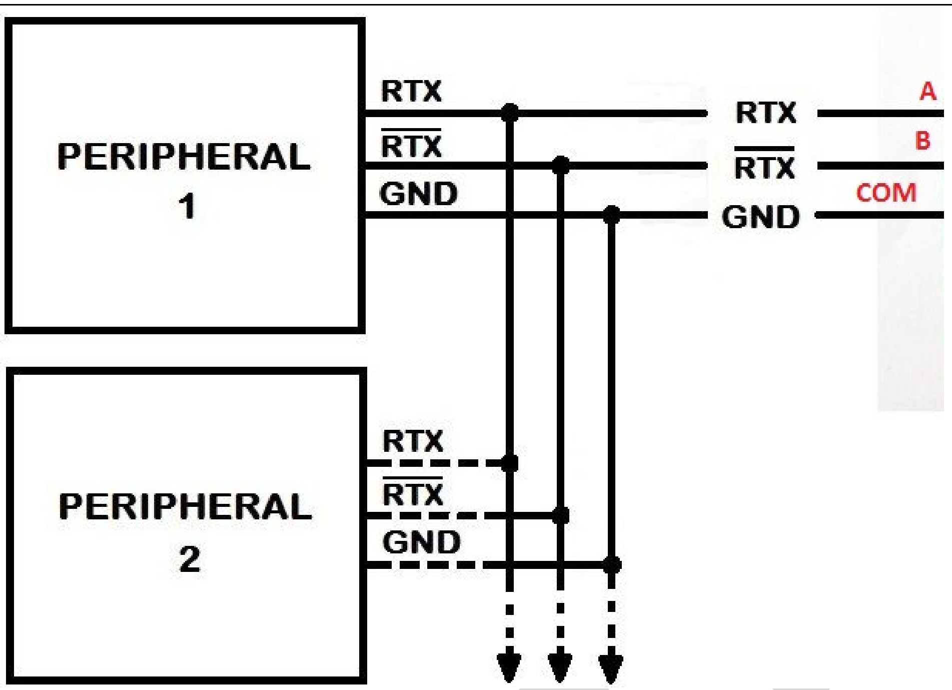
- 1 start bit - 8 data bits -1 stop bit (optional 1 parity bit)
- serial connection historically found on IBM-compatible PCs
- connecting a mouse, printer, or modem, as well as industrial instrumentation
- 1Driver-1 Receiver-----(6M)

RS-422



- serial connection historically used on Apple Macintosh computers
- uses a differential electrical signal, as opposed to unbalanced signals referenced to ground with the RS-232
- uses two lines each for transmit and receive signals which results in greater noise immunity
- better fit for industrial applications.
- 1Driver-10 Receivers-----(7M)

RS-485



- devices from 10 to 32 and defines the electrical characteristics necessary to ensure adequate signal voltages under maximum load
- enhanced multi-drop capability
- 32Drivers*- 32 Receivers

3. **Explain I/O Device ports and its characteristics. (APR/MAY 2019)** BTL2 (13M)

Answer: Page No. 2.2– Dr.G. Ramprabu

I/O Device ports

The largest, most complex subsystem – OS

Block transfer

- Disk, tape, CD, DVD
- Network
- Clocks
- Internal, external
- Graphics
- GUI, games

Multimedia

- Audio, video

Other

- Sensors, controllers

Special I/O instructions

- Opcode to stop, start, query, etc.
- Separate I/O address space
- Kernel mode only-----(6M)

Memory-mapped I/O control registers

- Each register has a physical memory address

- Writing to data register is output
- Reading from data register is input
- Writing to control register causes action
- Can be mapped to user-level virtual memory

-----(7M)

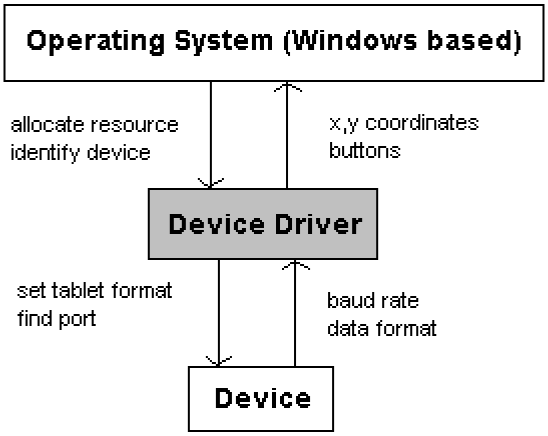
4. **What are the device drivers in embedded systems and explain its types.** BTL1 (13M)

Answer: Page No. 2.33 – Dr.G. Ramprabu

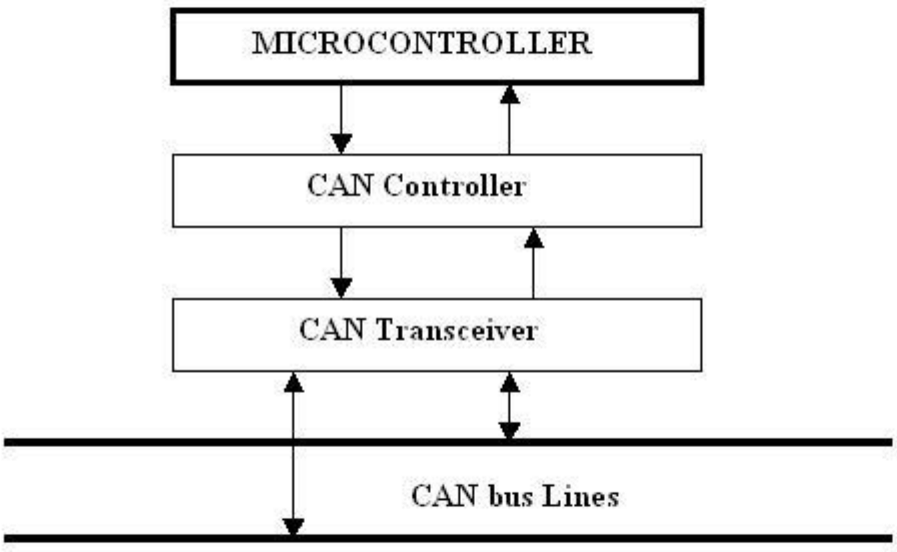
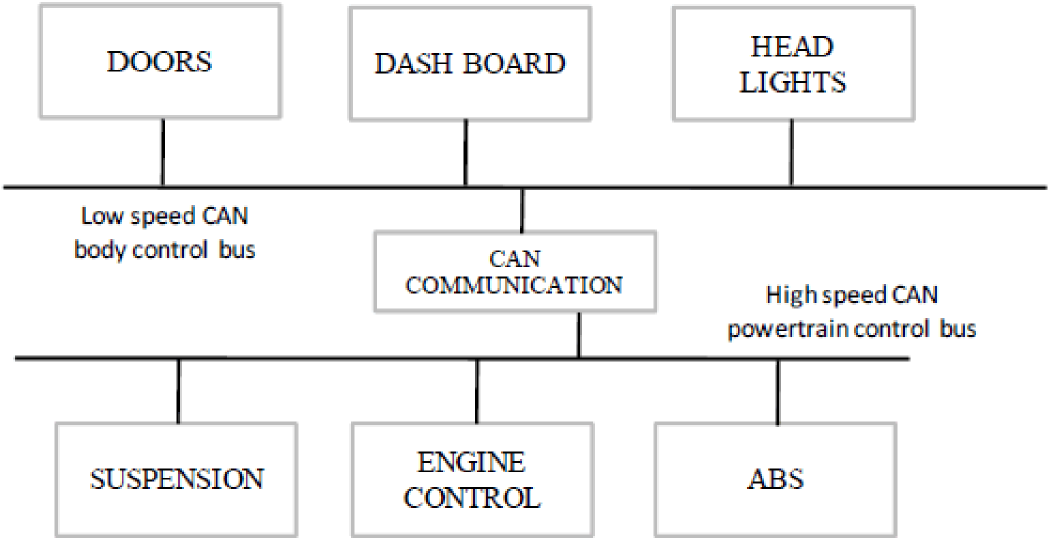
- Software interface to hardware device
- Well defined interface – kernel
- Adding new device – easy

Classification

- Block device drive – transfer data as blocks – disk drive – block sized buffer
- Character device drive – data as character – does not need buffer – line printer
- Network device drive – data transmission and reception – wifi devices
- A device driver has a set of routines (functions) - high-level language programmer.
- Does the interaction with the device hardware - sends control commands to the device - communicates data to the device.
- ISR relates to a device driver command. -----(6M)
- Programmer uses generic commands for device driver for using a device.
- Device drivers - Different in different operating system.
- Same device may have different code for the driver when system - using different operating system.
- Same device may have different code for the driver when system - using different operating system.
- Device driver can be considered software layer between an application program and the device-----(7M)



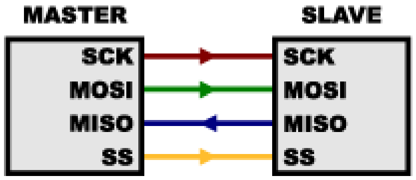
Part*C

Q.No	Question
1.	**Summarize short notes on CAN BUS. (May/June 2016)** BTL2 (15M) **Answer: Page No.2.17 – Dr.G. Ramprabu**  • Control Area Network example - a network of embedded systems in automobile • Developed by Bosch company – reduce the wiring inside the vehicle – 1984 • 1990 – very popular**-----(6M)** • gives the input and gets output between the physical and data link layers at the host node  • bus interface unit consisting of buffer and driver • Interconnecting networks Three standards:

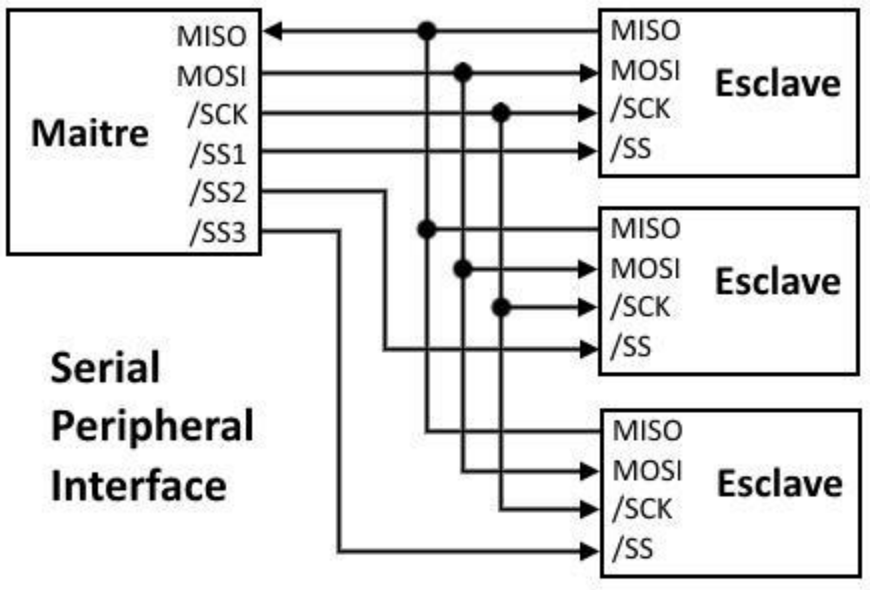
- low speed CAN – 125 Kbps -11 bit identifier – door lock, seat control, climate control,
- standard CAN 2.0A – 1 Mbps - 11 bit identifier
- Extended CAN 2.0B – 1 Mbps- 29 bit identifier
- Interconnecting buses is called bridges
- Reliable, low cost and efficient
- Message based protocol
- Four message format – data, remote, error and overland frames-----**(9M)**

2. **Explain the Serial Peripheral Interfacing SPI bus.(May/June 2016, Nov/Dec 2016)** BTL2 (15M)

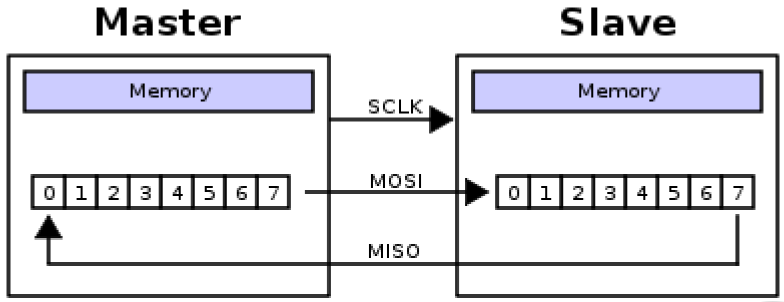
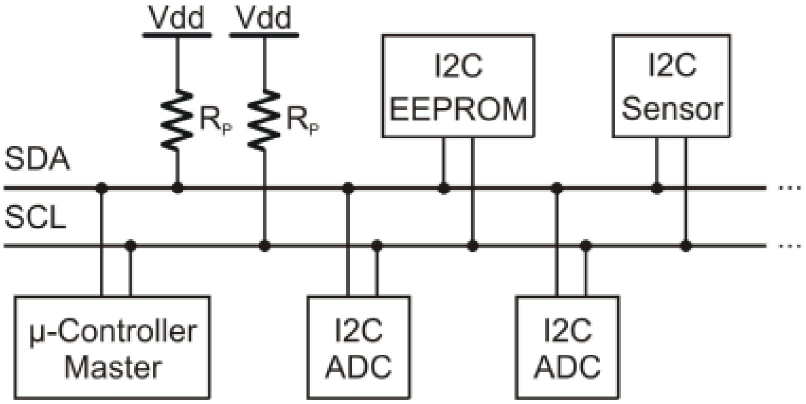
Answer: Page No. 2.24 – Dr.G. Ramprabu

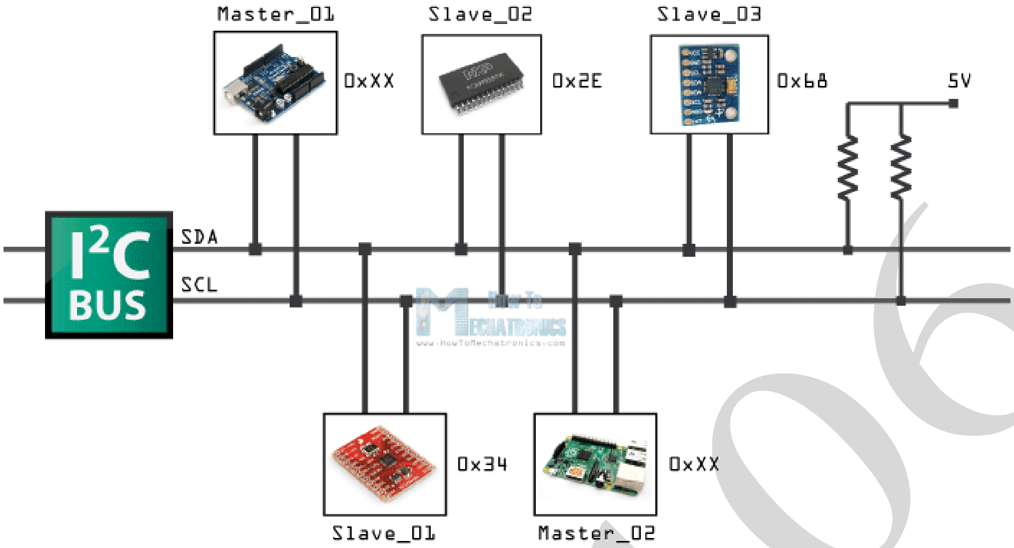


- Developed by Motorola
- Synchronous and full duplex
- Single master multi slave system
- Only one slave – enabled at a time
- Signals – MOSI , MISO,SCLK and SS
- MOSI – master out slave in
- MISO – master in slave out



- Large shift registers – shared between master and slave
- Clock – shared by two devices-----(6M)
- Ring buffer – master sends a byte to slave and slave send a byte to master

	• MOSI – slave reads the message. • MISO – master reads the message.  • Higher speed – no acknowledgement signal • Works best for single slave system-----(9M)
3.	**Explain in briefly about inter integrated circuit protocol.(May/June 2016, Nov/Dec 2016, April/May 2017)** BTL2 (15M) **Answer: Page No. 2.29 – Dr.G. Ramprabu**  • Developed by Philips – 1980 – TV application • I2C – I^2C • Widely used in embedded system • Synchronous, half duplex, serial protocol and byte oriented • Acknowledgement – to slave-----(6M)



- ROM read only – LCD
- Mater – MCU – micro controller Unit
- Slave – input – output devices
- SDA – serial data – each devices carry its unique address
- Slow – under 100 Kbps
- Fast – 400 Kbps
- High speed – 3.4 Mbps
- Very simple – not fast
- Include EPROM, thermal sensor and real time clock
- Easily – implemented protocol-----(9M)

UNIT III

Embedded Product Development Life Cycle-objectives, different phases of EDLC, Modelling of EDLC; issues in Hardware-software Co-design, Data Flow Graph, state machine model, Sequential Program Model, concurrent Model, object oriented Model.

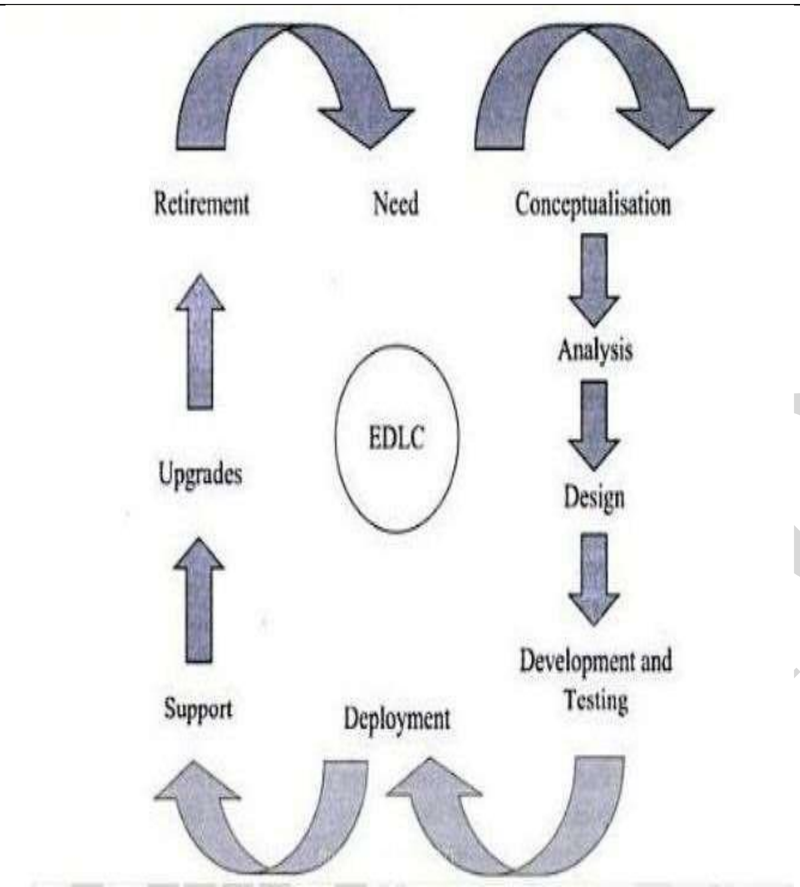
Part*A

SL No.	Questions
1.	**Mention different models used for the development of an embedded system.(May/June 2016)** BTL1 • Linear or Waterfall Model • Iterative/Incremental or Fountain Model • Prototyping/Evolutionary Model • Spiral Model
2.	**What are the processes involved in Co design ? (May/June 2016, Nov/Dec 2016)** BTL1 • Selecting the model

	• Selecting the architecture • Selecting the process • Partitioning system requirements into hardware and software.
3.	**What is state machine model?(Nov/Dec 2016, April/May 2017)** BTL1 The state machine model describes the system behavior with States, Events, Actions and Transitions. The state machine model is used for modeling reactive or event-driven embedded systems whose processing behavior are depend on the transitions.
4.	**List the different phases of EDLC.(April/May 2017)** BTL1 • Need • Conceptualization • Analysis • Design • Development and testing • Deployment • Support • Upgrades • Retirement/Disposal
5.	**What are the advantages of Assembly language? (APR/MAY 2019** BTL1 • It gives the precise control of the processor internal devices • Full use of processor specific features in its instruction sets and addressing modes. • The machine codes are compact, which requires only small memory. • Device drivers need only few assembly instructions.
6.	**What are advantages of high level languages?** BTL1 • Data type declaration • Type checking • Control structures • Probability of non-processor specific codes
7.	**Define In -line assembly** BTL1 Inserting an assembly code in between the processes of a system is said to be in-line assembly.
8.	**Mention the elements of C program.** BTL1 • Header files • Source files • Configuration files • Preprocessor directives • Functions: • Macro function • Main function • Interrupt service routines or device drivers • Others: • Data types • Data structures • Modifiers • Statements • Loops and pointers

9.	**What is the use of MACRO function?** BTL1 A macro function executes a named small collection of codes, with the values passed by the calling function through its arguments. It has constant saving and retrieving overheads.
10.	**What is the use of interrupt service routines or device drivers?** BTL1 It is used for the declaration of functions and datatypes, typedef and executes named set of codes. ISR must be small (short), reentrant or must have solution for shared data problem.
11.	**What are the datatypes available in C language?** BTL1 Char - 8 bit; byte - 8 bit; short - 16 bit; unsigned short - 16 bit; unsigned int - 32 bit; int - 32 bit; long double - 64 bit; float - 32 bit; double - 64
12.	**Mention the data structures available in C language.** BTL1 • Queue • Stack • Array (1-dimentional and multi-dimensional) • List • Tree • Binary-tree
13.	**Write the syntax for declaration of pointer and Null-pointer.** BTL2 Syntax for pointer: void *portAdata Syntax for Null-pointer: #define NULL (void*) 0x0000
14.	**Explain pass by values.** BTL2 • The values are copied into the arguments of the function. • Called programs does not change the values of the variables
15.	**Define queue.** BTL1 • A structure with a series of elements. • Uses FIFO mode. • It is used when an element is not directly accessed using pointer and index but only through FIFO. • Two pointers are used for insertion and deletion.
16.	**Define stack.** BTL1 • A structure with a series of elements which uses LIFO mode. • An element can be pushed only at the top and only one pointer is used for POP. • Used when an element is not accessible through pointer and index, but only through LIFO.
17.	**Define List.** BTL1 • Each element has a pointer to its next element. • Only the first element is identifiable and it is done using list-top pointer (header). • Other element has no direct access and is accessed through the first element.
18.	**What is Object oriented programming?** BTL1 An object-oriented programming language is used when there is a need for re-usability of defined objects or a set of objects that are common for many applications.
19.	**What are the advantages of OOPs?** BTL1 • Data encapsulation.

	• Data Abstraction. • Reusable software components. • Inheritance • Polymorphism
20.	**What are the characteristics of OOPs?** BTL1 • An identity - reference to a memory block • A state - data, field and attributes • A behavior - methods to manipulate the state of the object
21.	**Define Class.** BTL1 A class declaration defines a new type that links code and data. It is then used to declare objects of that class. Thus a class is an logical abstraction but an object has physical existence.
22.	**What is Multiple Inheritance?** BTL1 Inheritance is the process by which objects of one class acquire the properties of objects of another class. In OOP, the concept of inheritance provides the idea of reusability.
23.	**What is a Preprocessor Directive?** BTL1 A preprocessor directive starts with '#' sign. The following are the types of preprocessor directives: Preprocessor global variables Preprocessor constants
24.	**Mention the flags available for queue. (APR/MAY 2019**BTL1 • QerrrorFlag • HeaderFlag • TrailingFlag • cirQuFlag • PolyQuFlag
Part *B	
SL NO.	**QUESTIONS**
1.	**Illustrate with functional description about the different phases of Embedded Design Life Cycle Method. (May/June 2016, Nov/Dec 2016, April/May 2017)** BTL4 (13M) **Answer: Page No.3.7 – Dr.G. Ramprabu**



- Typical simple product contains five minimal phases namely:

'requirement analysis'. 'Design', 'development and test', 'deployment' and 'maintenance'.

Need

- articulated to initiate the Product Development Life.
- based on the need for the product, a 'Statement of Need' or 'Concept Proposal' is prepared. -----(6M)
- 'Concept Proposal' must be reviewed by the senior management and funding agency

Conceptualization

- the 'Product Concept Development Phase - begins immediately after a Concept Proposal -formally approved
- two types of activities, namely; ‘Planning Activity’ and ‘Analysis and Study Activity’.
- Cost Benefit Analysis – similar to loss and gain.
- Market choice based benefit measurement
- Target end users - Product Scope

Analysis

- starts immediately after the documents submitted during the ‘Conceptualization’
- the development of detailed user requirements.
- various activities performed during ‘Requirement analysis’.

Design

- 'Design phase' deals with the entire design of the product.
- design phase identifies the application environment

- creates an overall architecture for the product.
- the 'Preliminary Design Document (PDD) is sent for review to the end- user/client

Development and Testing

- 'Development Phase transforms the design into a realizable product.
- the installation and setting up of various development tools –performed.
- partitioned into embedded hardware development, embedded firmware development and product enclosure development.

Deployment

- the process of launching the first fully functional model.
- handing over the fully functional initial model to an end user/client.
- Product Installation.

Support

- the operations and maintenance of the product in a production environment.
- meets the requirements put forward by the end user/client - product mal-functioning or unexpected behavior or any operational error

Upgrades

- upgrade phase of product development deals with the development of new versions.
- subject to design modification to fix the major bugs reported
- embedded products, the upgrades may be for the product resident firmware.
- feature enhancements can also be performed easily.

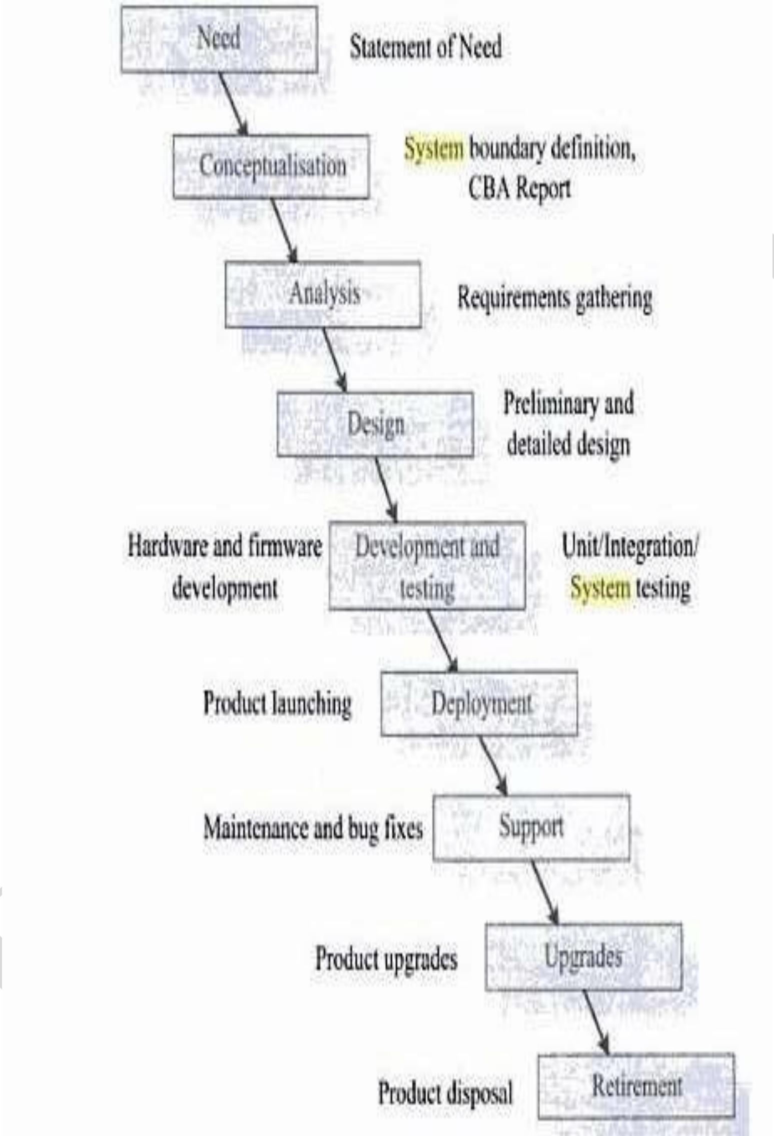
Retirement/Disposal

- technology you feel as the most advanced and best today may not be the same tomorrow.
- product cannot sustain in the market for a long time.
- the product manufacturer realizes that there is another powerful technology – old technology – disposal-----(7M)

2. **Mention the essential and objectives of EDLC. Discuss in detail about the different phases of EDLC. (APR/MAY 2019)**BTL1 (13M)

Answer: Page No. 3.2 – Dr.G. Ramprabu

- aim of any embedded product in a commercial production setup - Return on Investment (R01).
- A product is said to be profitable only - turnover from the selling - product - more than that of the overall investment expenditure
- Ensure that high quality products are delivered to end user.
- Risk minimization and defect prevention in product development through project management. -----(6M)
- The budget allocation might have done after studying the market trends.
- project management -essential in product development.
- 'Project management is essential for predictability, co-ordination and risk minimization'.
- estimate on the duration of the development and deployment activity should be given to the end user/client..
- Resource allocation is critical - having a direct impact on investment.

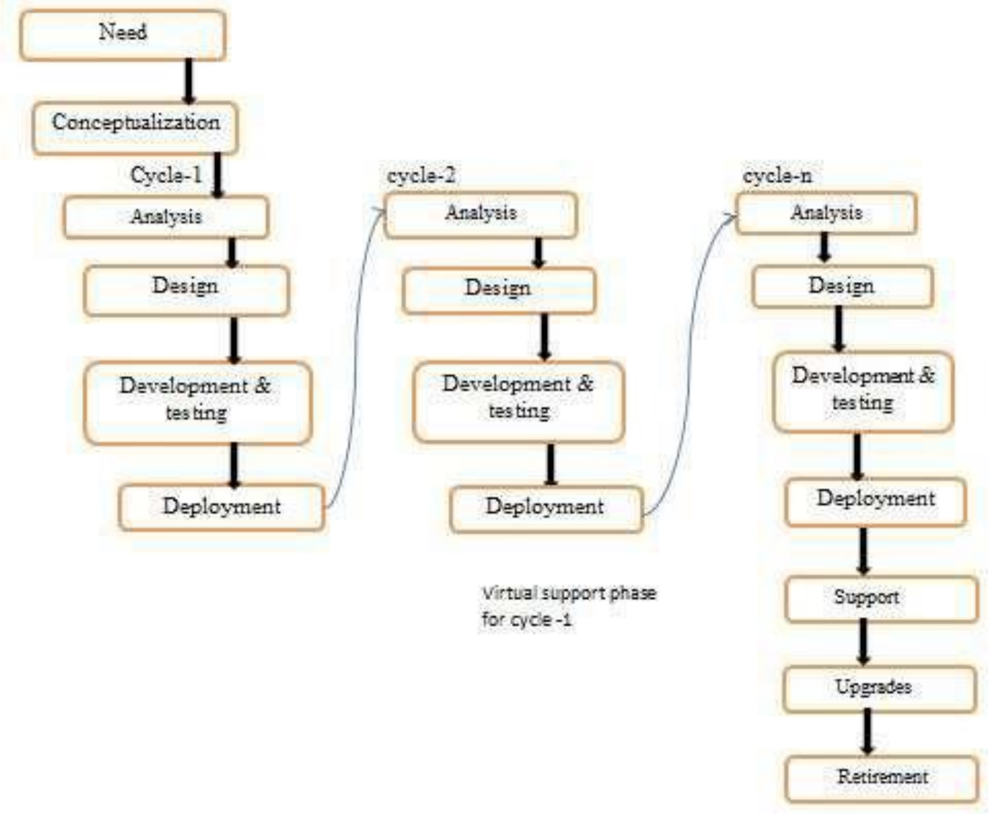
	• project management also covers activities like task allocation, scheduling, monitoring and project tracking. • Productivity - measure of efficiency as well as Return on Investment (ROT). • productivity measurement is based on total manpower efficiency. • using resources with specific skill sets which matches the exact requirement. • Recruiting people with desired skill sets for the current product development. -----(7M)
3.	**Generalize the Linear or Waterfall model in embedded design.** BTL2 (13 M) **Answer: Page No.3.24 – Dr.G. Ramprabu** Linear or Waterfall model  • adopted in most of the older systems - executed in sequence-----(6M) • linear model establishes a formal analysis and design methodology • the flow is unidirectional with output of one phase serving as the input to the next phase. • well documented, giving an insight into what should be done in the next phase.

- feedback of each phase is available locally and only after they are executed.
- fixes for the bugs are postponed till the support phase.
- easy project management and good control over cost and schedule.
- the risk analysis is performed only once throughout the development. -----(7M)

4.

Generalize the Iterative/Incremental or Fountain model in embedded design. BTL1 (13M)
Answer: Page No. 3.26 – Dr.G. Ramprabu

Iterative/Incremental or Fountain model

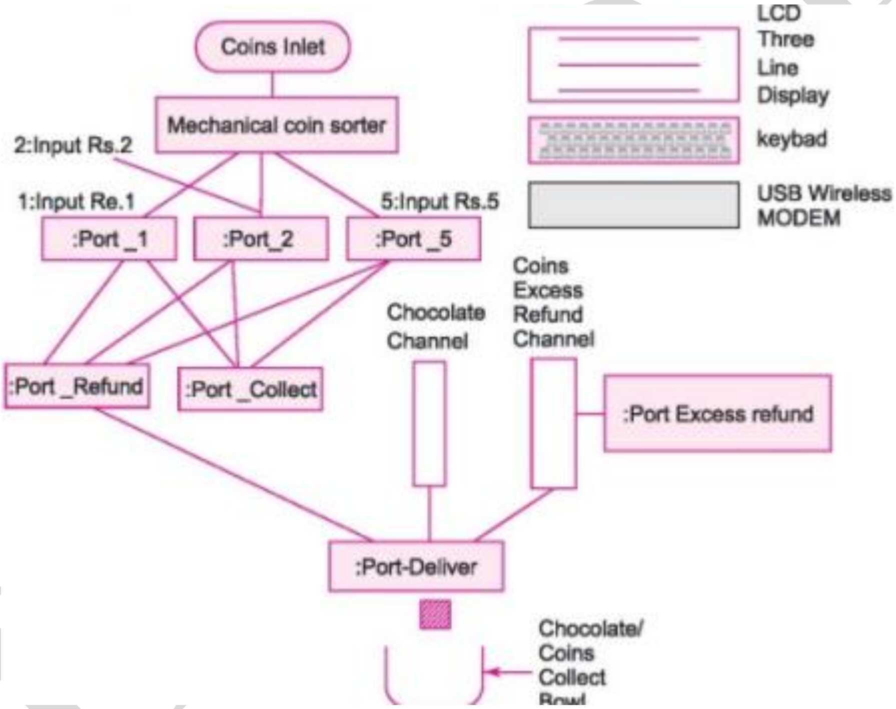


- Iterative model can be viewed as a cascaded series of linear models.
- the requirements are known at the beginning and they divided into different groups.
- each cycle is interconnected in a similar fashion of a fountain. -----(6M)
- very good development cycle feedback at each function/feature implementation.
- data can be used as a reference for similar product development in future.
- iterative model provides a working product model with at least minimum features at the first cycle itself.
- each new deployment at the end of each development cycle.
- model - best suited for product developments where the continued funding for each cycle -not assured. -----(7M)

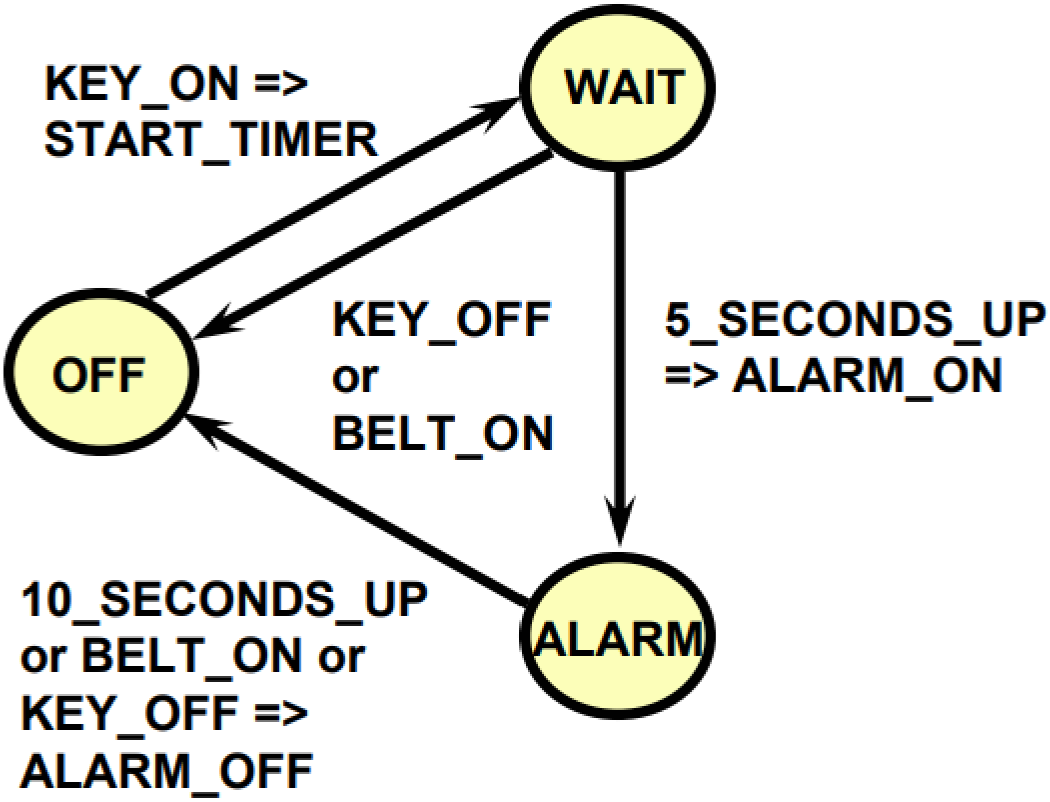
6.

Describe object oriented model. BTL1 (13M)
Answer: Page No. 3.48 – Dr.G. Ramprabu

- Object oriented model – Object based model for system.

	- Complex software – to simple defined process called object - Object oriented model – re usability – maintainability – productivity - Entity – representing or modeling a system - Character – unique behavior - Abstract description – blue print of object - Class – state of an object - Member variable, member function – private, protected and public - Public – access outside the class - Private – access only inside the class - Protected – access from derived class
Part*C	
SL NO	**QUESTIONS**
1.	**With a suitable example, explain about the State Machine Model of Chocolate Vending Machine (ACVM).(May/June 2016, Nov/Dec 2016)** BTL6 (15M) **Answer: Notes**  - state transition functions - changes a state to its next state. - States - Idle, Running, Blocked, Finished - A transition may be also be interrupt flag driven**-----(6M)** - state can receive multiple tokens - inputs, messages, flags interrupts or semaphores - coin inlet collects – coin from customer - Mechanical coin sorter- sorts the coin according customer requirement. **-----(9M)**
2.	**Explain the State Machine Model for seat belt warning system .** BTL2 **(15M)** **Answer: Page No. 3.40 – Dr.G. Ramprabu**

- State machine model – state, event, Action and transition
- State – current situation (Alarm OFF, Alarm ON and waiting)
- Event – an input (Ignition key ON, Ignition key OFF, Time expire)
- Action – Stimuli for state transition (ready for ON and OFF)
- Transition – one state to other (ON and OFF)
- Vehicle ignition turned ON – seat belt ON with in 10 S – if not Alarm ON
- Alarm OFF – seat belt ON or Time Expire-----**(6M)**



3. **Explain the Sequential Model Program for seat belt warning system.(April/May 2017)** BTL1 (15M)

Answer: Page No. 3.43 – Dr.G. Ramprabu

- Vehicle ignition turned ON – seat belt ON with in 10 S – if not Alarm ON
- Alarm OFF – seat belt ON or Time Expire
- If the driver - turns on the key - does not fasten the seat belt within 5 seconds
- then sound the alarm - for 5 seconds - until the driver fastens the seat belt - until the driver turns off the key-----(6M)
- Program

```
# define ON 1
# define OFF 0
# define YES 1
# define NO 0
Void seat_belt_warn()
```

```
{
Wait_10 sec();
If(check_ignition_key()== ON)
{
If(check_seat_belt()==OFF)
{
Set_timer(5);
Start_Alarm();
While((check_seat_belt()==OFF) && (check_ignition_key()== OFF) && (timer_expire()==ON));
Stop_alaram();
}
}
}-----(7M)
```

UNIT IV

Introduction to basic concepts of RTOS- Task, process & threads, interrupt routines in RTOS, Multiprocessing and Multitasking, Preemptive and non-preemptive scheduling, Task communication shared memory, message passing-, Inter process Communication – synchronization between processes-semaphores, Mailbox, pipes, priority inversion, priority inheritance, comparison of Real time Operating systems: VxWorks, чC/OS-II, RT Linux

Part*A

SL NO.	Questions
1.	**Compare preemptive and non preemptive scheduling.(May/June 2016, Nov/Dec 2016)** BTL2 **Non-preemptive Scheduling** is one which can be applied in the circumstances when a process terminates, or a process switches from running to waiting state. In **Non-Preemptive Scheduling**, once the resources (CPU) is allocated to a process, the process holds the CPU till it gets terminated or it reaches a waiting state.
2.	**Define thread and process.(May/June 2016)** BTL2 Thread : A thread is a sequential flow of control with a process. A thread is the preemptive that can execute code, Thread is known as light weight process Process :A process is a program, or a part of it, in execution. Process is also known as an instance of a program in execution.
3.	**What are the functions of RTOS? (Nov/Dec 2016, April/May 2017)** BTL1 • Task/Process management • Task/process scheduling • Task/process synchronization • Error/Exception handling • Memory management • Interrupt handling • Time management
4.	**Define Multi threading.(April/May 2017)** BTL2 Multithreading is a type of execution model that allow multiple threads to exist with in

	the context of process such that they execute independently but share their process resourse.
5.	**What is sophisticated multitasking embedded system?** BTL1 Multitasking provides the fundamental mechanism for an application to control and react to multiple, discrete real-world events. Multitasking creates the appearance of many threads of execution running concurrently when, in fact, the kernel interleaves their execution on the basis of a scheduling algorithm.
6.	**Explain multi task and their functions in embedded system.** BTL2 This system implements cooperative and time-sliced multitasking, provides resource locking and mailbox services, implements an efficient paged memory manager, traps and reports errors, handles interrupts, and auto starts your application at system startup. By following some simple coding practices as shown in the documented coding examples, you can take advantage of these sophisticated features without having to worry about the implementation details.

7.	**Give the function for sending a queue.** BTL1
	Each message is made up of two parts, which are defined in the template structure struct msgbuf, as defined in sys/msg.h:
	struct msgbuf{
	long mtype;
	char mtest [1]
	};
	The field mtype is used later when retrieving messages from the queue, and can be set to any positive number. mtext is the data this will be added to the queue

8.	**Give the needs for memory management. (APR/MAY 2019**BTL1 Each new model of computer seems to come with more main memory than the last, but, since the memory requirements of the software rise just as fast, memory is always a precious commodity, hence the need for memory management . Memory is allocated to a process when needed Memory is deallocated when no longer in use Swapping allows the total memory used by all the running processes to exceed main memory Virtual memory makes it possible to run a single program that uses more memory than the main memory (normally RAM) available on the system. Virtual memory is normally divided into pages. Programs refer to parts of memory using addresses. In a virtual memory system, these are virtual addresses The virtual address is mapped onto physical addresses by a memory management unit (MMU)
9.	**Name some application for the VxWorks RTOS.** BTL1 • Automobiles • Avionics • Consumer electronics • Medical devices • Military • Aerospace • Networking
10.	**What are the various features of VxWorks?** BTL1 • High performance

	• Host and target based development approach • Supports advanced processor architecture • Hard real-time applications
11.	**What are the basic functions of VxWorks?** BTL1 • System level functions • Task service functions • Task control functions • IPCs • Network and IO functions
12.	**What are the task service functions supported by VxWorks?** BTL1 Task creation and activation distinct states. Functions for the task creating, running, waiting, suspending. and resuming, task pending cum suspending with and without timeouts.
13.	**What are the different types of semaphores in vxworks? Which is the fastest?** BTL4 VxWorks supports three types of semaphores. Binary, mutual exclusion, and counting semaphores. Binary is the fastest semaphore.
14.	**What is signal servicing function?** BTL1 VxWorks supports a software signal facility. Signals asynchronously alter the control flow of a task. Any task or ISR can raise a signal for a particular task. The task being signaled immediately suspends its current thread of execution and executes the task specified signal handler routine the next time it is scheduled to run. The signal handler executes in the receiving task's context and makes use of that task's stack. The signal handler is invoked even if the task is blocked.
15.	**Define Micro C/OSII**. BTL1 Micro C/OSII (commonly termed uC/OSII or mC/OS-Il),i s a low-cost priorty-based preemptive real time multitasking operating system kemel for microprocessors, mainly in the C programming language. It is mainly intended for use in embedded systems.
16.	**What are the task states in MICRO C/OS-II?** BTL1 Task states: mC/OS-[is a multitasking operating system. Each task is an infinite loop and can be in any one of the following 5 states: • Dormant • Ready • Running • Waiting • ISR
17.	**What are the 2 source files in Micro C/OS-II?** BTL1 • Preprocessor dependent source file • Preprocessor independent source file
18.	**What are the basic functions of MUCOS?** BTL1 System level: OS initiate, start, system timer set, ISR enter and exit • Task service function: create, run, suspend, resume • Task delay • Memory allocation and partitioning • IPCs, mailbox and queues
19.	**Define software or soft modem**. BTL2

	A software modem or a soft modem is a modem with minimal hardware capacities, designed to use a host computer's resources to perform most of the task by a dedicated hardware in a traditional modem.
20.	**Give the steps to destroy a message queue.** BTL1 There are two ways: • Use the Unix command ipcs to get a list of defined message queues, then use the command ipcrm to delete the queue. • Write a program to do it for you
21.	**Define Alarm Clock.** BTL1 An alarm clock is a clock that is designed to make a sound or some other signal at a specific time. Microprocessors are used to read the clock's buttons and update the time displays.
22.	**Define Audio players.** BTL1 Audio players are usually referred as MP3 players after the well-known audio data format. The earliest portable MP3 players were based on compact disc mechanisms. Modern MP3 use either flash memory or disc drives to store music.
23.	**Define Video Accelerator.** BTL1 A video accelerator significantly speeds up the updating of the images on a screen, which also frees the CPU to take care of other tasks.
Part*B	
SL NO.	**Questions**
1.	**Explain preemptive and non preemptive scheduling in RTOS .** BTL2 (13M) **Answer: Page No.4.20 – Dr.G. Ramprabu** Preemptive scheduling • one which can be applied in the circumstances when a process terminates • a process switches from running to waiting state • Basic -The resources are allocated to a process for a limited time. • Interrupt - Process can be interrupted in between • Starvation - If a high priority process frequently arrives in the ready queue, low priority process may starve. -----(6M) • Overhead - Preemptive scheduling has overheads of scheduling the processes • Flexibility - Preemptive scheduling - flexible. • Cost - Preemptive scheduling - cost associated Non Preemptive scheduling • once the resources (CPU) - allocated to a process • the process holds the CPU till it gets terminated or it reaches a waiting state. • Basics -Once resources are allocated to a process, the process holds it till it completes its burst time or switches to waiting state. • Interrupt - Process can not be interrupted till it terminates or switches to waiting state. • Starvation - If a process with long burst time is running CPU, then another process with

	less CPU burst time may starve. • Overhead - Non-preemptive scheduling does not have overheads. • Flexibility - Non-preemptive scheduling is rigid. • Cost - Non-preemptive scheduling is not cost associative. -----(7M)
2.	**Explain in detail about Inter Process communication and context switching .(Nov/Dec 2016)** BTL2 (13M) **Answer: Page No. 4.36 – Dr.G. Ramprabu** Inter processor communication • used to generate information about certain sets of computations finishing on one processor • let the other processors waiting for finishing the computations take note of the information • need to send through the kernel an output data -for processing • Global variables problems – shared data and no encapsulation of the data • IPC - scheduler, task or ISR • generates an output so that it lets another process take note • generate message from the certain sets of computations finishing on one task • let the other tasks take note of signal or get the message-----(6M) context switching • Context switching means saving the context of interrupted routine - task and retrieving • loading the new context • The multitasking and multiple ISRs execute even though there is only one processor • first saving the one program context and retrieving another program context • Before executing new instructions of the new function, the current program's program counter – saved • Also status word, registers, and other program-contexts – saved - needed by the newly called function. • Getting an address - loading that address into the program counter - executing the called function's instructions • Program Counter- a part of the context of presently running program • A context of a program must include program counter as well as the program status word, stack pointer • A register set or memory block can hold context information-----(7M)
3.	**Explain the terminologies semaphores, Mail box, pipes and shared memory in RTOS.(May/June 2016)** BTL2 (13M) **Answer: Page No. 4.38, 4.29 – Dr.G. Ramprabu** Semaphore • A semaphore is a kernel object that one or more tasks can acquire - synchronization or mutual exclusion. • Mutual exclusion - a provision by which only one task at a time can access a shared resource. • semaphore as a key - task can make a request for the key - available, your task can check

	• Multiple semaphores can be used if desired - multiple tasks that are waiting • either the oldest task on the queue or the highest priority task is given the semaphore • Semaphores - global resources – task sync-----(6M) Mail Box • provide the mailbox and queue both IPC functions • mailbox - not provided by an OS, then the OS employs queue for the same purpose • mail box - an IPC through a message-block at an OS that can be used only by a single destined task. • include a header to identify the message-type • Deleting means message-pointer pointing to Null Pipes • Pipe - a device used for the inter process communication • has the functions create, connect and delete - open, write, read, close • a device for inserting (writing) and deleting (reading) • fwrite with a file name to write into a named file • fread with a file name to read into a named file • limited and have a variable number of bytes per message between the initial and final pointers. Shared memory • A shared memory - an extra piece of memory that is attached to some address spaces for their owners to use • all of the processes share the same memory segment • feature supported by UNIX System V, including Linux, SunOS and Solaris. • Server - One process must explicitly ask for an area, using a key, to be shared by other processes. • Client - the shared area can access-----(7M)
4.	**Explain how the interrupt is handled by RTOS and illustrate the features of RT Linux RTOS.** BTL2 **(13M)** **Answer: Page No. 4.53 – Dr.G. Ramprabu** • Time sharing software: switch between different tasks fast enough to create the illusion that all are going forwarded • Realtime software: switch between different tasks in time to meet deadline • Hard real time : Predictable performance at each moment in time: not as an average. • Low latency response to events. -----(6M) • Precise scheduling of periodic tasks. • Soft real time : Good average case performance • Low deviation from average case performance • Traditional problems with soft real time - The chips are usually placed on the solder dots • The machine tool generally stops the cut as specific • The power almost always shuts off before the turbine explode • The e cell-phone connect won't drop your Internet handset during a handoff unless there is heavy traffic -----(7M)
Part*C	

SL NO.	Questions
1.	**Explain how the interrupt routines are handled by RTOS and illustrated the features of VxWorks.(May/June 2016)** BTL2 (15M) **Answer: Page No. 4.41 – Dr.G. Ramprabu** • High -performance, Unix performance - Unix -like, multitasking Environment scalable and scalable and hierarchical RTOS • Host and target based development approach • Device Software Optimization - a new methodology that enables development and running of device • VxWorks 6.x processor abstraction layer - enables application design for new versions later-----**(6M)** • Supports advanced processor architectures ─ ARM, ColdFire, MIPS, Intel, SuperH • Supports kernel mode execution of Supports kernel mode execution of tasks • Provides for the preemption points at kernel - as well as round robin scheduling • Schedules the ISRs separately and has special functions for interrupt handling • Watchdog timers - Virtual I/O devices including the pipes and sockets • Virtual Memory Management functions • Power management functions - the ability to control power consumption • Automatic detection and reporting of common memory and other errors • Interconnect functions that support large number of protocols • System Level – OS initiate, start, system timer clock rate set, ISR enter and exit, enable and disable • Task Service Functions – initiate, resume, activate, run, suspend. **-----(9M)**
2.	**Explain how the interrupt is handled by RTOS and illustrate the features of µC/OS-II RTOS.(Nov/Dec 2016)** BTL2 (15M) **Answer: Page No. 4.48 – Dr.G. Ramprabu** • Preemptive RTOS • Different Platforms support • Multitasking • Portable as ROM image-----(6M) • Scalable - only needed OS functions become part of the application codes • software component for safety critical systems • Applications - Automotive, avionics, consumer electronics, medical devices, military, aerospace, networking, and systems-on-a-chip. • OSTaskCreate ( ) ─ a MUCOS function that creates a task • OS_NO_ERR─ a MUCOS macro that returns true in case no error is reported • OS_MAX_TASKS ─ user definable constant for specifying maximum number of tasks • System Level – OS initiate, start, system timer set, ISR enter and exit • Task Service Functions – create, run, suspend, resume • IPCs – Semaphore, Queue and Mailbox • Same Semaphore function usable as event flag-

	----(9M)
3.	**Explain the terms Priority inversion and priority Inheritance.** BTL2 (15M) **Answer: Page No. 4.39– Dr.G. Ramprabu** Priority inversion • Priorities of tasks be in an order such that task I highest priority • task J a lower, and task K the lowest priority • Only tasks I and K share the data and J does not share data with K • let tasks I and K alone share a semaphore s_{ik} and not J-----(6M) • latency becomes too high and may exceed the deadline if all tasks are blocked • small only if the time taken by the tasks that share the resource • an instant t0, suppose task K takes sik , it does not block task J - blocks only the task I. • happens because only tasks I and K share the data and J does not Priority Inheritance • a method for eliminating unbounded priority inversion • the priority inheritance protocol is that when a job blocks one or more high-priority jobs • executing its critical section and releasing its locks • the process returns to its original priority level • First Come First serve – method • Job 1 at 2 m – job 2 at 3 m • It will take job 1 first-----(9M)

Unit V

Case Study of Washing Machine- Automotive Application- Smart card System Application,.

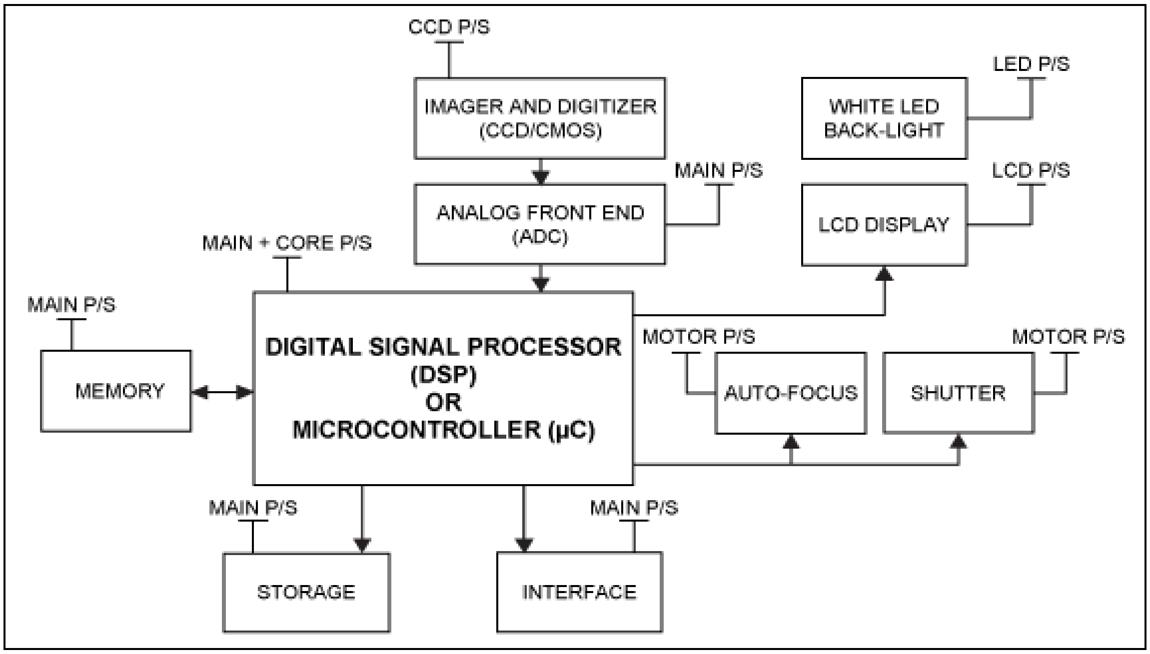
Q.No	Questions
1.	**Define Alarm Clock. (APR/MAY 2019** BTL2 An alarm clock is a clock that is designed to make a sound or some other signal at a specific time. Microprocessors are used to read the clock's buttons and update the time displays.
2.	**Define Audio players**. BTL2 Audio players are usually referred as MP3 players after the well-known audio data format. The earliest portable MP3 players were based on compact disc mechanisms. Modern MP3 use either flash memory or disc drives to store music.
3.	**Define Video Accelerator.** BTL2 A video accelerator significantly speeds up the updating of the images on a screen, which also frees the CPU to take care of other tasks.
4.	**Define software or soft modem.** BTL2 A software modem or a soft modem is a modem with minimal hardware capacities,

	designed to use a host computer's resources to perform most of the task by a dedicated hardware in a traditional modem.
5.	**What are the goals of design process? (Apr/May 2011)** BTL1 A design process has several important goals beyond function, performance, and power. They are time to market, design cost and quality
6.	**What is prototype?** BTL1 Prototype is the model of the system being designed. Prototypes are a very useful tool when dealing with end users rather than simply describe the system to them in road, technical terms, a prototype can let them see, hear, and touch at least some of the important aspects of the system
7.	**What is design technology?** BTL1 Design technology involves the manner in which we convert our concept of desired system functionality into an implementation. Design methodologies are used in taking the decisions at the time of designing the large systems with multiple design team members.
8.	**List some application of embedded system.(May/June 2016, Nov/Dec 2016, April/May 2017)** BTL1 • Washing machine • Digital camera • Automotive • Robotics • Smart card system
9.	**What are the events involved in smart card application? .(May/June 2016,Nov/Dec 2016)** BTL1 • Start up event • Battery monitoring and charge controlling event • Card read and write event • Communication event • Keyboard scanning event • LCD update event • Watch dog timer update event
10.	**Define spin phase. (APR/MAY 2019**BTL2 In the second phase of washing , water is pumped out from the tub and the inner tub uses centrifugal force to wring out more water from the cloth by spinning at several hundred rotations Per minute. This is called spin phase
11.	**Define engine control unit.** BTL2 It control the operating parameters, to make sure that the engine gets proper inputs. Thus they help protect the engine against damage. It is the brain of the engine.
12.	**What are the input parameters are used in engine control uni**t? BTL1 • Vehicle speed • Vehicle acceleration or deacceleration • Temperature • Air pressure • Throttle position center
13.	**What are the constructional parts of washing machine?** BTL1 • Inner tub

	• Outer tub • Water inlet pipe • Level sensor • Temperature sensor • Water outlet • Keypad - LCD • Control panel interface
14.	**Define testing.** BTL2 Testing is the process of make sure the program module will work properly. Testing can be performed in different kind of ways relayed with the application
15.	**What is high speed electronic unit?** BTL1 It is having fast response, Like fuel injection system, anti clock break system, engine control, electronic throttle, steering control, transmission control and central control unit
16.	**What is low speed electronic unit?** BTL1 It is deployed in applications not critical. They are low cost microprocessor or micro controllers and digital signal processors , Audio controllers, driver door locks, door glasses control etc
17.	**Define controller area network(CAN).** BTL1 The CAN bus was originally proposed by Robert Bosch, pioneer in automotive embedded solution providers. It supports medium speed and high speed data transfer. CAN is an event driven protocol interface with support for error handling in data transmission. It generally employed is safety system like air bag control, engine control and antilock break system (ABS)
18.	**Define Local Interconnect Network(LIN).** BTL2 Lin bus is a single master multiple slave communication interface. LIN is a low speed, single wire communication interface with support for data rates up to 20 Kbps and is used for sensor/actuator interfacing. LIN bus follows the master communication triggering technique to eliminate the possible bus arbitration problem that can occur by the simultaneous taking off different slave nodes connected to a single interface bus. LIN bus is employed in application like mirror control, Fan controls, seat positioning controls, window controls and position control where response time is not a critical issue
19.	**Define Media – Oriented System Transport (MOST) Bus.** BTL2 The MOST is the targeted for automotive audio/video equipment interfacing, used primarily in European cars. MOST bus is an optical fiber cables. The MOST bus specifications define the physical layer as well as the application layer, network layer and media access control.
20.	**What is the basic function of audio players?** BTL2 • Audio decompression • User interface • Audio storage

Part*B

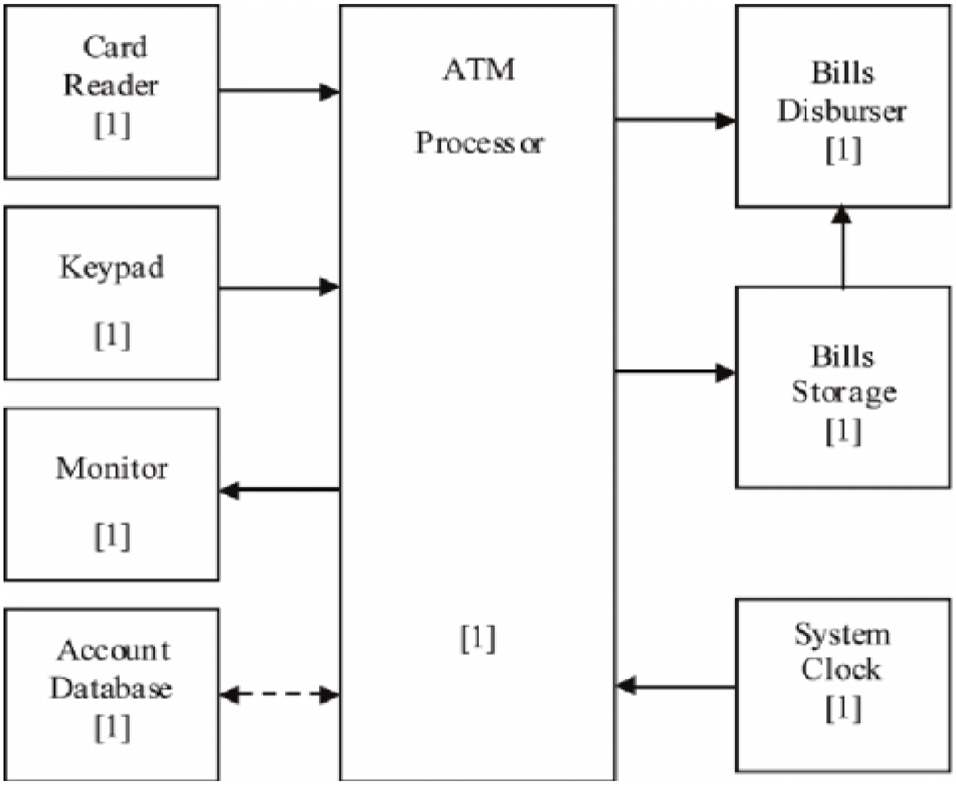
Q.No	**Question**
1.	With suitable diagram explain in detail about the concept of Digital Camera application in embedded system BTL2 (13M) **Answer: Page No. 5.49 – Dr.G. Ramprabu** Digital Camera in Embedded System



- General-purpose processor
- Camera records the pictures using a charge coupled devices (CCD) array
- The array consisting of large number of horizontal rows and vertical columns of CCD cells for the picture
- A number of CCD cell unexposed to the picture but used for off-set corrections in the each-row output. -----(6M)
- Each set of pixel has three cells, for the red, green and blue components in a pixel.
- Each cell gets exposed to a picture when shutter of camera opens on a user command.
- A set of controllers – to control shutter, flash, auto focus and eye-ball image control.
- User gives commands for switching on the camera, flash, shutter, adjust brightness, contrast, color, save and transfer.
- shutter is pressed, a flash lamp glows and a self-timer circuit switches off the lamp automatically.
- JPEG file for a picture can be copied or transferred to a memory stick using a controller
- A picture jpg can be copied to a computer connected through USB port controller.
- Digital recording and display of pictures Processing to get the pictures of required brightness, contrast and color
- Transfer files to a computer and printer through a USB port
- Intensity and color values for each picture horizontal and vertical rows and columns of pixels in a picture frame.
- Special-purpose processor Custom or Standard
- Memory
- Interfacing
- Encodes a digital images-----(7M)

2. With suitable diagram explain in detail about the concept of ATM application in embedded system BTL2 (13M)

Answer: Notes

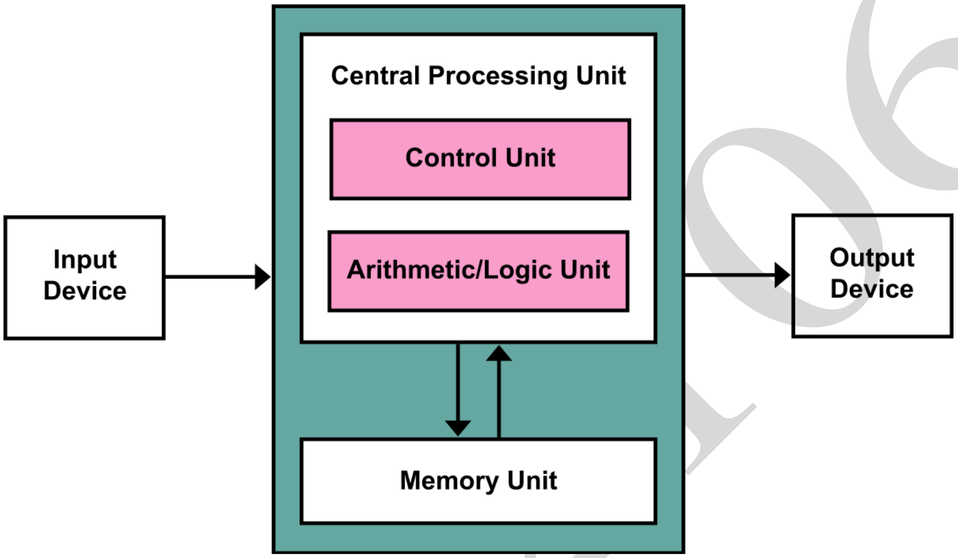


- ATM standard (defined by CCITT) is widely accepted by common carriers as mode of operation for communication – particularly BISDN.
- ATM is a form of cell_switching using small fixed-sized packets. -----(6M)
- ATM network will be organized as a hierarchy.
- Two levels of ATM connections:-virtual path connections-virtual channel connections
- Vast majority of ATM networks will run on optical fiber networks with *extremely low error rates.*
- ATM must supports low cost attachments
- ATM Adaptation Layer (AAL) – the protocol for packaging data into cells - collectively referred to as AAL
- Must efficiently package higher level data such as voice samples, video frames and datagram packets into a series of cells.
- ATM provides permanent virtual connections and switched virtual connections
- Permanent Virtual Connections (PVC)- permanent connections set up *manually* by network manager

- Switched Virtual Connections (SVC)-set up and released *on demand* by the end user via signaling procedures. -----(7M)

3. With suitable diagram explain in detail about the concept of Engine control Unit in embedded system BTL2 (13M)

Answer: Page No. 5.67– Dr.G. Ramprabu



- A system designed to perform a single well defined function life-long- embedded system
- Applications of embedded systems range from home to office, to automotive and avionics industries.
- Traditional design methodologies for designing embedded systems are generally based only on past experiences
- The hardware and software components are designed in a manner that ignores the interdependence between them-----(6M)
- The Engine Control Unit (ECU) - the brain of the engine
- Inputs - speed, temperature, pressure and pilot throttle
- advanced micro-processors and comprehensive software helps increase the engine life and ensure safety.
- An ECU consists of a set of sensors, a processing unit and a set of actuators.
- sensors periodically measure the engine status and provide input to the processing unit which processes this data
- actuators execute the commands received from the control unit.
- optimize the fuel injection and ignition so that it minimizes fuel consumption and emissions of pollutants and maximizes the torque and power.
- Injection : In order to burn the fuel completely and correctly, the ratio between air and the fuel which go into the piston should be kept constant.
- This ratio is maintained by the ECU by controlling the opening time of each injector.
- Ignition : The fuel should get enough time to burn completely. To let this happen, the spark has to be fired in advance with respect to the instant when the piston is at its highest point.

- Parameter also affects the emissions since unburnt fuel - pushed out of cylinder as emission or pollution.
- The timing difference between fuel injection and firing of spark is maintained by monitoring engine RPM-----(7M)

4. With suitable diagram explain in detail about the concept of Automotive application in embedded system BTL2 (13M)

Answer: Page No. 5.5 – Dr.G. Ramprabu

- **8-32bit 40 MHz microprocessor**
- **Analog-digital converter-----(6M)**
- **High-level digital outputs**
- **Digital-analog converter**
- **Signal conditioner**
- **Communication chips**
- **Each module communicates errors to a central module**
- **Can communicate errors to a diagnostic tool**

Instrument Cluster

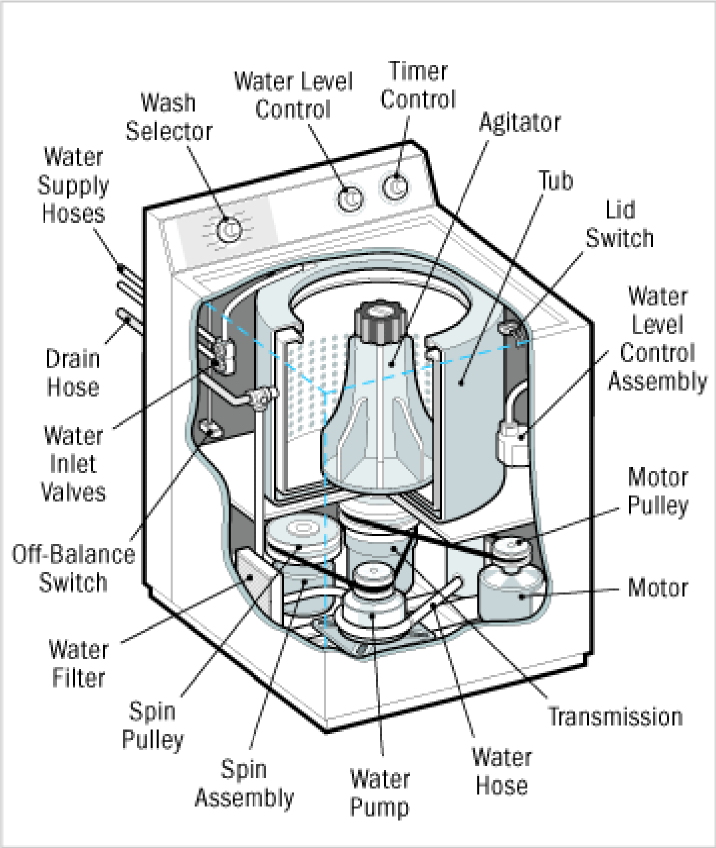
- **Displays data about the vehicle in its current state**
- **Various modules send data to ECU**
- **ECU send a packet of info**
- **Cluster module looks for specific headers**
- **Cluster is updated**

Other modules

- **Antilock Brakes**
- **Airbags**
- **Security systems**
- **Keyless entry**
- **Media center**
- **Cruise control**
- **Seat position and temperature**
- **Brake assist**
- **Stability control**
- **Anti-collision**
- **Reverse assist**
- **Traction control**
- **Self-parking-----(7M)**

Part*C

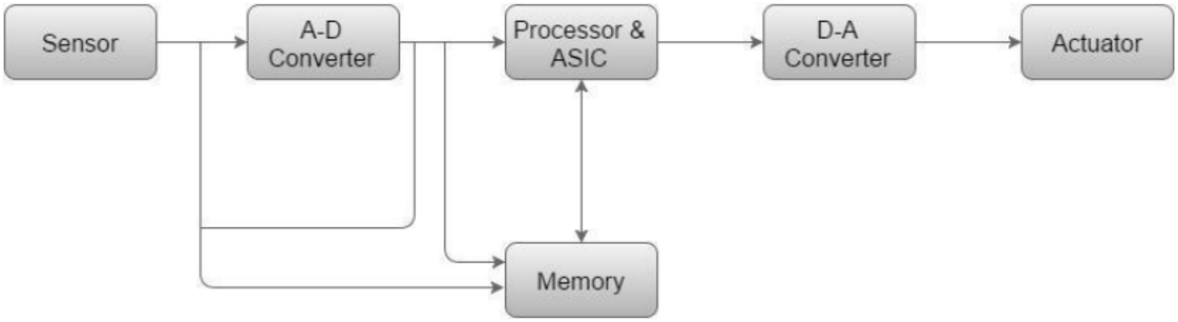
Q.No	Questions
1.	**With suitable diagram explain in detail about the concept of washing machine application.(May/June 2016, Nov/Dec 2016) (BTL4)** (15M) **Answer: Page No. 5.1 – Dr.G. Ramprabu**



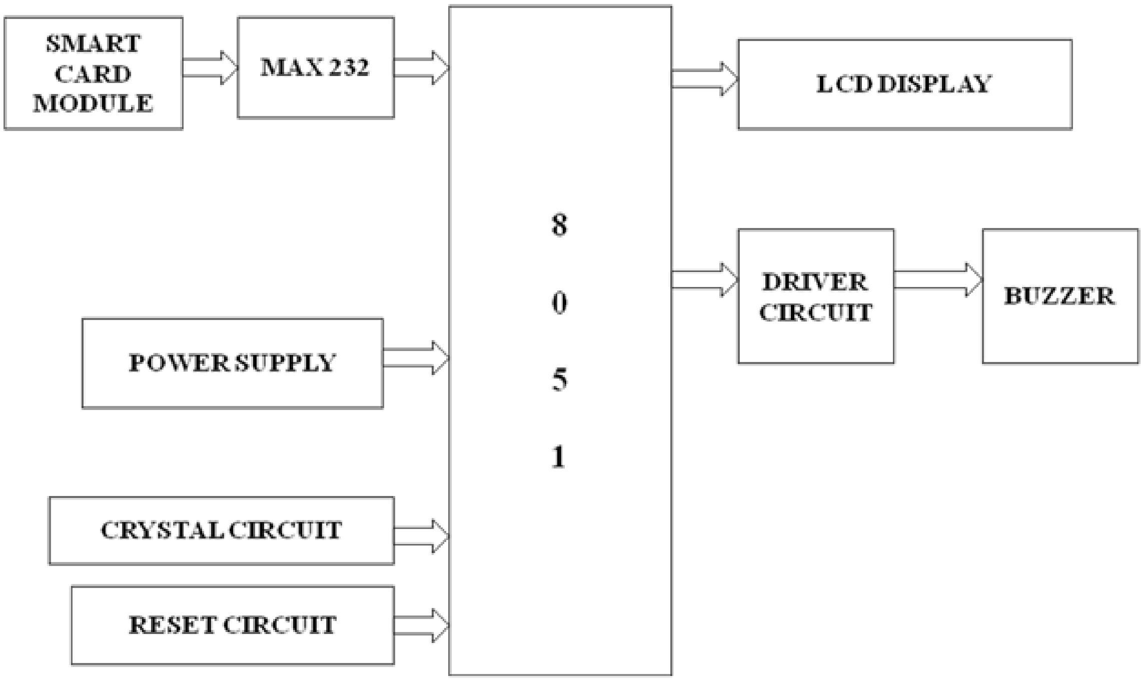
- Washing machine supports three functional modes
- The system should provide fully automatic mode, semi-automatic mode and manual mode. Modes should be selectable by a keypad
- Under fully automatic mode user intervention requirement should be zero
- after the completion of work it should notify the user about the completion of work
- semi-automatic mode also user requirement should be nil - But user has to choose any one of the semi-automatic mode. **-----(6M)**
- manual mode continuous intervention of user is required
- When the lid - open system should not work
- basic features of a washing machine - washing, rinsing, spinning, drying, cold wash, hot wash
- PWM feature of the microcontroller controls motor speed.
- PWM output is fed to driver circuit and then to motor
- rotate the motor in two different directions ‘forward’ and ‘reverse’ direction.
- Microcontroller reads the speed of the motor and appropriately controls the speed of the motor in different phases of washing.
- Part of home automation**-----(9M)**

2. Elucidate the selection of processor and memory for any one embedded system applications with suitable diagram in detail.(May/June 2016, April/May 2017) **(APR/MAY 2019** BTL3 (15M)

Answer: Notes



- An embedded system has three components
- It has hardware.
- It has application software.
- Real Time Operating system (RTOS) that supervises the application software and provide mechanism to let the processor run a process - plan to control the latencies.
- Single-functioned − An embedded system usually performs a specialized operation and does the same repeatedly - A pager always functions as a pager.
- Tightly constrained − All computing systems have constraints on design metrics - but those on an embedded system can be especially tight-----(6M)
- Reactive and Real time − Many embedded systems must continually react to changes in the system's environment and must compute certain results in real time without any delay.
- Microprocessors based − It must be microprocessor or microcontroller based.

	• Memory − It must have a memory, as its software usually embeds in ROM. • Connected − It must have connected peripherals to connect input and output devices • HW-SW systems − Software is used for more features and flexibility. Hardware is used for performance and security. • Advantages - Easily Customizable - Low power consumption - Low cost – Enhanced performance • Disadvantages - High development effort - Larger time to market • Sensor − It measures the physical quantity and converts it to an electrical signal which can be read by an observer or by any electronic instrument like an A2D converter. A sensor stores the measured quantity to the memory. • A-D Converter − An analog-to-digital converter converts the analog signal sent by the sensor into a digital signal. • Processor & ASICs − Processors process the data to measure the output and store it to the memory. • D-A Converter − A digital-to-analog converter converts the digital data fed by the processor to analog data • Actuator − An actuator compares the output given by the D-A Converter to the actual (expected) output stored in it and stores the approved output.
3.	With suitable diagram explain in detail about the concept of smart card system application.(Nov/Dec 2016, April/May 2017) BTL2 (15M) **Answer: Page No. 5.9 – Dr.G. Ramprabu**  • Enabling authentication and verification of card and card holder by a host

	• Enabling GUI at host machine to interact with the card holder • Received header and messages at IO port Port_IO from host through the antenna • powered charge pump supply of the card activated signal to start • Transmitted headers and messages at Port_IO through antenna • No control panel - at the card – in host • radiations from the host activate a charge pump at the card. • task_ReadPort sends requests for host identification and reads through the Port_IO the host-identification message-----(6M) • All transactions between cardholder/user now takes place through GUIs • Code size: optimum. card system memory needs should not exceed 64 kB memory • Limited use of data types; multidimensional arrays, long 64-bit integer and floating points • File system(s): Three-layered file system for data. • File management: fixed length file management • Microcontroller hardware: Generates distinct coded physical addresses for the program and data • Validity: System is embedded with expiry date • Extendibility: The system expiry date is extendable by transactions and authorization of master control unit • Performance: Less than 1s for transferring control from the card to host machine. • User Interfaces: At host machine, graphic at LCD or touch screen-------(9M)

EE8002 DESIGN OF ELECTRICAL APPARATUS L T P C 3 0 0 3

OBJECTIVES: To impart knowledge about the following topics:

- Magnetic circuit parameters and thermal rating of various types of electrical machines.
- Armature and field systems for D.C. machines.
- Core, yoke, windings and cooling systems of transformers.
- Design of stator and rotor of induction machines and synchronous machines.
- The importance of computer aided design method.

UNIT I DESIGN OF FIELD SYSTEM AND ARMATURE 9

Major considerations in Electrical Machine Design – Materials for Electrical apparatus – Design of Magnetic circuits – Magnetizing current – Flux leakage – Leakage in Armature. Design of lap winding and wave winding.

UNIT II DESIGN OF TRANSFORMERS 9

Construction - KVA output for single and three phase transformers – Overall dimensions – design of yoke, core and winding for core and shell type transformers – Estimation of No load current – Temperature rise in Transformers – Design of Tank and cooling tubes of Transformers. Computer program: Complete Design of single phase core transformer

UNIT III DESIGN OF DC MACHINES 9

Construction - Output Equations – Main Dimensions – Choice of specific loadings – Selection of number of poles – Design of Armature – Design of commutators and brushes – design of field Computer program: Design of Armature main dimensions

UNIT IV DESIGN OF INDUCTION MOTORS 9

Construction - Output equation of Induction motor – Main dimensions – choice of specific loadings – Design of squirrel cage rotor and wound rotor –Magnetic leakage calculations – Operating characteristics : Magnetizing current - Short circuit current – Circle diagram - Computer program: Design of slip-ring rotor

UNIT V DESIGN OF SYNCHRONOUS MACHINES 9

Output equations – choice of specific loadings – Design of salient pole machines – Short circuit ratio – Armature design – Estimation of air gap length – Design of rotor –Design of damper winding – Determination of full load field MMF – Design of field winding – Design of turbo alternators -Computer program: Design of Stator main dimensions-Brushless DC Machines

TOTAL: 45 PERIODS

OUTCOMES:

- Ability to understand basics of design considerations for rotating and static electrical machines
- Ability to design of field system for its application.
- Ability to design sings and three phase transformer.
- Ability to design armature and field of DC machines.
- Ability to design stator and rotor of induction motor.
- Ability to design and analyze synchronous machines.

TEXT BOOKS:

1. Sawhney, A.K., ‘A Course in Electrical Machine Design’, Dhanpat Ra i& Sons, New Delhi, Fifth Edition, 1984.
2. M V Deshpande ‘Design and Testing of Electrical Machines’ PHI learning Pvt Lt, 2011.
3. Sen, S.K., ‘Principles of Electrical Machine Designs with Computer Programmes’, Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, Second Edition, 2009.

REFERENCES

1. A.Shanmugasundaram, G.Gangadharan, R.Palani ‘Electrical Machine Design Data Book’, New Age International Pvt. Ltd., Reprint 2007.
2. ‘Electrical Machine Design’, Balbir Singh, Vikas Publishing House Private Limited, 1981.
3. V Rajini, V.S Nagarajan, ‘Electrical Machine Design’, Pearson, 2017.
4. K.M.Vishnumurthy ‘Computer aided design of electrical machines’ B S Publications, 2008

Subject Code: EE8002 **Year/Semester: IV /06**
Subject Name: DESIGN OF ELECTRICAL APPARATUS
Subject Handler: Dr.Prajith Prabhakar

	UNIT I DESIGN OF FIELD SYSTEM AND ARMATURE
	Major considerations in Electrical Machine Design – Materials for Electrical apparatus – Design of Magnetic circuits – Magnetizing current – Flux leakage – Leakage in Armature. Design of lap winding and wave winding.
	PART*A
1.	**What are the major considerations to evolve a good design of electrical machine?(Nov/Dec 2004, 2011)** BTL1 • Cost • Durability • Small size and less weight • Wider temperature operating limits
2	**Name the types of magnetic materials based on Hysteresis loops.(NOV/DEC 2004)** BTL1 • Soft magnetic material • Hard magnetic material
3	**State the properties which determine the suitability of a material for insulating materials. (NOV/DEC 2004)**BTL1 • Specific resistance • Thermal resistance • Dielectric strength • Mechanical Strength • Permittivity • High insulation resistance

4	**What are the types of electrical engineering materials used in the construction of AC generators and AC motors?(Nov-Dec 2005)** BTL1 • Conducting Materials--- Copper , Aluminum, Cast iron and Steel • Magnetic Materials ----- Cold rolled grain oriented steel • Insulating materials ----- Class A or E , Laminated paper, cotton cloth
5	**What is super conductivity?(May –June2006)** BTL1 State of the material in which it has zero resistivity. When the temperature is bought down below the transition temperature super conductivity is obtained or exhibited by the super conducting materials.
6	**List out the materials exhibit the property of Super conductivity?**BTL1 • Mercury • Metals • Alloys
7	**How are the materials classified according to their degree of magnetism? (April/May 2011, Nov-Dec 2011)** BTL1 • Properties of the materials are classified by their relative permeability. • Materials are classified as Diamagnetic, Paramagnetic and Ferro magnetic.
8	**List the various design limitation in Electrical design.** BTL2 • Saturation • Temperature Rise • Insulation • Efficiency • Commutation • Mechanical parts • Power factor • Specifications
9	**Define the terms real and apparent flux densities .(April –May 2004,April- May 2008, Nov- Dec 2003)** BTL1 • ***Apparent flux density, B_{app} = Total flux in a slot pitch/ tooth area*** • ***Real flux density, B_{real} = Actual flux in a tooth/ Tooth area***
10	**Define field form factor .(Nov-Dec 2004, Nov- Dec 2009, Nov-Dec 2009, 2010)** BTL1 • It is the defined as the ratio of average gap density over the pole pitch to maximum flux density in the gap. $K_f = B_{av} / B_g$ ***Also*** k_f ***= Pole arc / Pole pitch =*** $b/\tau = \psi$
11	**Define gap contraction factor for slots and ducts .(Nov- Dec 2009)** BTL1 • Gap contraction factor for slots is defined as the $K_{gs} = \frac{Reluctance\ of\ air\ gap\ of\ slotted\ armature\ with\ fringing\ flux}{Reluctance\ of\ air\ gap\ with\ smooth\ armature}$

$$K_{gs} = \frac{Y_s}{Y_s - K_{cs}W_s}$$

- Gap contraction factor for ducts is defined as

  $$K_{gd} = \frac{Reluctance\ of\ air\ gap\ with\ ducts}{Reluctance\ of\ air\ gap\ without\ ducts}$$

  $$K_{gs} = \frac{L}{L - K_{cd}n_dW_d}$$

12 **What is the difference of leakage magnetic flux from magnetic flux? (May- June 2009, Nov- Dec 2010)** BTL1

- In all practical applications magnetic circuits, most of the flux confined to the intended path by use of magnetic cores but a small amount of flux always leaks through the surrounding air.
- For magnetic circuit calculations, leakage flux is taken into account in terms of leakage coefficient **C_l = Total flux /Useful flux**.
- Flux which passes through unwanted path is called leakage flux. This flux neither contributes to transfer of energy nor conversion.

13 **State the relative merits of lap and wave windings of armature of dc machines.** BTL2

<u>Lap Winding</u>

- Number of parallel paths is equal to number of poles
- Number of conductors required is p/2 times that of wave winding
- Winding is easier and short pitched coils can be made that results in overhanging length
- Preferred for current ratings is more than 400A

<u>Wave Winding</u>

- Number of parallel path is two.
- Less no of conductors and less no of coils and reduces the cost in design.
- Equalizer connections are not needed.
- Used for small and medium rating machines.

14 **Explain about Flash Over.** BTL2

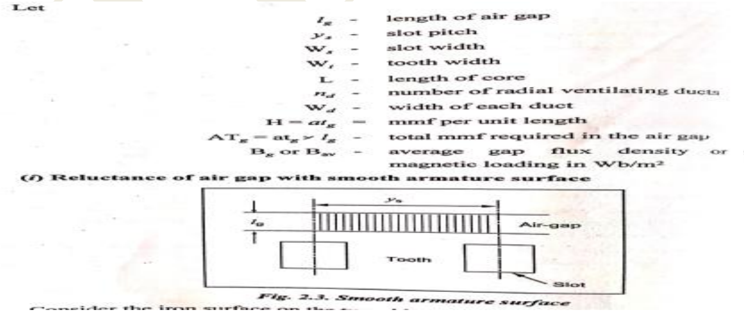
- In a Lap wounded machine, number of brush arms increases with increase in no of poles. Distance between adjacent brushes decreases as the no of poles increases. This will increase the possibility of flash over between brushes.

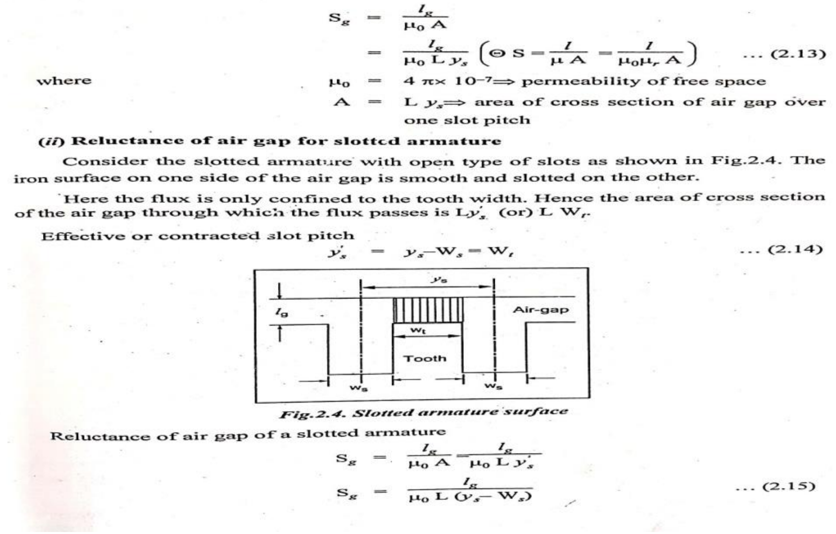
15 **What are the methods to estimate mmf required in teeth.** BTL1

- Graphical method
- Three coordinate method or Simpson's rule
- B_t 1/3 method.

16 **Define stacking factor or Iron Space factor.** BTL1

- This is defined as the ratio of the actual length of iron in a stack assembled core plates to total axial length of stack (value K_i =0.9)

17	**Give the relationship between real and apparent flux densities.** BTL1 $\boldsymbol{B_{app} = B_{real} + 4\pi X 10^{-7'} at'real(K_s - 1)}$
18	How the design problems of an electrical machine can be classified? BTL1 ✓ Electromagnetic design ✓ Mechanical design ✓ Thermal design ✓ Dielectric design
19	What are the constituents of magnetic circuit in rotating machines? BTL1 • The various elements in the flux path of salient pole machines are poles, pole shoes, air-gap, armature core and yoke. The various elements in the flux path of non salient pole machines are stator core, stator teeth, air-gap, rotor teeth and rotor core.
20	Write the rule for calculation mmf for tooth by $B_{t\,1/3}$ method. BTL1 • Mmf for tooth = $at_{1/3}$ x l_t $At_{1/3}$ = at for flux density at one third height from the narrow end L_t = length of tooth
21	What is magnetization curve? BTL1 The curve shows the relation between the magnetic field intensity (H) and the flux density (B) of a magnetic material. It is used to estimate the mmf required for the flux path in the magnetic material and it is supplied by the manufacturer of stampings or laminations
22	Write down the formula for computing the mmf for the air gap length. BTL1 • Mmf for the air gap = 800000BKglg in AT
23	Define field form factor. BTL1 • The filed form factor Kf is defined as the ratio of average gap density over the pole pitch to maximum flux density in the air gap. **Kf = Bav / Bg** **Kf ≈ ψ = pole arc/pole pitch**
	PART * B
1.	Derive the expression for calculation of mmf required in the air gap. **(8M)**BTL1 **Answer: Page: 2.5 to 2.12– M. Ramesh- Lekshmi Publications** **Solution:**  Let l_g - length of air gap y_s - slot pitch W_s - slot width W_t - tooth width L - length of core n_d - number of radial ventilating ducts W_d - width of each duct $H = at_g$ = mmf per unit length $AT_g = at_g \times l_g$ - total mmf required in the air gap B_g or B_{av} - average gap flux density or magnetic loading in Wb/m^2 (i) Reluctance of air gap with smooth armature surface Fig. 2.3. Smooth armature surface Consider the iron surface on the (2M)



$$S_g = \frac{l_g}{\mu_0 A}$$

$$= \frac{l_g}{\mu_0 L y_s} \left(\because S = \frac{l}{\mu A} = \frac{l}{\mu_0 \mu_r A}\right) \quad \ldots (2.13)$$

where $\mu_0 = 4\pi \times 10^{-7} \Rightarrow$ permeability of free space

$A = L\, y_s \Rightarrow$ area of cross section of air gap over one slot pitch

***(ii)* Reluctance of air gap for slotted armature**

Consider the slotted armature with open type of slots as shown in Fig.2.4. The iron surface on one side of the air gap is smooth and slotted on the other.

Here the flux is only confined to the tooth width. Hence the area of cross section of the air gap through which the flux passes is $L y_s'$ (or) $L\, W_t$.

Effective or contracted slot pitch

$$y_s' = y_s - W_s = W_t \quad \ldots (2.14)$$

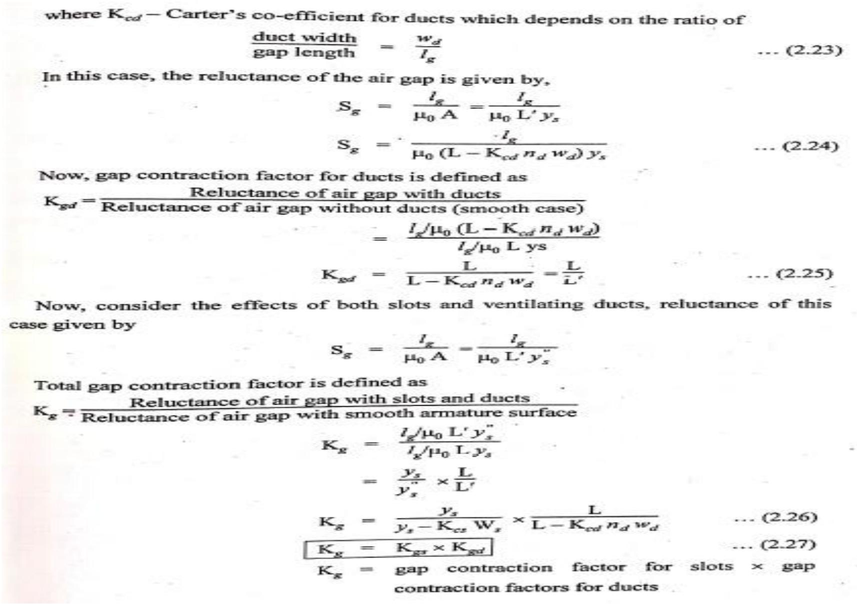
Fig.2.4. Slotted armature surface

Reluctance of air gap of a slotted armature

$$S_g = \frac{l_g}{\mu_0 A} = \frac{l_g}{\mu_0 L y_s'}$$

$$S_g = \frac{l_g}{\mu_0 L (y_s - W_s)} \quad \ldots (2.15)$$

(4M)



where K_{cd} – Carter's co-efficient for ducts which depends on the ratio of

$$\frac{\text{duct width}}{\text{gap length}} = \frac{w_d}{l_g} \quad \ldots (2.23)$$

In this case, the reluctance of the air gap is given by,

$$S_g = \frac{l_g}{\mu_0 A} = \frac{l_g}{\mu_0 L' y_s}$$

$$S_g = \frac{l_g}{\mu_0 (L - K_{cd}\, n_d\, w_d)\, y_s} \quad \ldots (2.24)$$

Now, gap contraction factor for ducts is defined as

$$K_{gd} = \frac{\text{Reluctance of air gap with ducts}}{\text{Reluctance of air gap without ducts (smooth case)}}$$

$$= \frac{l_g/\mu_0 (L - K_{cd}\, n_d\, w_d)}{l_g/\mu_0 L \text{ ys}}$$

$$K_{gd} = \frac{L}{L - K_{cd}\, n_d\, w_d} = \frac{L}{L'} \quad \ldots (2.25)$$

Now, consider the effects of both slots and ventilating ducts, reluctance of this case given by

$$S_g = \frac{l_g}{\mu_0 A} = \frac{l_g}{\mu_0 L' y_s''}$$

Total gap contraction factor is defined as

$$K_g = \frac{\text{Reluctance of air gap with slots and ducts}}{\text{Reluctance of air gap with smooth armature surface}}$$

$$K_g = \frac{l_g/\mu_0 L' y_s''}{l_g/\mu_0 L y_s}$$

$$= \frac{y_s}{y_s''} \times \frac{L}{L'}$$

$$K_g = \frac{y_s}{y_s - K_{cs} W_s} \times \frac{L}{L - K_{cd}\, n_d\, w_d} \quad \ldots (2.26)$$

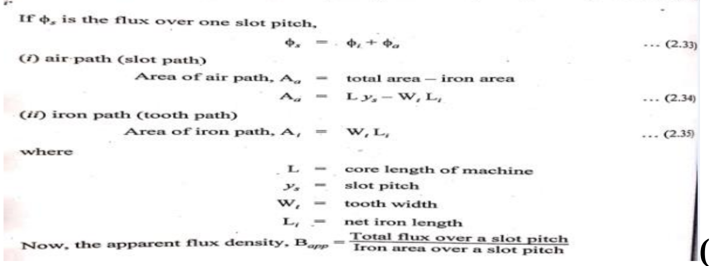
$$\boxed{K_g = K_{gs} \times K_{gd}} \quad \ldots (2.27)$$

K_g = gap contraction factor for slots × gap contraction factors for ducts

(2M)

2. Derive the Real and Apparent densities in a DC machine. **APRIL/MAY 2010) (NOV/DEC 2009) (8M)** BTL1

Answer: Page: 2.30 to 2.32– M. Ramesh- Lekshmi Publications



$$\text{Apparent flux density, } B_{app} = \frac{\text{Total flux in a slot pitch}}{\text{Tooth area}}$$

$$\text{Real flux density, } B_{real} = \frac{\text{Actual flux in a tooth}}{\text{Tooth area}}$$

Let the flux passing through air path ϕ_a and flux passing through the iron path

If ϕ_s is the flux over one slot pitch,

$$\phi_s = \phi_i + \phi_a \quad \ldots (2.33)$$

(i) air path (slot path)

$$\text{Area of air path, } A_a = \text{total area} - \text{iron area}$$

$$A_a = L\, y_s - W_t L_i \quad \ldots (2.34)$$

(ii) iron path (tooth path)

$$\text{Area of iron path, } A_i = W_t L_i \quad \ldots (2.35)$$

where

L = core length of machine

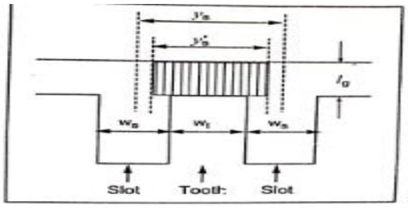
y_s = slot pitch

W_t = tooth width

L_i = net iron length

$$\text{Now, the apparent flux density, } B_{app} = \frac{\text{Total flux over a slot pitch}}{\text{Iron area over a slot pitch}}$$

(2 M)

	 *Fig. 2.12. Indication of armature slot and tooth* $B_{app} = \frac{\phi_s}{A_t}$ $= \frac{\phi_t + \phi_a}{A_t}$ $= \frac{\phi_t}{A_t} + \frac{\phi_a}{A_t}$ $B_{app} = \frac{\phi_t}{A_t} + \frac{\phi_a}{A_t} \times \frac{A_a}{A_a}$ Let The real flux density, $B_{real} = \frac{\phi_t}{A_t}$ Flux density in air, $B_a = \frac{\phi_a}{A_a}$ $\therefore B_{app} = B_{real} + B_a \times \frac{A_a}{A_t}$ $B_a = \mu_0 H = \mu_0 \text{ 'at'}_{real} = 4\pi \times 10^{-7} \text{ 'at'}_{real}$ $\frac{A_a}{A_t} = \frac{\text{air area}}{\text{iron area}} = \frac{L y_s - L_t W_t}{L_t W_t}$ $= \frac{L y_s}{L_t W_t} - 1$ (4 M) $B_{app} = B_{real} + 4\pi X 10^{-7'} at' real(K_s - 1) - - - - - (2M)$
3.	Discuss Quantitatively the effects of slots and ventilating ducts upon the reluctance of the air gap of a machine. (8M) (Nov- Dec 2010) BTL2 **Answer: Page: 2.5 to 2.11– M. Ramesh- Lekshmi Publications** Solution: Refer Question no – 1
4.	**Explain the methods for calculating the mmf for tapered teeth (APRIL/MAY 2011) (Nov- Dec 2010) (8M)** BTL1 **Answer: Page: 2.24 to 2.26– M. Ramesh- Lekshmi Publications** **Solution :** • **Graphical method ------------------(3 M)** • **Three coordinate Method ------------(3M)** • **Flux density at third height-------------(2M)**
5.	**Derive expressions for the reluctance of air gap in machines with smooth and slotted armature. (April /May 2017) (8 M)** BTL2 **Answer: Page: 2.5 to 2.7– M. Ramesh- Lekshmi Publications** Solution : refer question no 1.
6.	**Calculate the airgap length of a DC machine from the following particulars: gross length of core = 0.12m, No.of ducts = 1, and is 10mm width, slot pitch = 25 mm, slot width = 10mm, carter co-efficient for slots and ducts = 0.32 , gap density at pole centre = 0.7 Wb/m^2 ; field mmf per pole = 3900 AT, mmf required for iron parts of the magnetic circuit = 800 AT.(10 M)(April/May 2010, 2005, 2017, Nov- Dec 2009)** BTL 3

Answer: Page: 2.22 (problem 2.6) – M. Ramesh- Lekshmi Publications

- mmf required for the air gap $AT_g = 800000\ B_g\ K_g\ l_g$
- mmf required for the airgap = field mmf per pole – mmf in iron parts.
- **Length of air gap l_g --(3 M)**
- Total gap contraction factor K_g = Kgs x Kgd

$$K_{gs} = \frac{Y_s}{Y_s - K_{cs}W_s} \text{ --(3M)}$$

- Gap contraction factor for ducts is defined as

$$K_{gd} = \frac{Reluctance\ of\ air\ gap\ with\ ducts}{Reluctance\ of\ air\ gap\ without\ ducts}$$

$$K_{gd} = \frac{L}{L - K_{cd}n_dW_d}\text{--(2 M)}$$

- **Length of air gap = 4.702 mm --------------------------------------(2 M)**

7. What are the major considerations in the Electrical machine design? **(8M) (April /May 2017)** BTL1

Answer: Page: 1.2 – M. Ramesh- Lekshmi Publications

- Cost
- Durability
- Specifications of the performance criteria
- Wider temperature operating limits ------------------------(3M)
- 9 points on Design limitations ---------------------------------- (5M)

8. **Calculate the mmf required for the air gap of the machine having core length = 0.32m, including 4 ducts of 10 mm each : pole arc = 0.19 m: slot pitch = 65.4mm: slot opening = 5 mm: airgap length = 5mm: flux per pole = 52 mWb. Given carter coefficient is 0.18 for opening/ gap = 1; and is 0.28 for opening /gap = 2. (10 M)** BTL3

Answer: Page: 2.16 (problem 2.2) – M. Ramesh- Lekshmi Publications

- mmf required for the air gap $AT_g = 800000\ B_g\ K_g\ l_g$
- B_g = flux per pole / (pole arc x core length) -----------------------------(2M)
- Total gap contraction factor K_g = Kgs x Kgd

$$K_{gs} = \frac{Y_s}{Y_s - K_{cs}W_s} \text{ --(3M)}$$

- Gap contraction factor for ducts is defined as

$$K_{gd} = \frac{Reluctance\ of\ air\ gap\ with\ ducts}{Reluctance\ of\ air\ gap\ without\ ducts}$$

$$K_{gd} = \frac{L}{L - K_{cd}n_dW_d}\text{--(2 M)}$$

- ATg = 3591 AT --(3M)

9. A 15 kW ,230 V, 4 pole dc machine has the following data : armature diameter = 0.25m : armature core length = 0.25 m; length of the airgap at pole centre = 2.5 mm ; flux per pole = 11.7×10^{-3} Wb, ratio pole arc /pole pitch = 0.66.calculate mmf required for the air gap

I. If the armature surface is treated as smooth.

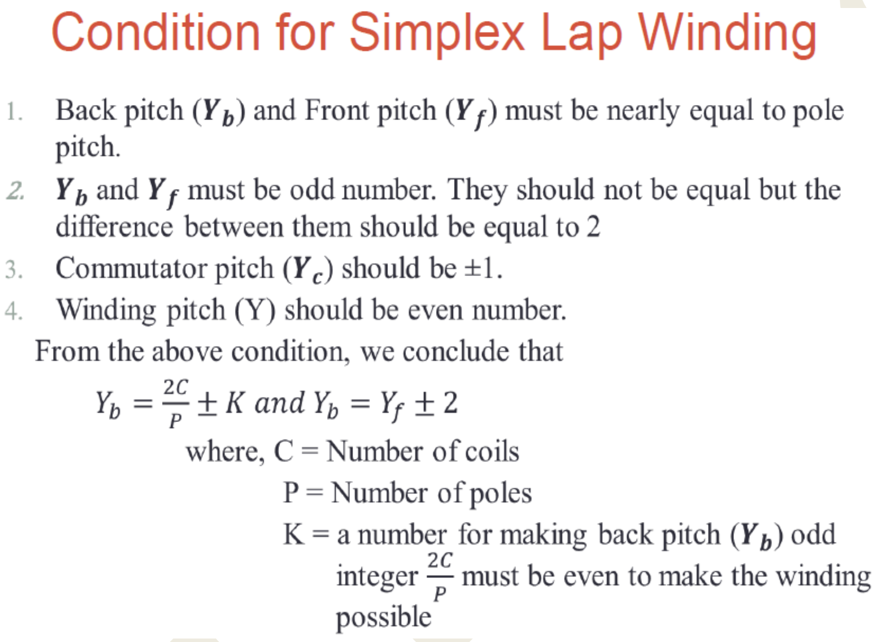
II. If armature is slotted and gap contraction factor is 1.18 **(Nov- Dec 2008)(10M)(** BTL3)

Answer: Page: 2.17 (problem 2.3) – M. Ramesh- Lekshmi Publications

- mmf required for the air gap $AT_g = 800000\ B_g\ K_g\ l_g$
- **Gap flux density $Bg = B_{av} / \psi$**
- **Specific magnetic loading $B_{av} = p\varphi / \pi DL$ ---------------------(3 M)**
- **ATg = 1445 AT --(2M)**
- **Mmf required for the air gap with slotted armature ATg = Kg x ATg in smooth armature**
- **ATg = 1705 AT---(5 M)**

10. Explain the steps in the design of Lap and Wave winding .(**13M)** BTL2

Solution :



Condition for Simplex Lap Winding

1. Back pitch (Y_b) and Front pitch (Y_f) must be nearly equal to pole pitch.
2. Y_b and Y_f must be odd number. They should not be equal but the difference between them should be equal to 2
3. Commutator pitch (Y_c) should be ±1.
4. Winding pitch (Y) should be even number.

From the above condition, we conclude that

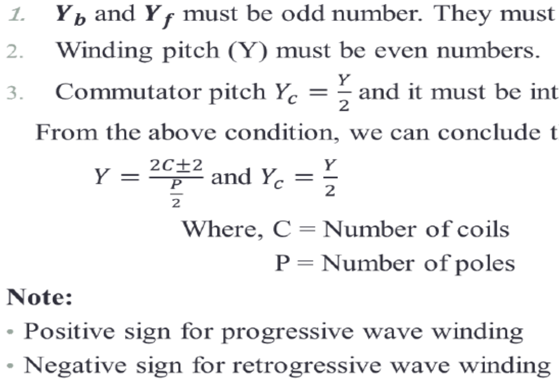
$$Y_b = \frac{2C}{P} \pm K \ and\ Y_b = Y_f \pm 2$$

where, C = Number of coils

P = Number of poles

K = a number for making back pitch (Y_b) odd integer $\frac{2C}{P}$ must be even to make the winding possible

(7 M)



1. Y_b and Y_f must be odd number. They must be equal or differ by 2.
2. Winding pitch (Y) must be even numbers.
3. Commutator pitch $Y_c = \frac{Y}{2}$ and it must be integer.

From the above condition, we can conclude that

$$Y = \frac{2C\pm2}{\frac{P}{2}} \text{ and } Y_c = \frac{Y}{2}$$

Where, C = Number of coils

P = Number of poles

Note:

- Positive sign for progressive wave winding
- Negative sign for retrogressive wave winding

(8 M)

PART *C

1. **Determine the apparent flux density in the teeth of a dc machine when the real flux density is 2.15 Wb/m^2; slot pitch 28 mm: slot width 10 mm and the gross core length 0.35 m. Number of ventilating ducts is 4 , each 10 mm wide. The magnetizing force for flux density of 2.15 Wb/ m^2 is 55000 A/m. Iron stacking factor is 0.9. (MAY/JUNE 2009, April /May 2011, Nov- Dec 2009, 2007) (14M)** BTL3

Answer: Page: 2.34 (problem 2.9) – M. Ramesh- Lekshmi Publications

- $B_{app} = B_{real} + 4\pi\ X\ 10^{-7'} at'real(K_s - 1)$
- $Ks = \frac{LYs}{LiWi}$**------------------------------------(4 M)**
- Li **= 0.279 m ----------------------(4 M)**
- Bapp = 2.2156 Wb/m^2 ----------------------(6 M)

2. **The stator of a machine has a smooth surface but its rotor has open type of slots with slot width Ws = tooth width, Wt = 14mm and length of the air gap lg= 3mm.Find the effective length of the air gap if the carter coefficient = $\frac{1}{1+5\ (\frac{lg}{Ws})}$. There are no radial ducts. (10M)** BTL3

Answer: Page: 2.14 (problem 2.1) – M. Ramesh- Lekshmi Publications

- **Effective length of the air gap lgs = Kg x Lg**
- Total gap contraction factor K$_g$ = Kgs x Kgd

$K_{gs} = \frac{Y_s}{Y_s - K_{cs} W_s}$ **---(3M)**

- **Ys = Ws +Wt = 28 mm--(4M)**
- **Kcs =** $\frac{1}{1+5\ (\frac{lg}{Ws})}$
- **Kgs = 1.318**
- **Kgd =1 (given)**
- **Lgs = Kg x Lg = 3.954 mm -- (3M)**

	UNIT II DESIGN OF TRANSFORMERS
	Construction - KVA output for single and three phase transformers – Overall dimensions –design of yoke, core and winding for core and shell type transformers – Estimation of No load current – Temperature rise in Transformers – Design of Tank and cooling tubes of Transformers. Computer program: Complete Design of single phase core transformer
Q.No.	**Questions**
1.	**Why the area of yoke of a transformer is usually kept 15 to 20 % more than that of core?(May 2016) BTL1** Sol: In order to reduce flux density in the yoke, thereby reducing iron losses and no load current in yoke section.
2	**Why stepped core are generally used for transformer? BTL1** Sol: LV & HV coils are circular, for better utilization of space, for reducing the mean length of LV & HV turns, resulting in saving of copper material.
3	**What are the factors on which no load current of transformer depends? (April /May 2010) BTL1** Sol: MMF per meter of the flux densities in yoke and core.
4	**Why the efficiency of transformer is so high? (May 2016) BTL1** Sol: Mechanical losses zero and iron losses are comparatively less
5	**What are the advantages of three phase over single phase transformers? (April May 2008, Nov/ Dec 2007)BTL1** Sol: Three phase supplies are more economical than single phase in generation, distribution and utilization of electrical energy; therefore they are used very extensively in power systems. A bank of three single phase transformers can be used a three phase unit costs about 15 % to 20 % less than a bank of single phase units and occupies less space.
6	**What is window space factor in design of transformer? (DEC 2009, 2010, May 2013, Nov 2016). BTL1** It is defined as the ratio of copper area in window to total area of window. $\boxed{K_w = A_c / A_w}$
7	**What are the usual values of maximum flux density in the core of power and distribution transformer? (May/June 2010) BTL1** Sol: Distribution transformer = 1.1 to 1.35 Wb/ m^2 Power transformer = 1.25 to 1.45 Wb/ m^2
8	**What are the different losses in a transformer? (JUNE 2009) BTL1** Sol: Losses in a transformer: a) Core (or) iron loss. b) Copper loss
9	**Why is the core of the transformer laminated? (MAY 2008) BTL1** Sol: The cores of transformer are laminate in order to reduce the eddy current losses. The eddy current loss is

proportional to the square of the thickness of laminations. This apparently implies that the thickness of the laminations should be extremely small in order to reduce the eddy current losses to a minimum.

10 **Differentiate core and shell type transformers. (JUNE 2009, Nov /Dec 2013) BTL1**

Core type	Shell type
Easy in design and construction	Comparatively complex
Has low mechanical strength due to non-bracing of windings	High mechanical strength

11 **Give the relationship between emf per turn and kVA rating in a transformer (MAY 2011) BTL1**

Sol: Emf per turn, $E_t = K\sqrt{Q}$ where, $K = \sqrt{(4.44 f \phi_m x 10^3 / AT)}$ and Q = kVA rating

12 **What are the factors affecting the choice of flux density of core in a transformer? (MAY 2011) BTL1**

- Flux
- Area of the core
- Area of the window

13 **What do you mean by stacking factor? (or) Iron space factor. (April/May 2011) BTL1**

Sol: core is made of laminations and the laminations are insulated from each other by a thin coating of varnish. When laminations are stacked to from coil, actual iron area will be less than the core area. Ratio area and total core area is called stacking factor. the value is usually 0.9.

14 **Define the term “Voltage Regulation” (DEC 2011) BTL2**

Sol: Voltage regulation of an alternator is defined as the rise in terminal voltage of the machine expressed as a fraction of percentage of the initial voltage when specified load at a particular power factor is reduced to zero, the speed and excitation remaining unchanged.

15 **What are the methods by which heat dissipation occurs in a transformer? (DEC 2011, Nov 2016)BTL1**

- Convection
- Convention
- Radiation

16 **What are the advantages of having circular coil in a transformer? / Why are the cores of large transformers built up of circular cross section (DEC ‘10, Nov – Dec 2013) BTL1**

Sol: The excessive leakage fluxes produced during short circuit and over loads develop severe mechanical stresses on the coils. On circular coils these forces are radial and there is no tendency for the coil to change its shape. But on rectangular coils these forces are perpendicular to the conductors and tend to deform the coil in circular form.

17 **How the heat dissipation is improved by the provision of cooling tubes? (April/ May 2010, Nove/Dec**

2013) BTL2

Sol:

- Temperature rise as calculated with plain wall tank exceeds the exceeds the specified limit , it can be reduced by provision of cooling tubes.
- The cooling tube increases the heat dissipation surface area and it can be improve the oil circulation and there by an additional 35% tube dissipation becomes effective for convection of heat loss.

20 **What are the cooling methods used for dry type transformers? (May 2013) BTL1**

- Air natural type & Air forced type

PART * B

1. **Derive the output equation of a three phase transformer (13M) (April /May 2011, April/May 2008, Nove/Dec 2008)** BTL1

Answer: Page: 3.5 to 3.6 , M. Ramesh , Lekshmi publications

Sol :

Voltage induced in a transformer winding with ‘T’ turns, (ie) voltage per turn,

$$E_t = \frac{E}{T} = 4.44\ f\ \varphi_m \quad -----(1)$$

The window in a 3ϕ transformer contains two primaries and two secondary winding.
Total copper area in window, A_c = 2 (copper area of primary winding + copper area of secondary winding)
= 2 (primary turns x area of primary conductor) + 2 (secondary turns x area of secondary conductor)

$$A_C = 2\ (T_P\ a_P + T_S\ a_S)$$

Take current density ‘δ’ be the same in both primary and secondary winding.

$$a_P = \frac{I_P}{\delta} \text{ and } a_S = \frac{I_S}{\delta}$$

Total conductor area in window,

$$A_C = 2\ (\ T_P\ a_P + T_S\ a_S) = 2(\ T_P \frac{I_P}{\delta} + T_S \frac{I_S}{\delta}\ )$$

$$A_C = \frac{2}{\delta}\ [\ T_P\ I_P + T_S\ I_S] = \frac{2}{\delta}\ (AT + AT)$$

$$A_C = \frac{4\ AT}{\delta} \quad ------(2)$$

The “window space factor”, K_W is defined as the ratio of copper area in window to the total area of window.

$$K_W = \frac{A_C}{A_W}$$

$$A_C = K_W A_W \text{ ------}(3)$$

$$\text{from (2)\& (3),} \qquad \frac{4\,AT}{\delta} = K_W A_W$$

$$AT = \frac{K_W A_W \delta}{4} \text{ ------}(4)$$

---**(8 M)**

Rating of a 3ϕ transformer in kVA,

$$Q = 3 V_P I_P \times 10^{-3}$$

$$Q = 3 E_P I_P \times 10^{-3}$$

$$Q = 3 \frac{E_P}{T_P} T_P I_P \times 10^{-3}$$

$$Q = 3 E_t AT \times 10^{-3}$$

$$Q = 3\,(4.44 f \varphi_m)\left(\frac{K_W A_W \delta}{4}\right) \times 10^{-3} \qquad \text{(from 1 \& 4)}$$

$$Q = 3.33 f \varphi_m K_W A_W \delta \times 10^{-3} \text{ kVA}$$

(or)$Q = 3.33 f B_m A_i K_W A_W \delta \times 10^{-3}$ kVA --------------------**(5 M)**

2 **Calculate the core and window areas required for a 1000kVA, 6600 / 400V, 50Hz, single phase core type transformer. Assume a maximum flux density of 1.25wb/m^2 & a current density of 2.5 A/mm^2. Voltage per turn = 30V; window space factor = 0.32 (8M) (Nov/Dec2017) BTL 3**

Sol:

Given data: kVA = 1000, V_P = 6600V, V_S = 400V, f = 50Hz, B_m = 1.25wb/m^2, δ = 2.5A/mm^2, E_t = 30V, K_W = 0.32

$$E_t = 4.44.f\,\varphi_m$$

$$\varphi_m = \frac{E_t}{4.44 f} = \frac{30}{4.44 \times 50} = 0.1351 \text{ wb}$$

$$B_m = \frac{\varphi_m}{A_i}$$

$A_i = \frac{\varphi_m}{B_m} = \frac{0.1351}{1.25} = \mathbf{0.108\ m^2}$---------------------------------------**(4 M)**

kVA rating of transformer, $Q = 2.22 f B_m A_i K_W A_W \delta \times 10^{-3}$

	$A_W = \frac{Q}{2.22\ f\ B_m\ K_W\ \delta\ A_i\ \times\ 10^{-3}} = \frac{1000}{2.22\ \times 50\ \times 1.25\ \times 0.32\ \times 2.5\ \times\ 10^6\ \times 0.108 \times 10^{-3}}$ $\mathbf{A_W = 0.0834\ m^2}$**---------------------------------------(4 M)**
3	**A 3-phase, 50Hz, oil cooled core type transformer has the following dimensions: Distance between core centres = 0.2m, Height of window = 0.24m, Diameter of circumscribing circle = 0.14m, flux density in the core = 1.25wb/m^2, current density = 2.5A/mm^2. Assume a window space factor of 0.2 and the core area factor = 0.56. the core is 2-stepped. Estimate kVA rating of the transformer. NOV/DEC 2014) (April- May 2018)(8M) BTL3** Given data: $3\varphi, f = 50Hz; D = 0.2m;\ H_W = 0.24m; d = 0.14m;\ B_m = 1.25\ wb/m^2\ ;\ \delta = 2.5\ \ A/mm^2\ ;\ K_W = 0.2;\ K_C = 0.56; 2 - stepped$ $\text{kVA rating of transformer}, Q = 3.33\ f\ B_m\ A_i\ K_W\ A_W\ \delta\ \times\ 10^{-3}$ $\text{width of window}, W_W = D - d = 0.2 - 0.14 = \mathbf{0.06m}$ $\text{window area}, A_W =\ W_W\ \times\ H_W = 0.06\ \times 0.24 = \mathbf{0.0144m^2}$**-----------------------(4 M)** $\text{for 2 stepped core}, K_C = 0.56$ $K_C = \frac{A_i}{d^2}$ $\text{net core area}, A_i =\ K_C\ d^2 = 0.56\ \times\ 0.14^2\ = 0.0109m^2$ $Q = 3.33\ \times 50\ \times 1.25 \times 0.0109 \times 0.2 \times 0.0144 \times 2.5 \times 10^6 \times 10^{-3}\ = \mathbf{16.3\ kVA}$**--------------**(4 M)

4

Determine the main dimensions and area of conductors of the core of a 5 KVA, 11000/400 volts, 50 Hz, single phase core type distribution transformer having the following data:
The net conductor area in the window is 0.6 times the net cross sectional area of iron in the core. The core is of square cross section, maximum flux density is 1 wb/m^2. Current density is 1.4 A/mm^2. Window space factor is 0.2. Height of the window is 3 times its width. (MAY 2008) (13 M) BTL3

Given data: $Q = 5kVA$; $V_p = 11000$; $V_s = 400$; $f = 50Hz$; $A_c = 0.6A_i$; $B_m = 1Wb/m^2$; $\delta = 1.4A/mm^2$; $K_w = 0.2$; $H_w = 3W_w$

$$A_C = 0.6\,A_i$$

$$\mathrm{A_W = \frac{0.6\ A_i}{K_W} = \frac{0.6\ A_i}{0.2} = 3\ A_i - - - - - - (1)}$$

$$\mathrm{A_W K_W = 0.6\ A_i\ since\ K_W = \frac{A_C}{A_W}}$$

$$\mathrm{kVA\ rating\ of\ transformer, Q = 2.22\ f\ B_m\ A_i\ K_W\ A_W\ \delta \times 10^{-3}}$$

$$\mathrm{5 = 2.22 \times 50 \times 1 \times A_i \times 3\ A_i \times 0.2 \times 1.4 \times 10^6 \times 10^{-3}} = \mathbf{16.3\ kVA}$$

$$\mathrm{5 = 93{,}240 \times A_i^2}$$

$$\mathrm{A_i^2 = 5.36 \times 10^{-5}}$$

$\mathbf{A_i = 0.00732\ m^2}$**------------------------------------(4 M)**

$$\mathrm{A_{gi} = \frac{A_i}{K_i} = \frac{0.00732}{0.9} = 0.0081\ m^2}$$

$$\mathrm{for\ square\ core, area, A_{gi} = a^2}$$

$$\mathbf{a} = \sqrt{\mathrm{A_{gi}}} = \mathbf{0.09m}$$

$\mathbf{A_W} = 3\ \mathrm{A_i} = \mathbf{0.02196\ m^2}$**--------------------------(4M)**

$$\mathrm{A_W = H_W \times W_W = 3W_W \times W_W}$$

$$\mathrm{W_W^2 = \frac{A_W}{3} = 0.00732}$$

$$\mathbf{W_W = 0.0856\ m}$$

$$\mathbf{H_W = 3W_W = 0.2568\ m}$$

$$\mathrm{E_t = 4.44.\,f\,\varphi_m}$$

$$\mathrm{E_t = 4.44.\,f\,(B_m\ A_i) = 1.625V}$$

$$\mathrm{E_t} = \frac{\mathrm{V_P}}{\mathrm{T_P}} = \frac{\mathrm{V_S}}{\mathrm{T_S}}$$

$$\mathrm{T_P} = \frac{\mathrm{V_P}}{\mathrm{E_t}} = \frac{11000}{1.625} = 6769$$

$$\mathrm{T_S} = \frac{\mathrm{V_S}}{\mathrm{E_t}} = \frac{400}{1.625} = 246$$

$$\mathrm{Q} = \mathrm{V_P\,I_P} \times 10^{-3} = \mathrm{V_S\,I_S} \times 10^{-3}$$

$$\mathrm{I_P} = \frac{\mathrm{Q}}{\mathrm{V_P} \times 10^{-3}} = \frac{5}{11000 \times 10^{-3}} = \mathbf{0.4545A}$$ **-----------------------------------(3 M)**

$$\mathrm{I_S} = \frac{\mathrm{Q}}{\mathrm{V_S} \times 10^{-3}} = \frac{5}{400 \times 10^{-3}} = \mathbf{12.5A}$$

$$\mathbf{a_P} = \frac{\mathrm{I_P}}{\delta} = \frac{0.4545}{1.4} = \mathbf{0.3246\ mm^2}$$

$$\mathbf{a_S} = \frac{\mathrm{I_S}}{\delta} = \frac{12.5}{1.4} = \mathbf{8.93\ mm^2}$$ **---(2M)**

5 **Estimate the main dimensions including winding conductor area of a 3 phase, Δ-Y core type transformer rated at 300kVA, 6600 / 440V, 50Hz. A suitable core with 3-steps having a circumscribing circle of 0.25m diameter and a leg spacing of 0.4m is available. Emf/turn = 8.5V, current density = 2.5A/mm², $\mathbf{K_W}$ = 0.28, $\mathbf{S_f}$ = 0.9 (Nov 2016) (10 M) BTL3**

Given data:

$$f = 50Hz; emf/turn = 8.5V;\ \delta = 2.5\ A/mm^2\,; K_W = 0.28; S_f = 0.9; Q = 300kVA;$$

$$V_P = 6600V;\ V_S = 440V; 3\ steps; d = 0.25m; leg\ spacing = W_W = 0.4m;$$

Solution;

Primary delta connected; secondary star connected

$$\mathrm{V_P} = 6600\mathrm{V};\ \mathrm{V_S} = \frac{440}{\sqrt{3}} = 254\mathrm{V};$$

$$\mathrm{T_P} = \frac{\mathrm{V_P}}{\mathrm{E_t}} = \frac{6600}{8.5} = 776\ \text{turns}$$

$$\mathrm{T_S} = \frac{\mathrm{V_S}}{\mathrm{E_t}} = \frac{254}{8.5} = 30\ \text{turns}$$

$$\mathrm{Q} = 3\,\mathrm{V_P\,I_P} \times 10^{-3} = 3\,\mathrm{V_S\,I_S} \times 10^{-3}$$

$$\mathrm{I_P} = \frac{\mathrm{Q}}{3\,\mathrm{V_P} \times 10^{-3}} = \frac{300}{3 \times 6600 \times 10^{-3}} = \mathbf{15.15A}$$

$$\mathrm{I_S} = \frac{\mathrm{Q}}{3\,\mathrm{V_S} \times 10^{-3}} = \frac{300}{3 \times 254 \times 10^{-3}} = \mathbf{393.7A}$$ **---(4M)**

$$\mathbf{a_P = \frac{I_P}{\delta} = \frac{15.15}{2.5} = 6.06\ mm^2}$$

$$\mathbf{a_S = \frac{I_S}{\delta} = \frac{393.7}{2.5} = 157.48\ mm^2}$$ **---(3M)**

$$A_C = 2(a_P\,T_P + a_S\,T_S) = 2[(6.06 \times 776) + (157.48 \times 30)] = 18{,}853 mm^2$$

$$A_W = \frac{A_C}{K_W} = \frac{18{,}853}{0.28} = 67{,}332\ mm^2$$

$$\text{for 3 stepped core,} \frac{A_{gi}}{\pi/_4\ d^2} = 0.84$$

$$A_{gi} = 0.84\left(\frac{\pi}{4}\ d^2\right) = 0.84 \times \frac{\pi}{4} \times 0.25^2 = 0.0412\ m^2$$

$$\text{net core area,} A_i = S_f \times A_{gi} = 0.9 \times 0.0412 = 0.0371 m^2$$

$$\text{area of window,} A_W = H_W \times W_W$$

$$\mathbf{H_W = \frac{A_W}{W_W} = \frac{67{,}332 \times 10^{-6}}{0.4} = 0.168m}$$ **---(3M)**

6

Explain the design of oil tank and tubes for a transformer (May June 2010, Nov/Dec 2016) (10M) BTL2

Or

Derive an expression for the number of cooling tubes needed for a transformer. (April/May 2011)BTL 2

Answer on page no. 3.71 to 3.73 , M. Ramesh , Lekshmi publications

Sol:
Loss dissipated by surface of the tank by radiation and convection = (6+6.5)S_t = 12.5S_t
Loss dissipated by tubes by convection,

$$= 6.5 \times \frac{135}{100} \times XS_t = 8.8XS_t$$

Total loss dissipated by walls and tubes

$$= 12.5S_t + 8.8XS_t \ ----(1)$$

Total area of tank walls and tubes

$$= S_t + XS_t \ ----(2)$$

Loss dissipated per m^2 of dissipating surface

$$= \frac{\text{total loss dissipated}}{\text{total area}} = \frac{S_t\,(12.5 + 8.8X)}{S_t(1 + X)} = \frac{12.5 + 8.8X}{1 + X} ----(3)$$

Temperature rise in transformer with cooling tubes,

$$\theta = \frac{\text{total loss}}{\text{loss dissipated}} = \frac{P_i + P_C}{12.5\,S_t + 8.8XS_t} \text{ where } P_i - \text{iron loss}; P_C - \text{copper loss}$$

$$\theta S_t(12.5 + 8.8X) = P_i + P_C$$

$$(12.5 + 8.8X) = \frac{P_i + P_C}{\theta\,S_t}$$

$$8.8X = \frac{P_i + P_C}{\theta\,S_t} - 12.5$$

$$\boldsymbol{X = \frac{1}{8.8}\left[\frac{P_i + P_C}{\theta\,S_t} - 12.5\right] ----(4)}$$

Total area of cooling tubes

$$= XS_t = \frac{S_t}{8.8}\left[\frac{P_i + P_C}{\theta\,S_t} - 12.5\right] = \frac{1}{8.8}\left[\frac{P_i + P_C}{\theta} - 12.5S_t\right] ----(5)$$

$$\text{let}, l_t - \text{length of the tube}, d_t - \text{diameter of the tube}$$

$$\text{area of each tube} = \pi\,d_t\,l_t \ \text{(cylinder)} ----(6)$$

$$\text{total number of tubes} = n_t = \frac{\text{total area of tubes}}{\text{area of each tube}}$$

$$\boldsymbol{\text{total number of tubes} = n_t = \frac{1}{8.8\,\pi\,d_t\,l_t}\left[\frac{P_i + P_C}{\theta} - 12.5\,S_t\right]}$$

7

Determine the dimensions of core and yoke for a 200 kVA, 50 Hz single phase core type transformer. A cruciform core is used with distance between adjacent limbs equal to 1.6 times the width of core laminations. Assume voltage per turn of 14 volts, maximum flux density of 1.1 Wb/m^2, window space face of 0.32, current density of 3 A/mm^2 and stacking factor equal to 0.9 the net iron area is 0.56 d^2 where d is diameter of circumscribing circle. Width of the large-stamping is 0.85d. (10M) (April/ May 2012) BTL3

Given data: $Q = 200\text{kVA}$; $f = 50\text{Hz}$; $D = 1.6a$; $E_t = 14\text{V}$; $B_m = 1.1\text{wb/m}^2$; $K_W = 0.32$; $\delta = 3\text{A/mm}^2$; $K_i = 0.9$; $A_i = 0.56d^2$; $a = 0.85d$;

$E_t = 4.44\ f\ \phi_m$

$\Phi_m = E_t / 4.44\ f$

$= 14 / (4.44 \times 50)$

$= 0.0631\text{Wb}$

$B_m = \phi_m / A_i$

$A_i = \phi_m / B_m$

$= 0.0631 / 1.1$

$= 0.0574\text{m}^2$

$A_i / d^2 = 0.56$

$d^2 = A_i / 0.56$

$= 0.1025$

$\boxed{d = 0.32\text{m}}$

$a = 0.85d$

$= 0.85 \times 0.32$

$= 0.272\text{m}$

$D = 1.6a$

$= 1.6 \times 0.272$

$\boxed{D = 0.4352\text{m}}$

$W_W = D - d$

$= 0.4352 - 0.32$

$= 0.1152\text{m}$

$Q = 2.22\ f\ B_m\ A_i\ A_w\ K_w\ \delta \times 10^{-3}$

$A_w = Q / 2.22\ f\ B_m\ A_i\ K_w\ \delta \times 10^{-3}$

$= 200 / (2.22 \times 50 \times 1.1 \times 0.0574 \times 0.32 \times 3 \times 10^6 \times 10^{-3})$

$= 0.0297\text{m}^2$

$A_w = W_w \times H_w$

$H_w = A_w / W_w$

$= 0.0297 / 0.1152$

$\boxed{H_w = 0.2578\text{m}}$

Yoke dimensions:

Depth of yoke, **$D_y = a = 0.272\text{m}$**

Height of yoke, **$H_y = 0.272\text{m}$**

Overall height of frame, $H = H_w + 2H_y$

$= 0.2578 + (2 \times 0.272)$

$= 0.8018\text{m}$

Overall length of frame, $W = D + a$

$= 0.4352 + 0.272$

$= 0.7072\text{m}$

8

Calculate the main dimensions of core of 100 KVA, 2000/400 Volts, 50 Hz, single phase shell type transformer. Voltage per turn = 10 volts. Peak flux density in the core is 1.1 Wb/ m^2. Window space factor is 0.33. Ratio of core depth to width of central limb = 2.5. Ratio of window height to window width = 3; current density in the winding is 2 A/mm^2, Stacking factor = 0.9. (10M) (JUNE 2009) BTL3

Given data: $Q = 100kVA$; $V_p = 2000$; $V_s = 400$; $f = 50Hz$; $E_t = 10V$; $B_m = 1.1wb/m^2$; $K_w = 0.33$; depth / width = 2.5; $H_w / W_w = 3$; $\delta = 2A/mm^2$; $S_f = 0.9$;

For single phase transformer, $Q = 2.22\ f\ B_m\ A_w\ K_w\ \delta \times 10^{-3}$

$A_w = Q / (2.22 \times f \times B_m \times K_w \times \delta \times 10^{-3})$

$= 100 / (2.22 \times 50 \times 1.1 \times 0.33 \times 2 \times 10^6 \times 10^{-3})$

$= 0.00124m^2$

$A_w = H_w \times W_w$

$= (3W_w) \times W_w$

$= 3W_w^2$

$W_w^2 = A_w / 3$

$W_w = \sqrt{(A_w / 3)}$

$= \sqrt{(0.00124 / 3)}$

$= 0.0203m$

$H_w = 3\ W_w$

$= 3 \times 0.0203$

$= 0.0609$

$\boxed{W_w = 0.0203m \qquad H_w = 0.0609m}$ ---(5 M)

$E_t = 4.44\ f\ \phi_m$

$\Phi_m = E_t / (4.44 \times f)$

$= 10 / (4.44 \times 50)$

$= 0.045Wb$

$A_i = \phi_m / B_m$

$= 0.045 / 1.1$

$= 0.0409m^2$

$A_{gi} = A_i / S_f$

$= 0.0409 / 0.9$

$= 0.0454$

Depth / width = 2.5

Depth = 2.5 x width

A_{gi} = depth x width

= (2.5 x width) x width

= 2.5 x width^2

Width^2 = A_{gi} / 2.5

Width = $\sqrt{(A_{gi} / 2.5)}$

$= \sqrt{(0.0454 / 2.5)}$

$= 0.1348m$

Depth = 2.5 x 0.1348

= 0.337m

$\boxed{\text{Depth of core} = 0.337m, \text{width of core} = 0.1348m}$ -----------------------------(5 M)

9

Derive the voltage per turn equation for a single phase transformer. (8 M) (April/ May 2004, 2011, Nov/Dec 2017)

Sol :

$$\text{kVA rating}, Q = V_P\ I_P \times 10^{-3}$$

$$Q = E_P I_P \times 10^{-3}$$

$$Q = \frac{E_P}{T_P} T_P I_P \times 10^{-3}$$

$$Q = E_t T_P I_P \times 10^{-3}$$

$$Q = (4.44 f \varphi_m)AT \times 10^{-3} \quad --------(1)$$

the ratio φ_m/AT is a constant

Let, $\varphi_m/AT = r$ where r is a constant

$$Q = (4.44 f \varphi_m)AT \times 10^{-3} = 4.44 f \varphi_m \frac{\varphi_m}{r} \times 10^{-3}$$

$$Q = 4.44\, {}^{f}\!/_{r}\, \varphi_m^2 \times 10^{-3}$$

$$(\text{or})\varphi_m^2 = \frac{Q\, r \times 10^3}{4.44\, f}$$

$$\varphi_m = \sqrt{Q}\sqrt{\frac{r \times 10^3}{4.44\, f}}$$

$$E_t = 4.44 f \varphi_m = 4.44 f(\sqrt{Q}\sqrt{\frac{r \times 10^3}{4.44\, f}})$$

$$E_t = \sqrt{Q}\sqrt{r \times 10^3}\sqrt{4.44\, f}$$

$$E_t = K\sqrt{Q} \text{ where}, K = \sqrt{r \times 10^3}\sqrt{4.44\, f}$$

PART C

1. **A 250 KVA 6600/400, 3 phase core type transformer has a total loss of 4800 W at full load. The transformer tank is l.25 m in height and 1m x 0.5m in plan. Design a suitable scheme for tubes if the average temperature rise is to be limited to 35^{0}C. The diameter of the tube is 50mm and is spaced 75 mm from each other. The average height of the tube is 1.05m. Assume that convection is improved by 35% due to the provision of tubes. (16 M) (MAY 2011, DEC 2010, Nov 2013, May 2016) BTL 3**

Given data: Q = 250kVA; V_p =6600; V_s = 400; total loss = 4800W; H_T = 1.25m; W_T = 1m; L_T = 0.5m; θ = 35^{0}C; d_t = 50mm; spaced between two tubes = 75mm; h_t = l_t = 1.05m; improvement in convection = 35%

Total area of vertical sides, $S_t = 2(L_T H_T + W_T H_T)$

$= 2\{(0.5 \times 1.25) + (1 \times 1.25)\}$

$= 3.75m^2$

Loss dissipated by tank due to convection and radiation = $(6+6.5)\, S_t$

$= 12.5\, S_t$

Loss dissipated by cooling tubes due to convection = $6.5 \times (135 / 100) \times XS_t$

$= 8.8XS_t$

Total loss dissipated by tank and tubes = $12.5\, S_t + 8.8\, XS_t$

Temperature rise,

$$\theta = \frac{\text{total loss}}{\text{loss dissipated}} = \frac{P_i + P_C}{12.5\, S_t + 8.8XS_t}$$

$$\theta = \frac{4800}{12.5\, S_t + 8.8XS_t} = \frac{4800}{(12.5 \times 3.75) + (8.8X \times 3.75)}$$

$$35 = \frac{4800}{46.875 + 33X}$$

$46.875 + 33X = \frac{4800}{35}$

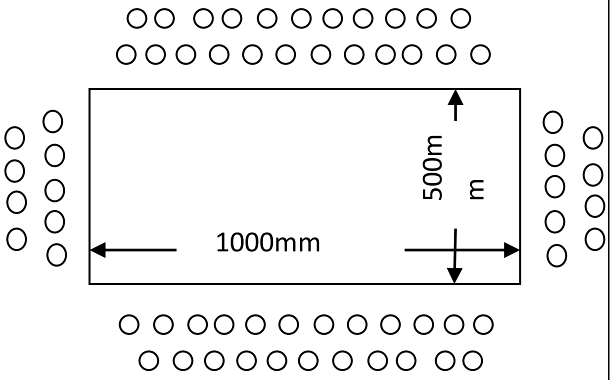
$$33X = \frac{4800}{35} - 46.875 = 90.27$$

$$\mathbf{X = \frac{90.27}{33} = 2.74}$$

$$\text{total number of tubes} = n_t = \frac{\text{total area of tubes}}{\text{area of each tube}}$$

$$\text{total number of tubes} = n_t = \frac{X\, S_t}{\pi\, d_t\, l_t} = \frac{2.74 \times 3.75}{\pi \times 50 \times 10^{-3} \times 1.05}$$

$$\textbf{total number of tubes}, \mathbf{n_t} = \textbf{62 tubes}$$



The width of the tank is 1000mm. We can arrange 12 or 13 tubes widthwise with a spacing of 75mm between the centres of tubes.

Total number of cooling tubes provided = 64

2 **A 6600V, 60Hz Single phase transformer has a core of sheet steel. The net iron cross sectional area is 22.6x10^{-3} m^2, the mean length is 2.23m and there are four lap joints. Each lap joint takes ¼ times as much reactive mmf as is required per metre of core. If B_m = 1.1wb/m^2, determine (1) the number of turns on the 6600V winding and (2) the no load current. Assume an amplitude factor of 1.52 and that for given flux density, mmf per metre = 232A/m; specific loss 1.76 W/kg, Specific gravity of plates = 7.5 kg/m^3 (16M) (DEC 2011) BTL3**

Given data: V = 6600; f = 60Hz; A_i = 22.6 x 10^{-3} m^2; mean length = 2.23m; B_m = 1.1wb/m^2; K_{pk} = amplitude factor x √2; amplitude factor = 1.52; mmf /metre = 232; P_i = 1.76W/kg; specific gravity = 7.5 x 10^3

(1) $\Phi_m = B_m A_i$
$= 1.1 \times 22.6 \times 10^{-3}$
= 0.0249Wb

$E = 4.44 f \phi_m T_p$
$T_p = E / 4.44 f \phi_m$
= 6600 / 4.44 x 60 x 0.0249

$$\boxed{T_p = 995 \text{ turns}}$$

(2) Mmf required for iron parts = 232 x 2.23
= 517
Mmf required for joints = 4 x (1/4) x 232
= 232
Total magnetizing mmf, AT_0 = 517 + 232
= 749
Magnetizing current, $I_m = AT_0 / K_{pk} T_p$
= 749 / (1.52 x √2 x 995)
= 0.35A
Weight of core = volume of the core x specific gravity
= length x area of iron core x specific gravity
= 2.23 x 22.6 x 10-3 x 7.5 x 10^3
= 378 kg
P_i = 1.76 x weight of core
= 1.76 x 378
= 665
$I_l = P_i / V$
= 665 / 6600
= 0.1

No load current,

$$I_0 = (I_m^2 + I_l^2)^{\frac{1}{2}} = \sqrt{0.4355^2 + 0.1^2}$$

$$I_0 = 0.36A$$

	UNIT III DESIGN OF DC MACHINES
	Construction - Output Equations – Main Dimensions – Choice of specific loadings – Selection of number of poles – Design of Armature – Design of commutators and brushes – design of field Computer program: Design of Armature main dimensions.
Q.No.	**PART-A**
1.	**State the factors which should be considered while selecting the no of poles in dc generator. (Nov/ Dec 2008, Nov/ Dec 2011) BTL 1** • Frequency • Weight of iron parts • Weight of copper • Length of commutators • Labor charges • Flash over between brushes • Distortion of field form
2	**What are the factors that affect the size of rotating machine? (Nov – Dec 2013, Nov-Dec 2016) BTL 1** • Armature or rotor diameter • Stator core length
3	**Define specific magnetic loading.BTL1** It is defined as the ratio of total flux around the air gap and the area of flux path at the air gap. $Bav = p \varphi / \pi D L$
4	**Define specific electric loading.(MAY ’11, May 2013, May 2014, Nov-Dec 2016) BTL1** It is defined as the ratio of total number of ampere conductors and the armature periphery at the air gap. $ac = I_z Z / \pi D$
5	**Why square pole is preferred? (Nov – Dec 2013) BTL 1** • To reduce copper requirements.
6	**What is equalizer connection? BTL 1** They are low resistance copper conductors employed in lap winding to equalize the induced emf in parallel path.
8	**State the relationship between number of armature coils and number of commutators segments in DC machine.(Dec 2007) BTL 1** Relationship between number of armature coils and number of commutators segments in a d.c. machine $\beta_C = \frac{\pi D_C}{C}$
9	**State different losses in a DC generator. BTL 1** Losses in a DC generator 1) Copper losses i) Armature copper loss = $I_a^2 R_a$. ii) Field copper loss = $(I^2_{sh} R_{sh}, I^2_{se} R_{se})$ 2) Magnetic losses (iron (or) copper loss)

	i) Hysteresis loss, $W_h B^{1.6}_{max} f$ ii) Eddy current loss $W_e B^{2}_{max} f$ iii) Mechanical loss
10	**State different losses in a machine (DEC 2007, MAY 2008) BTL 1** 1. Rotational losses i. frictional and windage losses & ii. Iron losses 2. Copper loss
11	**Give the main parts of a DC motor. (JUNE 2009, May 2008) BTL 1** • Field system (stator) • Armature (Rotor) • Commutators • Main poles • Inter poles • Frame
12	**What is slot loading? (MAY 2011) BTL 1** Slot loading = $I_z Z_{ss}$ where I_z = current in conductor and Z_{ss} = no of conductors
13	**Write down the output equation of a DC machine (May 2013, Nov 2016) BTL 1** $P_a = C_0 D^2 L n_s$ in kW $C_0 = \pi^2 B_{av}\, ac \times 10^{-3}$ Where, C_0 = output coefficient in kW / m^3 - rps B_{av} = specific electric loading ac = specific magnetic loading D = diameter of the core L = length of the core n_s = synchronous speed in rps
14	**What are the factors to be considered in the design of commutator of a DC machine? BTL 1** • Number of segments • Commutator diameter • Length of commutator
15	**What is peripheral speed ? (April/ May 2010) BTL1** It is a translational speed that may exist at the surface of the rotor while it is rotating**.** This is equivalent to the angular speed at the surface of rotor. **$V_a = \pi D n$ in m/sec**
16	Give the significance of core length to pole arc in the design. (Nov/ Dec 2010) BTL1 Sol: ratio is used to separate the D and L values in machine. • Square section type L=b= (0.45 to 0.55) τ • In long pole construction, L = (0.45 to 0.11) τ • Square pole face , L=b= 1

- Rectangular pole type , $L = (0.7 \text{ to } 0.9)\ \tau$

PART-B

1. **Derive output equation of a DC machine and point out its salient features. (Dec 2010, Nov 2012, May 2016) (8 M) BTL2**

Answer: Page: 2. 39 . Ramesh , Lekshmi Publications

Sol:

The output of a machine can be expressed in terms of its main dimensions, specific magnetic and electric loadings and speed. The equation which relates the power output to D, L, B_{av}, ac & n of the machine is known as "output equation".

Equation of induced emf as, $E = \phi ZN / 60\ (p/a)$

$= \phi Znp / a$ --------------(1)

In the armature of DC machine the conductors are connected in parallel paths.

Current through each conductor, $I_z = I_a / a$

(Or) $I_a = aI_z$ ---------------(2)

Specific magnetic loading, $B_{av} = p\phi / \pi DL$

(Or) $p\phi = \pi DL\ B_{av}$ ---------------(3)

Specific electric loading, $ac = I_zZ / \pi D$

(Or) $I_zZ = \pi D\ ac$ ---------------(4)

Power developed in armature, $P_a = EI_a \text{ x } 10^{-3}$ in kW ---------------(5)

Sub (1), (2) in (5)

$Pa = [\phi Znp / a]\ [aI_z\ ] \text{ x } 10^{-3}$

$= (p\phi)\ (I_zZ)\ n \text{ x } 10^{-3}$

$= (\pi DL\ B_{av})\ (\pi D\ ac)\ n \text{ x } 10^{-3}$

$\boxed{P_a = C_0D^2Ln \text{ where, } C_0 = \pi^2 B_{av}\ ac \text{ x } 10^{-3}}$ ---------------- (6) output equation

C_0 is called output coefficient

2 **A 5 KW, 250 volts and 4 poles, 1500 rpm DC shunt generator is designed to have a square pole face. The average magnetic flux density in the air gap is 0.42 wb/m^2 and ampere conductors per metre = 15,000. Compute the main dimensions of the machine. Assume full load efficiency = 87%. The ratio of pole arc to pole pitch = 0.66 (MAY 2011) (8 M)** BTL 3

Given data: P=5kW; V=250; p=4; N=1500rpm; square pole face; B_{av}=0.42wb/m^2; ac = 15,000 amp.cond/m; η=0.87; pole arc / pole pitch = 0.66

Input power, P_a = output power / η

= 5 / 0.87

= 5.75kW

Synchronous speed, n = N / 60

= 1500 / 60

= 25rps

Output coefficient, $C_0 = \pi^2 B_{av}\ ac \text{ x } 10^{-3}$

$= \pi^2 \text{x} 0.42 \text{x} 15,000 \text{x } 10^{-3}$

$= 62.1 \text{kW/m}^3\text{-rps}$

$P_a = C_0D^2Ln$

$D^2L = P_a / C_0 n$

$= 5.75 / (62.1x25)$

$= 3.7x10^{-3} m^3$ ---------(1)

For square pole face,

$L = \psi \tau$

$= \psi \pi D / p$

$= 0.66 \text{ x } \pi D / 4$

$L = 0.518D$ --------(2)

Sub (2) in (1)

$D^2 (0.518D) = 3.7 \text{ x } 10^{-3}$

$0.518D^3 = 3.7 \text{ x } 10^{-3}$

$\boxed{D = 0.193m}$

(2) →L=0.518(0.193)

$\boxed{L = 0.1m}$

3 **Find the main dimensions and the number of poles of a 37kW, 230V, 1400 rpm shunt motor so that a square pole face is obtained. The average gap density is 0.5 wb/m^2 and the ampere conductors per metre are 22,000. The ratio of pole arc to pole pitch is 0.7 and the full load efficiency is 90%(May 2016) BTL3**

Given data: $P_a = P = 37kW$ (for motor); V = 230; N = 1400 rpm; $B_{av} = 0.5$ wb/m^2; ac = 22,000; $\psi = 0.7$; $\eta = 90\%$;

To find number of poles:

If p = 2, then f = p N / 120 = (2x1400) / 120 = 23.33 Hz

If p = 4, then f = (4x1400) / 120 = 46.67Hz

Output power, $P = VI \text{ x } 10^{-3}$

$$I = \frac{P}{V \times 10^{-3}} = \frac{37}{230 \times 10^{-3}} = 160.86A$$

$$Let\ I_a \approx I \approx 160.86\ A < 200A$$

Current / parallel path < 200A

Frequency lies between 25 to 50Hz

p = 2 or 4

Let, p = 4 is the best choice.

Main dimensions:

Output coefficient, $C_0 = \pi^2 B_{av}\ ac \text{ x } 10^{-3}$

$= \pi^2 \text{ x } 0.5 \text{ x } 22{,}000 \text{ x } 10^{-3}$

$= 108.46$ kW / m^3-rps

$P_a = P = C_0 D^2 L n$

$D^2 L = P / C_0 n$

$= 37 / 108.46 \text{ x } (1400/60)$

$= 0.0146 \text{ m}^3$ ----------(1)

For square pole,

$L = \psi \tau = 0.7\ \tau$

$$L = 0.7\,\frac{\pi\,D}{p} = 0.7\,\frac{\pi\,D}{4} = 0.5495\,D - - - - - (2)$$

Sub (2) in (1), $D^2(0.5495D) = 0.0146$

$D^3 = 0.0265$

$\boxed{D = 0.298m = 0.3m}$

(2) → L = 0.5495 (0.3)

$\boxed{L = 0.16m}$

4

Explain the selection of number of poles in a DC machine. (April /May 2004, Nov/Dec 2017) (10M) BTL2

Sol:

1. **Frequency:**
   Frequency, f = pn / 2
   Therefore, if we choose a large number of poles, ‘f’ is high. Generally, the value of ‘f’ lies between 25-50 Hz but may be more in small machines.

2. **Weight of iron parts:**
   (i) Yoke area:
   Consider 2 pole machines
   Flux per pole = $\Phi_T / 2$
   At the yoke, this flux divides itself into 2 parts and therefore the yoke has to carry a flux $\Phi_T / 4$.
   Consider 4 pole machines
   Flux per pole = $\Phi_T / 4$
   Flux in the yoke = $\Phi_T / 8$
   Therefore, if number of poles is doubled, the flux carried by yoke is halved.

   Therefore the flux carried by yoke is inversely proportional to number of poles. Therefore, by using greater number of poles, the area of cross section of yoke is proportionally decreased.

   (ii) Armature core area:
   For 2 pole machine, flux in the armature core = $\Phi_T / 4$
   For 4 pole machine, flux in the armature core = $\Phi_T / 8$
   Let, B_c – flux density in armature core
   f – Frequency of flux reversals
   n – Speed in rps
   A_2 & A_4 – area of core for 2 pole and 4 pole machines

Consider eddy current loss
2 pole machine:

$$Eddy\ current\ loss \propto B_c^2\ f^2 \propto B_c^2\ (\frac{p\ n}{2})^2$$

$$Eddy\ current\ loss \propto (\frac{\varphi_T}{4A_2})^2 \times (\frac{2n}{2})^2$$

$$Eddy\ current\ loss \propto \frac{\varphi_T^2\ n^2}{16\ A_2^2} ------(1)$$

4 pole machine:

$$Eddy\ current\ loss \propto B_c^2\ f^2 \propto B_c^2\ (\frac{p\ n}{2})^2$$

$$Eddy\ current\ loss \propto (\frac{\varphi_T}{8A_4})^2 \times (\frac{4n}{2})^2$$

$$Eddy\ current\ loss \propto \frac{\varphi_T^2\ 4\ n^2}{64\ A_4^2}$$

$$Eddy\ current\ loss \infty \frac{\varphi_T^2\, n^2}{16\, A_4^2} - - - - - - (2)$$

From (1) & (2) for larger number of poles, cross sectional area of core is decreased and eddy current in core would be increased.

Consider hysteresis loss:

For 2 pole machine:

$$hysteresis\ loss \infty B_c^2\, f \infty B_c^2\ (\frac{p\, n}{2})$$

$$hysteresis\ loss \infty (\frac{\varphi_T}{4A_2})^{\,2} \times (\frac{2\, n}{2})$$

$$hysteresis\ loss \infty \frac{\varphi_T^2\, n}{16\, A_2} - - - - - - (3)$$

For 4 pole machine:

$$hysteresis\ loss \infty B_c^2\, f$$

$$hysteresis\ loss \infty (\frac{\varphi_T}{8A_4})^{\,2} \times (\frac{4\, n}{2})$$

$$hysteresis\ loss \infty \frac{\varphi_T^2\, 2n}{64\, A_4}$$

$$hysteresis\ loss \infty \frac{\varphi_T^2\, n}{32\, A_4} - - - - - - (4)$$

From (3) & (4), hysteresis loss decreases with increase in number of poles and also weight of iron in the armature core can be decreased.

3. **Weight of copper:**

(i) Armature copper:

The portion of conductors responsible for emf production in generators or torque production in motors is called the "active copper". Therefore, the portion of conductors embedded in slots is called the "active portion" while the portion of conductors in the overhang which just provides a connection between the active portion of conductors and thus does not take part in the energy conversion process, is called "inactive copper" or inactive portion of conductors.

Therefore, lesser the ratio of inactive conductor material to active conductor material, the machine will be cheaper.

(ii) Field copper:

Field mmf / pole vary inversely as the number of poles. Area of cross section of each pole in 2 pole machine is double that in the 4 pole machine.

Therefore, field mmf / pole in 2 pole machine is double that in the 4 pole machine.

Therefore, weight of field copper is more in 2 pole machines.

Therefore, total weight of field copper decreases with increase in number of poles.

4. **Length of commutator:**

For 2 pole machine, current / parallel path = $I_z = I_a / 2$

Therefore, current in each brush arm, $I_b = 2\ I_z = I_a$

For 4 pole machine, current / parallel path = $I_z = I_a / 4$

Therefore, current in each brush arm, $I_b = 2\ I_z = I_a / 2$

Therefore, area of brushes in each arm decreases if the number of poles increases. This results in reduction in the length of the commutator and incidentally results in reduction of overall length of machine.

5. **Labour charges:**

) **Armature coils:**

Emf equation, $E = (\Phi Znp) / a$

$E \infty Zn / a$ (since $p\Phi$ is constant)

For lap winding, $E \infty Zn / p$

$Z \infty p$

Therefore, the number of conductors increases with increase in number of poles.

i) **Field coils:**

The number of field coils is equal to the number of poles. Therefore, there are more field coils to be assembled if the number of poles is higher.

6. **Flash over**:

The use of a large number of poles results in increased danger of flashover between adjacent brush arms.

7. **Distortion of field form**:

Armature mmf per pole, $At_a = (ac \text{ x pole pitch}) / 2$

$= (ac / 2)\ (\pi\ D / p)$

Armature mmf per pole varies inversely with the number of poles. Hence, with a smaller number of poles, the armature mmf per pole increases resulting in distortion of field form and reduction in flux under load conditions. It causes poor commutation conditions and sparking.

Advantages of having large number of poles:

Reduction in

- Weight of armature core & yoke
- Cost of armature & field conductors
- Overall length & diameter of machine
- Length of commutator
- Distortion of field form under load conditions

Disadvantages of large number of poles:

Increase in

- Frequency of flux reversals
- Labour charges
- Possibility of flash over between brush arms

Guiding factors for choice of number of poles

(i) Frequency lies between 25 to 50Hz

(ii)Current / parallel path is limited to about 200A. thus current / brush arm should not be more than 400A

(iii) Armature mmf should not be excessively large

Output (kW)	Armature mmf pole (A)
Up to 100	5,000 or less

100 to 500	5,000 to 7,500
500 to 1500	7,500 to 10,000
Over 1500	Up to 12,500

Armature mmf / pole, Ata = (ac / 2) (π D / p)

5

Determine the main dimensions, number of poles and length of air gap of a 600kW, 500V, 900rpm generator. Assume average gap density as 0.6wb/m^2 and the ampere conductors per metre are 35,000. The ratio of pole arc to pole pitch is 0.75 & the efficiency is 91%. The following are the design constraints:

peripheral speed $\ngtr 40 m/s$; frequency of flux reversals $\ngtr 50$Hz ; current per brush arm $\ngtr 400$A; armature mmf per pole $\ngtr 7500$A

Assume that the mmf required for air gap is 50% of armature mmf and the gap contraction factor is 1.15 . (April /May 2018) BTL3

Given data:
P=600kW; V = 500; N = 900rpm; B_{av} = 0.6wb/m^2; ac = 35,000; ψ = 0.75; η = 91%; AT_g = 50% of AT_a; K_g = 1.15

Number of poles:

(i) f = pn / 2
If p = 2, f = 2 x (900 / 60) / 2 = 15
If p = 4, f = 30
If p = 6, f = 45
Frequency lies between 25 to 50Hz
Number of poles may be '4' or '6'
(ii) current per brush arm = $2I_a$ /a
$current\ per\ brush\ arm \ngtr 400A$

$P = VI \times 10^{-3}$
$I = P / V \times 10^{-3}$
$= 600 / 500 \times 10^{-3}$
$= 1200A \approx I_L \approx I_a$
Consider lap winding;
For p=4; Current / brush arm = 2 x 1200 / 4
= 600 > 400A
For p=6; Current / brush arm = 2 x 1200 / 6
= 400A

$\boxed{p=6}$ is the best choice.

Main dimensions:
$P_a = P / \eta = 600 / 0.91$

$P_a = 659.34kW$

$C_0 = \pi^2 B_{av}\, ac \times 10^{-3}$

$= \pi^2 \times 0.6 \times 35{,}000 \times 10^{-3}$

$$\boxed{C_o = 207 \text{ kW/m}^3\text{-rps}}$$

$P_a = C_0 D^2 L n$

$D^2 L = P_a / C_0 n$

$= 659.34 / 207 \times (900/60)$

$= 0.2123 m^3$ ----------(1)

$for\ square\ pole, L = \psi\, \tau$

$= 0.75 \times \pi D / p$

$= 0.75 \times \pi \times D / 6$

$L = 0.3925D$ -----------(2)

Sub (2) in (1)

$D^2\,(0.3925D) = 0.2123$

$D^3 = 0.5408\ m^3$

$D = 0.8147\ m$

$(2) \rightarrow L = 0.3925 \times 0.8147$

$L = 0.3197\ m$

$$\boxed{D = 0.81\text{ m};\ L = 0.32\text{ m}}$$

Air gap length: $l_g = \frac{AT_g}{8{,}00{,}000\ B_g\ K_g} = \frac{0.5 \times AT_a}{8{,}00{,}000 \times \frac{B_{av}}{\psi} \times 1.15}$

$$l_g = \frac{0.5 \times \frac{35{,}000 \times \pi \times 0.81}{6 \times 2}}{8{,}00{,}000 \times \frac{0.6}{0.75} \times 1.15} = 5mm$$

Checks:

$(i)\text{peripheral speed}, V_a = \pi\, D\, n = \pi \times 0.81 \times \frac{900}{60} = 38.151 \ngtr 40 m/s$

$(ii)\text{armature mmf per pole}, AT_a = \frac{ac\,\tau}{2} = \frac{35{,}000 \times (\pi \times 0.81/6)}{2} = 7418.25 \ngtr 7500A$

This is within specified limits.

6

A 250 kW, 500 volt, 600 rpm. DC generator is built with an armature diameter of 0.75 m and a core length of 0.3 m. The lap connected armature has 720 conductors. Using the data obtained from this machine, determine the armature diameter core length, number of armature slots, armature conductors and commutator segments for 350 kW, 440 volt, 720 rpm. 6 pole DC generator.
Assume a square pole face with ratio of pole to pole pitch is equal to 0.66. The 'full load efficiency is 0.91 and the internal voltage drop is 4 percent of rated voltage. The diameter of commutator is 0.7 of armature diameter. The pitch of commutator segments should not be less than 4mm. The voltage between adjacent segments should not exceed 15 V at no load. (14 M) (DEC 2008) BTL3

Sol: Machine 1

$P_a = P / \eta$

$C_0 = P_a / D^2Ln = \underline{\mathbf{= 163kW / m^3 – rps}}$

$E = V + I_aR_a = 520\ V$

$E = \phi Zn\ (p/a)$

$= (p\phi)\ (Zn/a)$

$= (B_{av}\pi DL)\ (Zn/a)$

$B_{av} = aE / \pi DLZn$

$\underline{\mathbf{= 0.61 Wb/m^2}}$

Machine 2 :

$P_a = 350 / 0.91$

$= 385kW$

(C_0 value same as Machine I)

$D^2L = P_a / C_0n$

$= 0.1968m^3$ -----------(1)

For square pole, $L = \psi\ \tau$

$= 0.66 \times \pi D / p$

$= 0.3454D$ ------------(2)

Sub (2) in (1), $D^2(0.3454D) = 0.1968$

$D^3 = 0.5698m^3$

$\boxed{D = 0.83m}$

(2) →

$L = (0.3454)\ (0.83)$

$\boxed{L = 0.29m}$

Number of armature conductors, $Z = Ea / \phi np$

$\boxed{Z= 496}$

No of slots = 87

No of coils = 348

Diameter of commutator, $D_c = 0.7 \times 0.83$

$= 0.581m$

Pitch of commutator segments, $\beta_c = \pi D_c / C$

$= \pi \times 0.581 / 348$

$= 5.24 \times 10^{-3}m$

7 **Find the minimum number of poles for a 1200 kW generator if the average voltage between commutator segments is not to exceed 15 & the armature mmf / pole is not to exceed 10,000 A. (April /May 2011,Nov / Dec 2018) (8 M) BTL3**

Sol:

output, $P = E\,I_a \times 10^{-3}$ kW

$$P = \frac{15\,Z}{2\,p}\,I_a \times 10^{-3}\ \text{kW since } C = E\,p/15 \Rightarrow E = 15\,C/p = 15\ (Z/2)/p$$

$$\text{armature mmf per pole, } AT_a = \frac{ac\,\tau}{2} = \frac{I_z\,Z}{\pi\,D}\,\frac{\pi\,D}{p\,2}$$

$$AT_a = \frac{I_a}{a}\,\frac{Z\,\pi\,D}{\pi\,D\,2\,p} = \frac{I_a\,Z}{a\,2\,p}$$

$$(\text{or})\frac{I_a\,Z}{2p} = AT_a\,a$$

$$therefore, P = (a\,AT_a)I_a \times 10^{-3}$$

$$a = \frac{P}{AT_a\,I_a \times 10^{-3}} = \frac{1200}{10{,}000 \times 15 \times 10^{-3}} = 8$$

For lap winding, a=p

Therefore, number of poles = 8

PART C

1 **Determine main dimensions, number of poles and length of air gap of a 1000kW, 500V, 300rpm DC generator. Assume average gap density as 0.7wb/m^2 and ampere conductors per metre as 40000. The pole arc to pole pitch ratio is 0.7 and the efficiency is 92%. The mmf required for air gap is 55% of armature mmf and gap contraction factor is 1.15. The following are the design constraints: peripheral speed should not exceed 30m/sec, frequency of flux reversals should not exceed 50Hz, current per brush arm should not exceed 400A, and armature mmf per pole should not exceed 10000A (DEC 2012) (15M) BTL3**

SOL:

Number of poles:

(i) f = pn / 2

If p = 2, f = 2 x (300 / 60) / 2 = 5

If p = 4, f = 10

If p = 6, f = 15

If p = 8, f = 20

If p = 10, f = 25

Frequency lies between 25 to 50Hz

Number of poles may be ‘10’

(ii) current per brush arm = $2I_a / a$

$P = VI \times 10^{-3}$

$I = P / V \times 10^{-3}$

$= 1000 / 500 \times 10^{-3}$

$= 2000A \approx I_L \approx I_a$

Current / brush arm = 2 x 2000 / 10

= 400 <= 400A

$\boxed{p=10}$ is the best choice for medium size machines

Main dimensions:

$P_a = P / \eta$

$= 1000 / 0.92$

$= 1086.95kW$

$C_0 = \pi^2 B_{av}\ ac \times 10^{-3}$

$= \pi^2 \times B_{av}\ ac \times 10^{-3}$

$= \pi^2 \times 0.7 \times 40000 \times 10^{-3}$

$= 276.068kW/m^3\text{-rps}$

$P_a = C_0 D^2 Ln$

$D^2L = P_a / C_0 n$

$= 1086.95 / 276.068 \times (300/60)$

$= 0.7874m^3$ ----------(1)

Assume square pole, $L = \psi\ \tau$

$L = 0.7 \times \tau$

$= 0.7 \times \pi D / p$

$= 0.7 \times \pi \times D / 10$

$L = 0.2198D$ -----------(2)

Sub (2) in (1)

$D^2 (0.2198D) = 0.7874$

$D^3 = 3.5823m^3$

$D = 1.53m$

(2) → $L = 0.2198 \times 1.53$

$L = 0.34m$

$\boxed{D = 1.53m;\ L = 0.34m}$

Air gap length:

$B_g = B_{av} / \psi$

$= 0.7 / 0.7$

$= 1$

$AT_a = ac\ \tau / 2$

$= (40000 \times \pi D) / (p \times 2)$

$= 9608.4 < 10,000$ (condition satisfied)

$l_g = AT_g / 8,00,000\ B_g K_g$

$= (0.55 \times AT_a) / 8,00,000 \times 1 \times 1.15$

$= (0.55 \times 9608.4) / (800000 \times 1 \times 1.15)$

$\boxed{l_g = 5.74mm}$

	UNIT IV DESIGN OF INDUCTION MOTORS
	Construction - Output equation of Induction motor – Main dimensions – choice of specific loadings – Design of squirrel cage rotor and wound rotor –Magnetic leakage calculations – Operating characteristics : Magnetizing current - Short circuit current – Circle diagram -Computer program: Design of slip-ring rotor
Q.No	**PART*A**
1.	**What is rotating transformer?(Nov 2016) BTL1** The principle of operation of induction motor is similar to that a transformer. The stator winding is equivalent to primary of a transformer and the rotor winding is equivalent to short circuited secondary of a transformer. In transformer the secondary is fixed but in induction motor it is allowed to rotate.
2	**What type of slots is preferred in Induction motor? (April /May 2011, Nov/ Dec 2019) BTL 1** **Sol:** Open slots and semi –enclosed slots
3	**Write the expression for output equation and output coefficient of induction motor. (DEC 2011, May 2013, May 2014) BTL1** Sol: The input KVA, $Q=C_oD^2Ln_s$in KVA Output coefficient, $C_o=11K_{ws}B_{av}ac$ x 10^{-3} in KVA/m^3-rps D = diameter of the core L = length of the core B_{av} = specific electric loading ac = specific magnetic loading K_{ws} = space factor n_s = synchronous speed
4	**What type of connection is preferred for stator of induction motor?BTL1** Sol: Under running condition the stator of induction motor is normally connected in delta. (In delta connection the torque developed will be higher than the star connection). But for reducing the starting current, the stator can be connected in star while starting and then changed to delta.
5	**What are the benefits of skewing the rotor of an induction motor? (May/June 2009, Nov/ Dec 2010, April/May 2018) BTL1** **Sol:** • Power factor • Overload capacity • Pulsation loss • Unbalanced magnetic pull • Cooling • Noise
6	**What are the factors to be considered for the choice of specific electric loading? (May 2016) BTL1** Sol: The choice of specific electric loading depends on copper loss, temperature rise, voltage rating and overload capacity.

7	**How the induction motor can be designed for best power factor? (Nov – Dec 2013, May 2016) BTL1** Sol: For best power factor the pole pitch, τ is chosen such that $\tau = \sqrt{(0.18 L)}$
8	**What is slot space factor? BTL1** Sol: The slot space factor is the ratio of conductor (or copper) area per slot and slot area. It gives an indication of the space occupied by the conductors and the space available for insulation. The slot space factor for induction motor varies from 0.25 to 0.4.
9	**What are the advantages and disadvantages of large air-gap length, in induction motor? BTL1** Sol: Advantages: A large air-gap length results in higher overload capacity, better cooling, reduction in noise and reduction in unbalanced magnetic pull. Disadvantages: The disadvantage of large air-gap length is that it results in high value of magnetizing current.
10	**What are the methods to reduce harmonic torques? (DEC 2010) BTL1** Sol: The methods used for reduction or elimination of harmonic torques are chording, integral slot winding, skewing and increasing the length of air-gap.
11	**What is crawling and clogging? BTL1** Sol: Crawling is a phenomenon in which the induction motor runs at a speed lesser than sub synchronous speed. Clogging is a phenomenon in which the induction motor refuses to start.
12	**What are the different losses in an induction motor? (DEC 2007) BTL1** a. **Constant loss**: These can be further classified as core losses and mechanical losses. b. **Variable loss**: This includes the copper losses in stator and rotor winding due to current flowing in the winding.
13	**What are the merits of slip-ring induction motor over cage-induction motor? (April/ MAY 2008) BTL1** • It is possible to insert resistances in the rotor circuit for the purpose of increasing the starting torque. • Starting current is low when compared to the cage induction motor.
14	**How does the external resistance of slip-ring induction motor influence the motor performance? (April/ MAY 2008) BTL1** Sol: The starting torque of a slip ring motor is increased by improving its power factor by adding external resistance in the rotor circuit from the star connected rheostat resistance being progressively cut out as the motor gathers speed. Addition of external resistance, however increases the rotor impedances and so reduces the rotor current.
15	**State the effect of change of air gap length in a 3 phase Induction motor (DEC2009, DEC2008) BTL1** • Length of the air gap determines the magnetizing current.

- Greater the length of the air gap, greater will be the over load capacity.

16 **How crawling can be prevented by design in an induction motor? (MAY 2011) BTL1**

Proper choice of coil pitch and distribution of coils while designing the winding, the harmonic flux in the air gap is reduced to very low value, which eliminates the crawling effect.

17 **Define dispersion coefficient of an induction motor (MAY 2011, DEC 2010, DEC 2009)BTL1**

Sol:

It is the ratio of magnetizing current to ideal short circuit current.

Dispersion coefficient = I_m / I_{sci} where, I_m = magnetizing current and I_{sci} = ideal short circuit current

18 **Define stator slot pitch (DEC 2011, May 2014) BTL1**

Stator slot pitch, y_{ss} = gap surface / total number of stator slots

$= \pi D / S_s$

19 **List the advantages of using open slots. (Nov – Dec 2013, Nov 2016) BTL1**

- Assembly of winding are easy
- Repair of winding are easy
- Magnetizing current is reduced

20 **What is meant by an ideal short circuit current? (May 2013)BTL1**

Ideal short circuit current is defined as the current drawn by the motor at standstill if its resistance is neglected.

PART B

1. **Derive the output equation of three phase Induction motor. (8 M) (Nov/Dec 2005, Nov / Dec 2007, April May 2011, April May 2018) BTL2**

Sol:

kVA rating of machine, Q = number of phases x output voltage per phase x current per phase x 10^{-3}

$$Q = m\,E_{ph} I_{ph} \times 10^{-3} \;----(1)$$

[Since terminal voltage = induced emf]

Induced emf / phase,

$E_{ph} = 4.44\ \mathrm{f}\ \varphi_m\ T_{ph}\ K_W \;----(2)$

sub (2)in (1), $Q = m(4.44\ \mathrm{f}\ \varphi_m\ T_{ph}\ K_W) I_{ph} \times 10^{-3}$

$Q = m\ 4.44 \left(\frac{p\ n_s}{2}\right) \varphi_m\ T_{ph}\ K_W\ I_{ph} \times 10^{-3} \;----(3)$

current in each conductor, $I_Z = \frac{I_a}{a} = I_a$ (since a = 1)

i.e. $I_Z = I_a = I_{ph}$

Total number of conductor, Z = number of phases x 2 x number of turns / phase

$\mathrm{Z = m\ 2\ T_{ph}}$

$\mathrm{total\ electric\ loading = \ I_Z\ Z = 2\ m\ T_{ph}\ I_{ph} ----(4)}$

$\mathrm{(3) \Longrightarrow Q = 1.11\ (p\varphi_m)\big(2\ m\ T_{ph}\ I_{ph}\ \big)n_S\ K_W\ \times\ 10^{-3}}$

$\mathrm{Q = 1.11\ (p\varphi_m)(\ I_Z\ Z\ )n_S\ K_W\ \times\ 10^{-3}}$

$\mathrm{Q = 1.11\ (B_{av}\ \pi\ DL)(\ ac\ \pi\ D\ )n_S\ K_W\ \times\ 10^{-3}}$

$\mathrm{Q = 1.11\ \pi^2\ B_{ac}\ ac\ D^2\ L\ n_S\ K_W\ \times\ 10^{-3}}$

$\mathrm{Q = (11\ B_{ac}\ ac\ K_W\ \times\ 10^{-3}\ )\ D^2\ L\ n_S}$

$$\boxed{Q = C_0\ D^2\ \ L\, n_S\ \ where\ C_0 = 11\ B_{av}\ ac\ K_W\ \times\ 10^{-3} = output\ coefficent}$$

$$kVA\ input = \frac{kW}{\eta\ cos\phi}$$

$$kVA\ input = \frac{kW}{\eta\ cos\phi} = \frac{HP\ \times 0.746}{\eta\ cos\phi}$$

2 Explain the factors governing the choice of ampere conductors per meter in the design of a three phase Induction motor. (8 M) (Nov/ Dec 2007, April/ may 2010) BTL2

Sol:

Copper loss & temperature rise:

A large value of ac means that a greater amount of copper is employed in the machine. This results in higher copper losses, poor power factor and also large temperature rise of embedded conductors.

Voltage:

A small value of ac should be taken for high voltage machines as the space required for insulation is large

Overload capacity:

A large value of ampere conductors would result in large number of turns per phase. Therefore, the leakage reactance of the machine becomes high and the diameter of circle diagram is reduced resulting in reduced value of overload capacity.

3 **Compute the' main dimensions of a 15 KW, three phase, 400 volts, 50 Hz, 2810 rpm squirrel cage induction motor having efficiency of 88 percent and full load power factor of 0.9.Assume specific magnetic loading equal to 0.5 Wb/m^2 and specific electric loading equal to 25,000 A/m. The rotor peripheral speed' may be approximately 20 m/sec at' synchronous speed. (10 M) (JUNE 2009, DEC 2010) BTL3**

Sol: kVA input = kW / (η x pf)

= 15 / (0.88 x 0.9)

= 18.94kVA

Output coefficient, $C_0 = 11\ B_{av}\ ac\ K_w \times 10^{-3}$

$= 11 \times 0.5 \times 25{,}000 \times 0.955 \times 10^{-3}$

= 131.31kVA /m^3-rps

Speed of rotor = 2810rpm & the nearest synchronous speed = 3000rpm

$Q = C_0\ D^2\ L\ n$

$D^2\ L = Q / C_0\ n$

$= 18.94 / (131.31 \times 3000 / 60)$

$= 2.88 \times 10^{-3}\ m^2$ ---------- (1)

$V_a = \pi D n$

$= 20m/s$

$D = V_a / \pi n$

$= 20 / (\pi \times 3000/60)$

$D = 0.127m$

$(1) \rightarrow D^2 L = 2.88 \times 10^{-3}$

$L = 2.88 \times 10^{-3}$

$\boxed{L = 0.179m}$

4 **Determine diameter and length of the stator core for an 11 kW, 400 V, 3 phase, 4-pole, 1425 rpm induction motor. Specific magnetic loading is 0.45 Wb/m^2 and specific electric loading is 23000 ac/m. Full load efficiency is 0.85 and full load power factor is 0.88. The ratio of core length to pole pitch = 1 (10 M) (DEC 2008, Nov / Dec 2011) BTL3**

Sol:

kVA input = kW / (η x pf)

= 11 / (0.85 x 0.88)

= 14.7kVA

Output coefficient, $C_0 = 11\ B_{av}\ ac\ K_w \times 10^{-3}$

$= 11 \times 0.45 \times 23{,}000 \times 0.955 \times 10^{-3}$

$= 108.73 kVA/m^3$-rps

Speed of rotor = 1425 rpm & the nearest synchronous speed = 1500rpm

$Q = C_0 D^2 L n$

$D^2 L = Q / C_0 n$

$= 14.7 / (108.73 \times 1500 / 60)$

$= 5.41 \times 10^{-3}\ m^2$ ---------- (1)

$L/_\tau = 1$

$L = \tau$

$= (\pi D / p)$

$= (\pi D / 4)$

$= 0.7854 D$ ------------ (2)

Sub (2) in (1), $D^2 (0.7854 D) = 5.41 \times 10^{-3}$

$D^3 = 0.0068$

$\boxed{D = 0.19m}$

L = (0.7854) (0.19)

$\boxed{L = 0.15m}$

5 **Find the values of diameter and length of stator core of a 7.5 kW, 220 V, 50 Hz, 4 pole, 3 phase induction motor for best power factor. Given: specific magnetic loading = 0.4Wb/m2; specific electric loading=22,000A/m; efficiency=0.86; power factor=0.87. Also find the main dimensions if the ratio of core length to pole pitch is unity (DEC 2008, Dec 2011) (10 M) BTL3**

Sol:

For best power factor:

Speed, $n = 2 f / p$

$= (2 \times 50) / 4$

$= 25$rps

kVA input, $Q = kW / (\eta \times pf)$

$= 7.5 / (0.86 \times 0.87)$

$= 10.02$kVA

Output coefficient, $C_0 = 11 B_{av} ac K_w \times 10^{-3}$

$= 11 \times 0.4 \times 22{,}000 \times 0.955 \times 10^{-3}$

$= 92.444$kVA /m^3-rps

$Q = C_0 D^2 L n$

$D^2 L = Q / C_0 n$

$= 10.02 / (92.444 \times 25)$

$= 4.34 \times 10^{-3}$ m^3 ---------- (1)

For best power factor,

$\tau = \sqrt{0.18 L}$

$\tau^2 = 0.18 L$

$$\left(\frac{\pi D}{p}\right)^2 = 0.18 L$$

$$D^2 = \frac{0.18 L p^2}{\pi^2}$$

$$D^2 = \frac{0.18 L 4^2}{\pi^2} = 0.2921 L - - - - - (2)$$

sub (2) in (1), $(0.2921L)L = 4.34 \times 10^{-3}$

$L^2 = 0.0148$

$\mathbf{L = 0.12\ m}$

$D^2 = (0.2921)(0.12) = 0.035$

$\boxed{\mathbf{D = 0.19\ m}}$

For core length to pole pitch unity:

$\mathbf{L/\tau = 1}$

$L = \tau$

$$L = \frac{\pi D}{p} = \frac{\pi D}{4} = 0.7854 D - - - - - (3)$$

sub (3) in (1), $D^2 (0.7854 D) = 4.34 \times 10^{-3}$

$D^3 = 0.0055$

$$\boldsymbol{D = 0.18\ m}$$
$$\boldsymbol{L = (0.7854)(0.18) = 0.14\ m}$$

6 **Determine the main dimensions, number of radial ventilating ducts, number of stator slots and turns per phase of a 3.7kW, three phases, 400V, 4 poles, and 50Hz squirrel cage induction motor to be started by a star-delta starter. Given that the average flux density in the air gap=0.45wb/m^2; ampere conductor per meter of armature periphery=23,000; full load efficiency=0.85, full load power factor=0.84 and K_w=0.955. Take L/τ = 1.5 (MAY 2011, DEC 2009) (13 M)**

Sol:

Main dimensions:

$$\text{speed}, n = \frac{2f}{p} = \frac{2 \times 50}{4} = 25 \text{ rps}$$

$$\text{kVA input}, Q = \frac{kW}{\eta \times pf} = \frac{3.7}{0.85 \times 0.84} = 5.18 \text{ kVA}$$

$$\text{output coefficient}, C_0 = 11\, B_{av}\, ac\, K_W \times 10^{-3}$$

$$C_0 = 11 \times 0.45 \times 23{,}000 \times 0.955 \times 10^{-3} = 108.73 \text{ kVA/m}^3 \text{ rps}$$

$$Q = C_0 D^2 L n$$

$$D^2 L = \frac{Q}{C_0 n} = \frac{5.18}{108.73 \times 25} = 1.9 \times 10^{-3} \text{ m}^2 - - - - - - (1)$$

$$\textbf{given}, \mathbf{L/\tau = 1.5}$$

$$L = 1.5\,\tau = 1.5 \frac{\pi D}{p} = 1.5 \frac{\pi D}{4} = 1.1775\, D - - - - - - -(2)$$

$$\text{sub (2)in (1)}, D^2 (1.1775\, D) = 1.9 \times 10^{-3}$$

$$D^3 = 0.0016$$

$$\boxed{\begin{array}{l}\mathbf{D = 0.12\ m} \\ \mathbf{L = (1.1775)(0.117) = 0.13\ m}\end{array}}$$

The length of core is 0.13m and therefore one radial duct 10mm wide is provided.

$$\boxed{\text{Number of ducts} = n_d = 1}$$

$$\text{net iron length}, L_i = S_f (L - n_d w_d) = 0.9\,(0.13 - 0.01) = 0.108 \text{ m}$$

Turns per phase:

$$\text{flux per pole}, \varphi_m = B_{av} L \tau = 0.45 \times 0.13 \times 0.094 = 5.5 \times 10^{-3} \text{ wb}$$

As the machine is started by a star delta starter, it is designed for delta connection.

Stator voltage per phase, E_s = 400V

$$\textbf{stator turns per phase}, \mathbf{T_S} = \frac{E_S}{4.44\, f\, \varphi_m K_W} = \frac{400}{4.44 \times 50 \times 5.5 \times 10^{-3} \times 0.955} = \mathbf{343\ turns}$$

Number of stator slots:

(i)**Let q = 2**

Number of stator slots = number of phases x q x number of poles
= 3 x 2 x 4 = 24

$$y_{SS} = \frac{\pi D}{S_S} = \frac{\pi \times 0.12}{24} = 0.0157\text{m} = 15.7\text{mm} > 15\text{mm}$$

(ii) **Let q = 3**

Number of stator slots = number of phases x q x number of poles
= 3 x 3 x 4 = 36

$$y_{SS} = \frac{\pi D}{S_S} = \frac{\pi \times 0.12}{36} = 0.01046\text{m} = 10.46\text{mm} < 15\text{mm} \;\&\; \text{also} > 10\text{mm}$$

$$\boxed{\text{Hence, } S_S = 36}$$

Total number of stator conductors = 6 T_s

= 6 x 343

= 2058

Conductors per slot, $Z_{ss} = 6\ T_s / S_s$

= 6 x 2058 / 36

= 57

Actual number of turns per phase, $T_s = S_s \times Z_{ss} / 6$

= (36 x 57) / 6

$$\boxed{T_s = 342 \text{ turns}}$$

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7 **11 kW, three phase, 6 poles, 50 Hz, 220 volts star connected induction motor has 54 stator slots, each containing 9 conductors. Calculate the value of bar and end ring currents. The number of rotor bars is 64. The machine has an efficiency of 86 percent and a power factor of 0.85. The rotor MMF may be assumed to be 85 percent of stator MMF. Also find the bar 'and the end ring sections if the current density is 5 A/mm^2 (JUNE 2009, DEC 2012)BTL3**

Sol:

Rotor bar current:

$$I_b = 0.85 \times \frac{6\ T_S\ I_S}{S_r} \quad \text{(rotor mmf = 85\% of stator mmf)}$$

$$\text{kVA input, } \mathbf{Q} = \frac{\text{kW}}{\eta \times \text{p.f}} = \frac{11}{0.86 \times 0.85} = \mathbf{15.05}\ \text{kVA}$$

$$I_S = \frac{\text{kVA}}{3\ E_S \times 10^{-3}} = \frac{15.05}{3 \times \frac{220}{\sqrt{3}} \times 10^{-3}} = 39.5\ \text{A}$$

Number of stator conductors = $Z_{ss} \times S_s$

= 9 x 54

= 486

(ie) $6T_{ph} = 486$

$T_{ph} = 81$

$$\boldsymbol{I_b} = 0.85 \times \frac{6 \times 81 \times 39.5}{64} = \mathbf{254.96}\boldsymbol{A}$$

$$\boldsymbol{I_e} = \frac{S_r\ I_b}{\pi\ p} = \frac{64 \times 254.96}{\pi \times 6} = \mathbf{866}\ \boldsymbol{A}$$

$$\boldsymbol{a_b} = \frac{I_b}{\delta_b} = \frac{254.97}{5} = \mathbf{50.99}\ \boldsymbol{mm^2}$$

$$\boldsymbol{a_e} = \frac{I_e}{\delta_e} = \frac{866.11}{5} = \mathbf{173.22}\ \boldsymbol{mm^2}$$

Part C

1. **Estimate the stator core dimensions and the total number of stator conductors for a 3ϕ, 100kW, 3300V, 50Hz, 12 pole star connected slip ring induction motor. Assume: average gap density = 0.4Wb/m^2; conductor per metre=25,000A/m; efficiency=0.9, power factor=0.9 and winding factor=0.96. Choose main dimensions to give best power factor. The slot loading should not exceed 500 ampere conductors (DEC 2011, DEC 2009, May 2013, Nov 2013, Nov 2014)(15 M) BTL3**

Sol:

Main dimensions:

$$\text{speed, n} = \frac{2\text{ f}}{\text{p}} = \frac{2 \times 50}{12} = 8.33\text{ rps}$$

$$\text{kVA input, }\mathbf{Q} = \frac{\text{kW}}{\eta \times \text{p.f}} = \frac{100}{0.9 \times 0.9} = \mathbf{123.46}\text{kVA}$$

Output coefficient, $C_0 = 11\ B_{av}\ ac\ K_w \times 10^{-3}$

$= 11 \times 0.4 \times 25{,}000 \times 0.96 \times 10^{-3}$

$= 105.6\text{kVA /m}^3\text{-rps}$

$Q = C_0\ D^2\ L\ n$

$$D^2L = \frac{Q}{C_0\ n_S} = \frac{123.46}{105.6 \times 8.33} = 0.1404\ m^3 - - - - - (1)$$

$$\textbf{for best power factor, } \boldsymbol{\tau} = \sqrt{\mathbf{0.18\ L}}$$

$$\tau^2 = 0.18\ L$$

$$\left(\frac{\pi\ D}{p}\right)^2 = 0.18\ L$$

$$D^2 = \frac{0.18\ L\ p^2}{\pi^2} = 2.6289\ L - - - - - (2)$$

$$(1) \Longrightarrow (2.6289L)L = 0.1404$$

$L^2 = 0.0534$

$L = 0.23m$

$D^2 = (0.2.6289)\ (0.23)$

$= 0.6046$

$D = 0.78m$

$$B_{av} = \frac{p\ \phi}{\pi\ D\ L}$$

$$\phi = \frac{B_{av}\ \pi\ D\ L}{p} = \frac{0.4 \times \pi \times 0.78 \times 0.23}{12} = 0.0188\text{ wb}$$

$$T_{ph} = \frac{E_{ph}}{4.44\ f\ \phi_m\ K_W} = \frac{3300/\sqrt{3}}{4.44 \times 50 \times 0.0188 \times 0.96} = 476\text{ turns}$$

Number of slots:

(i)y_{SS} varies between 15mm and 25mm

$$\text{when } y_{SS} = 15\text{mm}, S_S = \frac{\pi D}{y_{SS}} = \frac{\pi \times 0.78}{0.015} = 163$$

$$\text{when } y_{SS} = 25\text{mm}, S_S = \frac{\pi D}{y_{SS}} = \frac{\pi \times 0.78}{0.025} = 98$$

$\mathbf{S_S \text{ lies between } 98}$ & 163

$(\text{ii})S_S = \text{number of phases } \times \text{poles } \times q$

$\text{for } q = 2, S_S = 3 \times 12 \times 2 = 72$

$\text{for } q = 3, S_S = 3 \times 12 \times 3 = 108$

$\text{for } q = 4, S_S = 3 \times 12 \times 4 = 144$

$\text{for } q = 5, S_S = 3 \times 12 \times 5 = 180$

$\boldsymbol{S_S \text{ may be } 108 \text{ or } 144}$

Conductors per slot:

$$Z_{SS} = \frac{6\,T_{ph}}{S_S} = \frac{6 \times 476}{108} = 26 \; (\text{for } S_S = 108)$$

$$Z_{SS} = \frac{6\,T_{ph}}{S_S} = \frac{6 \times 476}{144} = 20 \; (\text{for } S_S = 144)$$

$$I_S = \frac{kVA}{3\,E_S \times 10^{-3}} = \frac{123.46}{3 \times \frac{3300}{\sqrt{3}} \times 10^{-3}} = 21.6\text{ A}$$

Slot loading should be less than 500

$I_S Z_{SS} = 21.6 \times 26 = 561.6 > 500 \; (\text{for } S_S = 104)$

$I_S Z_{SS} = 21.6 \times 20 = 432 < 500 \; (\text{for } S_S = 144)$

$\boldsymbol{\text{choose } S_S = 144}$ & $\boldsymbol{Z_{SS} = 20}$

2 **Estimate the main dimensions, air gap length, stator slots, stator turns per phase and cross sectional area of stator and rotor conductors for a 3Φ, 15HP, 400V, 6 pole, 50Hz induction motor. The motor is suitable for star delta starting B_{av} = 0.45 wb/m^2, ac = 20,000 amp cond / m, L/τ = 0.85, η = 0.9, power factor = 0.85**

Sol:

$$Q = \frac{HP \times 0.746}{\eta \times p.f} = \frac{15 \times 0.746}{0.9 \times 0.85} = 14.63\text{ kVA}$$

$C_0 = 11\,B_{av}\,ac\,K_W \times 10^{-3}$

$C_0 = 11 \times 0.45 \times 20{,}000 \times 0.955 \times 10^{-3} = 94.55\ \text{kVA/m}^3\text{ rps}$

$Q = C_0\,D^2\,L\,n_S$

$$n_S = \frac{2\,f}{p} = \frac{2 \times 50}{6} = 16.7\text{ rps}$$

$$D^2L = \frac{Q}{C_0\,n_S} = \frac{14.63}{94.55 \times 16.7} = 0.00927\text{ m}^3 - - - - - (1)$$

$L/_{\tau} = 0.85$

$$L = 0.85\,\tau = 0.85\,\frac{\pi D}{p} = 0.85\,\frac{\pi \times D}{6} = 0.4448\,D - - - (2)$$

$\text{sub (2)in (1)}, D^2\,(0.4448\,D) = 0.00927$

$D^3 = 0.0208$

$\boxed{\boldsymbol{D = 0.275\ m}}$

$$\boldsymbol{L = 0.4448 \times 0.275 = 0.122\ m}$$

Length of air gap:

$$l_g = 0.2 + 2\sqrt{D\ L}\ mm$$

$$\boldsymbol{l_g} = 0.2 + 2\sqrt{0.275 \times 0.122}\ mm = \mathbf{0.566\ mm}$$

Turns per phase:

$$\mathrm{B_{av}} = \frac{\mathrm{p}\ \phi}{\pi\ \mathrm{D\ L}}$$

$$\phi = \frac{\mathrm{B_{av}}\ \pi\ \mathrm{D\ L}}{\mathrm{p}} = \frac{0.45 \times \pi \times 0.275 \times 0.122}{6} = 0.0079\ \mathrm{wb}$$

$$\mathbf{T_{ph}} = \frac{\mathrm{E_{ph}}}{4.44\ \mathrm{f}\ \phi_{\mathrm{m}}\ \mathrm{K_W}} = \frac{400}{4.44 \times 50 \times 0.0079 \times 0.955} = \mathbf{239\ turns}$$

Number of slots:

(i)$\mathrm{y_{SS}}$ varies between 10mm and 15mm

$$\text{when } \mathrm{y_{SS}} = 10\mathrm{mm}, \mathrm{S_S} = \frac{\pi\ \mathrm{D}}{\mathrm{y_{SS}}} = \frac{\pi \times 0.275}{0.010} = 86$$

$$\text{when } \mathrm{y_{SS}} = 15\mathrm{mm}, \mathrm{S_S} = \frac{\pi\ \mathrm{D}}{\mathrm{y_{SS}}} = \frac{\pi \times 0.275}{0.015} = 58$$

$\mathbf{S_S}$ **lies between 58** & 86

(ii)$\mathrm{S_S}$ = number of phases × poles × q

for $\mathrm{q} = 2, \mathrm{S_S} = 3 \times 6 \times 2 = 36$

for $\mathrm{q} = 3, \mathrm{S_S} = 3 \times 6 \times 3 = 54$

for $\mathrm{q} = 4, \mathrm{S_S} = 3 \times 6 \times 4 = 72$ (lies between 58 & 86)

for $\mathrm{q} = 5, \mathrm{S_S} = 3 \times 6 \times 5 = 90$

$$\boldsymbol{S_S = 72}$$

$$\text{conductors/slot}, \mathrm{Z_{SS}} = \frac{6\ \mathrm{T_{ph}}}{\mathrm{S_S}} = \frac{6 \times 239}{72} = 20$$

$$\text{total stator conductors} = \mathrm{S_S} \times \mathrm{Z_{SS}} = 72 \times 20 = 1440$$

$$\mathrm{I_S} = \frac{\mathrm{kVA}}{3\ \mathrm{E_S} \times 10^{-3}} = \frac{14.63}{3 \times 400 \times 10^{-3}} = 12.19\ \mathrm{A}$$

$$\mathbf{a_S} = \frac{\mathrm{I_S}}{\delta} = \frac{12.19}{3} = \mathbf{4.06\ mm^2}\ (\text{assume } \delta = 3\ \mathrm{A/mm^2})$$

Rotor slots:

S_S-S_r # 0, ±p, ±2p, ±3p, ±5p, ±1, ±2, ± (p±1), ± (p±2)

Here, p = 6;

S_S-S_r cannot be 0, ±6, ±12, ±18, ±30, ±1, ±2, ±7, ± 5, ±8, ± 4

S_S-S_r can be ±3, ±9, ±10, ±11 …

Let, S_S-S_r = 3

S_r = S_S – 3 = 72 – 3 = 69

$$\text{rotor bar current}, I_b = 0.85 \times \frac{6\ T_S\, I_S}{S_r} \quad (\text{rotor mmf} = 85\% \text{ of stator mmf})$$

$$\boldsymbol{I_b} = 0.85 \times \frac{6\ \times 239\ \times 12.19}{69} = \mathbf{215.34A}$$

$$let, \delta_b = 4\ A/mm^2$$

Area of cross section of rotor bar,

$$\boldsymbol{a_b} = \frac{I_b}{\delta_b} = \frac{215.34}{4} = \mathbf{53.84\ mm^2}$$

End ring current,

$$\boldsymbol{I_e} = \frac{S_r\ I_b}{\pi\ p} = \frac{69 \times 215.34}{\pi\ \times 6} = \mathbf{788.67\ A}$$

Area of cross section of end ring,

$$let, \delta_e = 4\ A/mm^2$$

$$\boldsymbol{a_e} = \frac{I_e}{\delta_e} = \frac{788.67}{4} = \mathbf{197.17\ mm^2}$$

3 **A 415V, 3ϕ, 50Hz, 6 poles delta connected induction motor has a specific magnetic loading of 0.5wb/m^2 and a specific electric loading of 24,000A/m. The stator core length and diameter are 0.275m and 0.15m respectively. Find the output of the machine if the full load efficiency and power factor are 0.88 and 0.89 respectively. Determine the number of stator slots, conductors per slot and length of air gap (DEC 2010) BTL3**

Sol:

Output of the machine:

Speed, n = 2 f /p
= 2 x 50 / 6
= 16.67rps

Output coefficient, $C_0 = 11\ B_{av}\ ac\ K_w \times 10^{-3}$
= 11 x 0.5 x 24000 x 0.955 x 10-3
= 126.06 kVA / m^3 – rps

Input kVA, $Q = C_0\ D^2\ L\ n$
= 126.06 x 0.15^2 x 0.275 x 16.67
= 87.84 kVA

η = output / (input x pf)

Output = η x input x pf
= 0.88 x 87.84 x 0.89

Output = 68.79kW

Number of stator slots:

y_{ss} lies between 15 to 25mm

(i) Let q = 2

Number of stator slots = number of phases x q x number of poles

= 3 x 2 x 6

= 36

$y_{ss} = \pi D / S_s$

$= \pi \times 0.15 / 36$

= 13.08mm <15mm

(ii) Let q = 3

Number of stator slots = number of phases x q x number of poles

= 3 x 3 x 6

= 54

$y_{ss} = \pi D / S_s$

$= \pi \times 0.15 / 54$

= 8.7mm <15mm

Let $S_s = 36$

Conductors per slot:

Flux per pole, $\phi_m = B_{av} \pi D L / p$

$= 0.5 \times \pi \times 0.15 \times 0.275 / 6$

= 0.0108 Wb

As it is delta connected,

Stator voltage per phase, E_s = 415V

Stator turns per phase, $T_s = E_s / (4.44 f \phi_m K_w)$

= 415 / (4.44 x 50 x 0.0108 x 0.955)

$T_s = 181$

For $S_s = 36$, $Z_{ss} = 6 T_{ph} / S_s$

= (6 x 181) / 36

Z_{ss} = 30

	UNIT V DESIGN OF SYNCHRONOUS MACHINES
	Output equations – choice of specific loadings – Design of salient pole machines – Short circuit ratio – Armature design – Estimation of air gap length – Design of rotor –Design of damper winding – Determination of full load field MMF – Design of field winding – Design of turbo alternators Computer program: Design of Stator main dimensions-Brushless DC Machines
Q.No.	**PART*A**
1.	**Why salient pole construction is rejected for high speed alternators?** (Nov/Dec 2009, April May 2011) BTL1 • Rotating parts are subjected to very high mechanical Stress • Excessive windage loss • Noisy operation
2	**What is runaway speed?** (Nov/ Dec 2009, April/ May 2011, 2010, Nov/Dec 2010, April May 2004) BTL1 **Sol:** Speed at which the prime mover will run when its rated load is suddenly thrown off.
3	**Define short circuit ratio.** (April may 2011, Nov/ Dec 2010, May/ June 2010, Nov/Dec 2004, April/May 2008, Nov / Dec 2009, Nov/ Dec 2012. BTL1 Sol: ratio of the field current required producing rated voltage on open circuit to field current required to circulate rated current at short circuit. *SCR = 1/* X_d *= 1/ Synchronous reactance*
4	**What are the factors to be considered for the choice of specific magnetic loading**? (DEC 2011, May 2013) BTL1 Ans: • Iron loss • Voltage rating • Transient short circuit current • Stability • Parallel operation
5	**What are the factors to be considered for the choice of specific electric loading?**BTL1 Ans: The factors to be considered for the choice of specific electric loading are • Copper loss • Temperature rise • Voltage rating • Synchronous reactance • Stray load losses
6	**Write the expressions for length of air-gap in salient pole synchronous machine?** BTL1 Length of air-gap,

	$l_g = \frac{AT_{for}}{B_g K_g 10^{-6}}$ (Or) $l_g = \frac{AT_a SCRK_f}{B_{av} K_g 10^6}$
7	**What is the limiting factor for the diameter of synchronous machine?** (Nov – Dec 2013) BTL1 The limiting factor for the diameter of synchronous machine is the peripheral speed. The limiting value of peripheral speed is 175 m/sec for cylindrical rotor machines and 80 m/sec for salient pole machines.
8	**What are the constructional differences between salient pole type alternator and cylindrical rotor type alternator?** (DEC 2007, April/ May 2011)BTL1 Ans: term salient pole means projected pole. This type of rotor is used for low and medium speed machines. The prime mover used is water turbine which gives low speed 50 to 500 rpm. In order to get standard frequency 50 Hz, the number of poles lies in the range 12 to 120. Because of low speed such machines are characterized by large diameter and small length. Since water turbine is used' as a prime mover type of alternator is also called hydro electric generator.
9	**What is the use of-damper winding?** (April/MAY 2011, Nov/DEC 2008) BTL1 • To reduce the oscillations developed in the rotor of alternator when it is suddenly loaded • To start the synchronous motor as an induction motor
10	**How is cylindrical pole different from salient pole in a synchronous machine? (JUNE 2009)BTL1** i) Cylindrical pole are non projecting pole whereas the salient pole machines are projecting pole. ii) Cylindrical rotor construction is used for turbo alternators which are driven by high speed steam or gas turbines where as salient pole construction is used for generators driven by hydraulic turbine
11	**Determine the total number of slots in the stator of an alternator having 4 poles, 3 phase, 6 slots per pole for each phase?** (Nov 2016) BTL3 Number of slots = 3 x 4 x 6 = 72 slots
12	**List out the various methods for the elimination of harmonics from the generated voltage of synchronous machine.** (Nov/Dec 2003, May / June 2010) • Skewing • Chording • Distribution • Fractional slot winding • Large air gap length

13	**What are the effects of large air gap length on the performance of synchronous machine**? (Nov/ Dec 2003, 2012, 2018) BTL1 • Machine requires large mmf that results in an increase in the cost of machine. • Low regulation
15	**How are synchronous machines classified?** Nov/Dec 2010 BTL1 • Synchronous generator or alternator • Synchronous motor • Salient pole type • Non- Salient pole type.
16	**What are the advantages of short pitch coils?** April /May 2010 BTL1 ✓ Saves copper of end connections ✓ More sinusoidal waveform by reducing harmonic component ✓ Eddy current loss and hysteresis loss is reduced.
17	What are the factors to be considered for the selection of number of armature slots in synchronous machines? (May /June 2010) BTL1 ✓ Balanced winding ✓ Cost ✓ Hotspot temperature
	PART* B
1.	**Explain the design of Turbo alternators in detail** . (Nov/Dec 2015) BTL2 Sol: **<u>Main dimensions:</u>** Values of specific loadings are (small cooled generator) B_{av} = 0.54 to 0.65 wb/m^2; ac = 50,000 to 75,000 A/m Specific loadings now used in large water cooled generator are, B_{av} = 0.54 to 0.62 wb/m^2; ac = 1,80,000 to 2,00,000 A/m Maximum peripheral speed = 175 m/s **<u>Length of air gap:</u>** $armature\ mmf\ per\ pole, AT_a = \frac{ac\ \tau}{2}$ $no\ load\ field\ mmf, AT_{fo} = SCR \times AT_a$ SCR of modern turbo alternators is about 0.5 to 0.7 Assume 80% of no load mmf to be loss in the air gap. $mmf\ required\ for\ air\ gap, AT_g = 0.8 \times SCR \times \frac{ac\ \tau}{2}$ $also, AT_g = 8{,}00{,}000\ B_g\ K_g\ l_g$ $8{,}00{,}000\ B_g\ K_g\ l_g = 0.8\ SCR\ \frac{ac\ \tau}{2}$

$$l_g = \frac{0.8\, SCR\, ac\, \tau}{2\ \times 8{,}00{,}000\ \times\ B_g\, K_g}$$
$$l_g = \frac{5\ \times\ SCR\, ac\, \tau}{B_g\, K_g}\ \times\ 10^{-7}$$
$$for\ sinusoidal\ distribution, B_g =\ \left(\pi/_2\right) B_{av}$$

Stator Design:

Number of stator slots per pole per phase lies between 2 to 4 but in turbo alternators 8 or 9 slots per pole per phase may be used.
Slot pitch = 25 to 60mm
For large turbo alternators, slot pitch = 75 to 90mm
Current density = 8 to 9.5 A/mm^2

2

A 3000 rpm, 50Hz, 3Φ turbo alternator has a core length of 0.94m. The average gap density is 0.45 wb/m^2 & the ampere conductors per metre are 25,000. The peripheral speed of rotor is 100 m/s & the length of air gap is 20mm. Find the kVA output of the machine when the coils are (a) full pitch (b) chorded by 1/3 pole pitch. The winding can be taken as infinitely distributed with a phase spread of 60^0. (10 M) BTL3

Sol:

$$V_a = \pi\, D_r\, n = 100\ (given)$$
$$\mathrm{D_r} = \frac{100}{\pi\, \mathrm{n}} = \frac{100}{\pi\ \times\ \frac{3000}{60}} = 0.637\mathrm{m}$$
$$\mathrm{stator\ bore, D} =\ \mathrm{D_r} +\ 2\,\mathrm{l_g} = 0.637 + 2\ (\ 20\ \times\ 10^{-3}\ ) =\ 0.677\mathrm{m}$$
$$\mathrm{for}\ 60^0\ \mathrm{phase\ spread,} \mathrm{K_d} = 0.955$$

$$\mathrm{(a) for\ full\ pitch\ coil,} \mathrm{K_p}\ = 1$$
$$\mathrm{K_W} =\ \mathrm{K_d}\ \times\ \mathrm{K_P} = 0.955\ \times 1 = 0.955$$
$$\mathrm{C_o} =\ 11\ \mathrm{B_{av}}\ \mathrm{ac}\, \mathrm{K_W}\ \times\ 10^{-3} = 11\ \times 0.45\ \times 25000\ \times 0.955\ \times\ 10^{-3}$$
$$\mathrm{C_o} =\ 118.18\ \mathrm{kVA/m^3\ rps}$$
$$Q =\ C_o\, D^2\, L\, n = 118.18\ \times\ (0.677)^2\ \times 0.94\ \times\ \frac{3000}{60}$$
$$Q =\ 2545\ kVA$$

$$\mathrm{(b) angle\ of\ chording,} \alpha =\ {}^{180}/_{3} = 60^0$$
$$K_P = \cos{}^{\alpha}/_{2} = 0.866$$
$$\mathrm{K_W} =\ \mathrm{K_d}\ \times\ \mathrm{K_P} = 0.955\ \times 0.866 = 0.827$$
$$\mathrm{C_o} =\ 11\ \mathrm{B_{av}}\ \mathrm{ac}\, \mathrm{K_W}\ \times\ 10^{-3} = 11\ \times 0.45\ \times 25000\ \times 0.827\ \times\ 10^{-3}$$
$$\mathrm{C_o} =\ 102.34\ \mathrm{kVA/m^3\ rps}$$
$$\mathrm{Q} =\ \mathrm{C_o}\, \mathrm{D^2}\, \mathrm{L\, n} = 102.34\ \times\ (0.677)^2\ \times 0.94\ \times\ \frac{3000}{60}$$
$$Q =\ 2204\ kVA$$

3 **Estimate the diameter, core length, size and number of conductors, number of slots for stator of a 15MVA, 11kV, 50Hz, 2 pole star connected turbo alternator with 600 phase spread. Assume B_{av} = 0.55 wb/m^2, ac = 36,000 A/m, current density = 5 A/mm^2, peripheral speed = 160 m/s. The winding should be arranged to eliminate 5th harmonic . (8 M) BTL3**

Sol:

$$\mathrm{n} = \frac{2\,\mathrm{f}}{\mathrm{p}} = \frac{2\ \times 50}{2} = 50\ \mathrm{rps}$$

$$\mathrm{V_a} = \ \pi\,\mathrm{D}\,\mathrm{n} = 160$$

$$\mathrm{D} = \frac{160}{\pi\ \times 50} = 1.02\ \mathrm{m}$$

$$\text{for } 60^0 \text{ phase spread}, \mathrm{K_d} = 0.955$$

$$\text{to eliminate } 5^{\text{th}} \text{ harmonic, the coils should be chorded by an angle}, \alpha = \ {}^{180}\!/_{5} = \ 36^0$$

$$\mathrm{K_P} = \cos {}^{\alpha}\!/_{2} = \cos {}^{36}\!/_{2} = 0.951$$

$$\mathrm{K_W} = \ \mathrm{K_d}\ \times\ \mathrm{K_P} = 0.951\ \times 0.955 = 0.908$$

$$\mathrm{C_o} = \ 11\ \mathrm{B_{av}}\ \mathrm{ac}\ \mathrm{K_W}\ \times\ 10^{-3} = 11\ \times 0.55\ \times 36000\ \times 0.908\ \times\ 10^{-3}$$

$$\mathrm{C_o} = \ 198\ \mathrm{kVA/m^3\ rps}$$

$$\mathrm{Q} = \ \mathrm{C_o}\ \mathrm{D^2}\ \mathrm{L}\ \mathrm{n}$$

$$\mathrm{D^2L} = \ \frac{\mathrm{Q}}{\mathrm{C_o}\ \mathrm{n}} = \ \frac{15{,}000}{198\ \times 50} = 1.5151\ \mathrm{m^3}$$

$$(1.02)^2 L = = 1.5151$$

$$\mathrm{L} = 1.45\ \mathrm{m}$$

$$\text{pole pitch}, \tau = \frac{\pi\,\mathrm{D}}{\mathrm{p}} = \frac{\pi\ \times 1.02}{2} = 1.6014$$

$$\mathrm{B_{av}} = \ \frac{\mathrm{p}\ \varphi}{\pi\,\mathrm{D}\,\mathrm{L}}$$

$$\varphi = \ \frac{\mathrm{B_{av}}\ \pi\,\mathrm{D}\,\mathrm{L}}{\mathrm{p}} = \frac{0.55\ \times\ \pi\ \times 1.02\ \times 1.46}{2} = 1.2859\ \mathrm{wb}$$

$$\mathrm{T_{ph}} = \frac{\mathrm{E_{ph}}}{4.44\ \mathrm{f}\ \varphi\ \mathrm{K_W}} = \ \frac{{}^{11{,}000}\!/_{\sqrt{3}}}{4.44\ \times 50\ \times 1.2859\ \times 0.908} = 25$$

$$\text{number of stator conductors} = 6\ \mathrm{T_{ph}} = 6\ \times 25 = 150$$

$$\text{number of stator conductors} = 150$$

$$\text{number of slot}, \mathrm{S_S} = \mathrm{m}\ \mathrm{p}\ \mathrm{q} = 3\ \times 2\ \times 5$$

$$\mathrm{S_S} = 30$$

$$\text{conductors per slot}, \mathrm{Z_{SS}} = \frac{6\ \mathrm{T_{ph}}}{\mathrm{S_S}} = \ \frac{150}{30}$$

$$\mathrm{Z_{SS}} = 5$$

4 **588 MVA, 22,000V, 50 Hz, 2 pole, 3 Φ, star connected direct water cooled generator has a stator bore of 1.3m and a stator core length of 6m. If the stator winding has 2 conductors per slot and there are two circuits per phase, calculate (a) number of stator slots (b) the average flux density in the air gap. The specific electric loading is 2, 00,000 amp.cond / m. Assume a winding factor of 0.92. (10 M) BTL3**

Sol:

$$(a) S_S = \frac{6\ T_{ph}}{Z_{SS}}$$

$$ac = \frac{I_Z Z}{\pi\ D}$$

$$Z = \frac{ac\ \pi\ D}{I_Z}$$

$$I_Z = \frac{I_{ph}}{a}$$

$$I_{ph} = \frac{Q}{3\ V_{ph}\ \times\ 10^{-3}} = \frac{588\ \times\ 10^3}{3\ \times\ \frac{22000}{\sqrt{3}}\ \times\ 10^{-3}} = 15{,}430A$$

$$I_Z = \frac{15430}{2} = 7715A$$

$$Z = \frac{200000\ \times\ \pi\ \times 1.3}{7715} = 106$$

$$\text{conductors per slot}, Z_{SS} = \frac{6\ T_{ph}}{S_S}$$

$$S_S = \frac{6\ T_{ph}}{Z_{SS}} = \frac{6\ \times 18}{2} = 54$$

$$(b) B_{av} = \frac{p\ \varphi}{\pi\ D\ L}$$

$$\varphi = \frac{E_{ph}}{4.44\ f\ \left(\frac{T_{ph}}{a}\right)\ K_W} = \frac{22{,}000/\sqrt{3}}{4.44\ \times 50\ \times \frac{18}{2}\ \times 0.92} = 6.91\ \text{wb}$$

$$B_{av} = \frac{2\ \times 6.91}{\pi\ \times 1.3\ \times 6} = 0.564\ wb/m^2$$

5 **The following is the design data available for a 1250kVA, 3Φ, 50Hz, 3300V, star connected, 300 rpm alternator of salient pole type: stator bore D = 1.9m, stator core length L = 0.335m, pole arc / pole pitch = 0.66, turns / phase = 150, single layer concentric winding with 5 conductors / slot, short circuit ratio = 1.2. Assume that the distribution of gap flux is rectangular under the pole arc with zero values in the inter polar region. Calculate a) specific magnetic loading b) armature mmf / pole c) gap density over pole arc d) air gap length. Mmf required for air gap is 0.88 of no load field mmf and the gap contraction factor is 1.15. BTL3 10M**

Sol:

a)

$$B_{av} = \frac{p\,\varphi}{\pi\, D\, L}$$

$$p = \frac{2\,f}{n_S} = \frac{2\ \times 50}{300/60} = 20$$

$$E_{ph} = 4.44\, f\, \varphi\, T_{ph}\, K_W$$

$$\varphi = \frac{E_{ph}}{4.44\, f\, T_{ph}\, K_W} = \frac{3300/\sqrt{3}}{4.44\ \times 50\ \times 150\ \times 0.955} = 0.0599\ \text{wb}$$

$$B_{av} = \frac{20\ \times 0.0599}{\pi\ \times 1.9\ \times 0.335} = 0.599\ wb/m^2$$

$$b\ )\ I_{ph} = \frac{Q}{3\, V_{ph}\ \times\ 10^{-3}} = \frac{1250}{3\ \times\ \frac{3300}{\sqrt{3}}\ \times\ 10^{-3}} = 218.69\ A$$

$$AT_a = 2.7\ \frac{I_{ph}\, T_{ph}\, K_W}{p}$$

$$AT_a = 2.7\ \frac{218.69\ \times 150\ \times 0.955}{20} = 4229\ A$$

$$c)\ B_g = \frac{B_{av}}{\psi} = \frac{0.599}{0.66} = 0.9076\ wb/m^2$$

$$\text{d) } AT_g = 0.88\ \times\ AT_{FO}$$

$$8{,}00{,}000\ B_g\ K_g\ l_g = 0.88\ (AT_a\ \times SCR)$$

$$l_g = \frac{0.88\ AT_a\ \times SCR}{8{,}00{,}000\ B_g\ K_g} = \frac{0.88\ \times 4229\ \times 1.2}{8{,}00{,}000\ \times 0.9076\ \times 1.15}$$

$$\boxed{\boldsymbol{l_g = 5.35\ mm}}$$

PART C

1\. **Describe the procedure for the design of filed winding of alternator .(13 M) (** Nov /Dec 2012) BTL3

I. Full load field mmf is twice the armature mmf

$AT_{fl} = 2\ AT_a$

II. Voltage across each field coil E_f

III. Length mean turn

	IV. Area of field conductor , a_f V. Field current , a_f / I_f = δ_f ----- field conductor current density VI. Total area of the field conductors and conductors per slot.
2	**The field coils of a salient pole alternator are wound with a single layer winding of bare copper strip 30 mm drop, with separating insulation 0.15 mm thick. Compute thickness of the conductor, number of turns and height of the winding to develop an mmf of 12000 ampere turns with a potential difference of 5 volts per coil and a loss of 1200 watts/m^2 of coil surface area. Mean length of turn is 1.2 metre. Resistivity of copper is 0.021.Ω/m & mm^2. (15 M)(DEC 2010). BTL3** Sol: Area of field conductor, $a_f = AT_{fl}\ \rho\ L_{mtf} / E_f$ $= 12,000 \times 0.021 \times 1.2 / 5$ $= 60.48\ mm^2$ Height of conductor = a_f / d_f $= 60.48 / 30$ $= 2mm$ Total heat dissipating surface, $S = 2\ L_{mtf}\ (h_f + d_f)$ $= 2 \times 1.2\ (h_f + 0.03)$ $= 2.4\ h_f + 0.072$ Total loss dissipated, $Q_f = q_f\ (S)$ $= 1200\ (2.4\ h_f + 0.072)$ ---------------- (1) $I_f = Q_f / E_f$ $= 1200\ (\ 2.4\ h_f + 0.072) / 5$ $= 576\ h_f + 17.28$ Field mmf = $I_f\ T_f$ $= (576\ h_f + 17.28)\ T_f$ $576\ h_f\ T_f + 17.3\ T_f = 12,000$ ---------------- (2) Height occupied by each conductor = 2 + 0.15 = 2.15mm Winding height, $h_f = T_f \times 2.15 \times 10^{-3}$ (1) $\rightarrow 576\ (\ T_f \times 2.15 \times 10^{-3})\ T_f + 17.3\ T_f = 12,000$ $1.2384\ T_f^2 + 17.3\ T_f - 12,000 = 0$ $T_f = 92\ \&\ -106$ $T_f = 92$ $h_f = T_f \times 2.15 \times 10^{-3}$ $h_f = 0.1978m$
3	**A 1250kVA, 3 Φ, 6600V, salient pole alternator has the following data: air gap diameter = 1.6m, length of core = 0.45m, number of poles =20, armature ampere conductors per metre = 28,000, ratio pole arc / pole pitch = 0.68, stator slot pitch = 28mm, current density in damper bars = 3 A/mm^2. Design a suitable damper winding for the machine. (15 M) BTL3** Sol:

$$area\ per\ pole\ of\ damper, A_d = 0.2\ ac\ \tau/\delta_d$$

$$\mathrm{A_d} = \frac{0.2\ \times 28000\ \times \frac{\pi\,\mathrm{D}}{\mathrm{p}}}{3} = \frac{0.2\ \times 28{,}000\ \times \frac{\pi \times 1.6}{20} \times\ 10^3\ \times\ 10^{-3}}{3}$$

$$\boxed{A_d = 469\ mm^2}$$

$$\mathrm{N_d} = \frac{\text{pole arc}}{0.8\ \times\ \mathrm{y_{SS}}} = \frac{0.68\ \times \frac{\pi \times 1.6}{20} \times\ 10^3}{0.8\ \times 28} = 7.6\ \approx 8$$

$$\boxed{N_d = 7.6\ \approx 8}$$

$$\text{area of each bar}, \mathrm{a_d} = \frac{\mathrm{A_d}}{\mathrm{N_d}} = \frac{469}{8} = 59\ \mathrm{mm^2}$$

$$\text{diameter of each bar}, \mathrm{d_d} :\ \mathrm{a_d} = {}^{\pi}/_{4}\ \mathrm{d_d^2}$$

$$\mathrm{d_d^2} = \frac{4\ \mathrm{a_d}}{\pi}$$

$$\mathrm{d_d} = \sqrt{\frac{4\ \times 59}{\pi}} = 8.7\ \mathrm{mm}$$

$$\boxed{\mathrm{d_d} = 8.7\ \mathrm{mm}}$$

$$\boxed{length\ of\ each\ bar, L_b = 1.1\ L = 1.1\ \times 0.45 = 0.5m}$$

EE8006	POWER QUALITY	L	T	P	C
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OBJECTIVES: To impart knowledge about the following topics:

- Causes & Mitigation techniques of various PQ events.
- Various Active & Passive power filters.

UNIT I INTRODUCTION TO POWER QUALITY 9

Terms and definitions & Sources – Overloading, under voltage, over voltage - Concepts of transients - Short duration variations such as interruption - Long duration variation such as sustained interruption - Sags and swells - Voltage sag - Voltage swell - Voltage imbalance – Voltage fluctuations - Power frequency variations - International standards of power quality **–** Computer Business Equipment Manufacturers Associations (CBEMA) curve

UNIT II VOLTAGE SAG AND SWELL 9

Estimating voltage sag performance - Thevenin's equivalent source - Analysis and calculation of various faulted condition - Estimation of the sag severity - Mitigation of voltage sag, Static transfer switches and fast transfer switches. - Capacitor switching – Lightning - Ferro resonance - Mitigation of voltage swell.

UNIT III HARMONICS 9

Harmonic sources from commercial and industrial loads - Locating harmonic sources – Power system response characteristics - Harmonics Vs transients. Effect of harmonics – Harmonic distortion - Voltage and current distortions - Harmonic indices - Inter harmonics – Resonance Harmonic distortion evaluation, IEEE and IEC standards.

UNIT IV PASSIVE POWER COMPENSATORS 9

Principle of Operation of Passive Shunt and Series Compensators, Analysis and Design of Passive Shunt Compensators Simulation and Performance of Passive Power Filters- Limitations of Passive Filters Parallel Resonance of Passive Filters with the Supply System and Its Mitigation. Fundamentals of load compensation – voltage regulation & power factor correction.

UNIT V POWER QUALITY MONITORING & CUSTOM POWER DEVICES 9

Monitoring considerations - Monitoring and diagnostic techniques for various power quality problems - Quality measurement equipment - Harmonic / spectrum analyzer - Flicker meters Disturbance analyzer - Applications of expert systems for power quality monitoring. Principle& Working of DSTATCOM – DSTATCOM in Voltage control mode, current control mode, DVR Structure – Rectifier supported DVR – DC Capacitor supported DVR - Unified power quality conditioner.

TOTAL : 45 PERIODS

OUTCOMES:

- Ability to understand various sources, causes and effects of power quality issues, electrical systems and their measures and mitigation.
- Ability to analyze the causes & Mitigation techniques of various PQ events.
- Ability to study about the various Active & Passive power filters.
- Ability to understand the concepts about Voltage and current distortions, harmonics.

- Ability to analyze and design the passive filters.
- Ability to acquire knowledge on compensation techniques.
- Ability to acquire knowledge on DVR.

TEXT BOOKS:

1. Roger. C. Dugan, Mark. F. Mc Granagham, Surya Santoso, H.WayneBeaty, “Electrical Power Systems Quality”, McGraw Hill,2003
2. J. Arrillaga, N.R. Watson, S. Chen, “Power System Quality Assessment”, (New York : Wiley),2000.
3. Bhim Singh, Ambrish Chandra, Kamal Al-Haddad,” Power Quality Problems & Mitigation Techniques” Wiley, 2015.

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1. G.T. Heydt, “Electric Power Quality”, 2nd Edition. (West Lafayette, IN, Stars in a Circle Publications, 1994.
2. M.H.J Bollen, “Understanding Power Quality Problems: Voltage Sags and Interruptions”, (New York: IEEE Press), 2000.

	UNIT I – INTRODUCTION TO POWER QUALITY
	Terms and definitions & Sources – Overloading, under voltage, over voltage - Concepts of transients - Short duration variations such as interruption - Long duration variation such as sustained interruption - Sags and swells - Voltage sag - Voltage swell - Voltage imbalance – Voltage fluctuations - Power frequency variations - International standards of power quality Computer Business Equipment Manufacturers Associations (CBEMA) curve
	PART*A
1	**Define voltage swell.A/M 2016** BTL2 Voltage swell is defined as a temporary increase in the RMS value of the voltage of more than 10 percent of the nominal voltage, at the power frequency, for durations from 0.5 cycles to 1 min.
2	**List the major power quality issue.N/D 2017** BTL1 ➢ Power frequency disturbances ➢ Power system transients ➢ Grounding and Bonding ➢ Electromagnetic interference ➢ Power system harmonics ➢ Electrostatic discharge ➢ Power factor
3	**Define voltage sag.**BTL2 A/M 2015 Voltage sag is defined as a decrease to between 0.1 and 0.9 pu in RMS voltage or current at the power frequency for durations of 0.5 cycles to 1 min.
4	**What are the commonly used terms that describe the parameters of electrical power that describe or measure power quality? N/D 2016** BTL1 Sag, swell, interruption, transients, harmonics, waveform distortion, over voltages, under voltages, voltage imbalance, power frequency variations, etc.
5	**What is the most common power quality problem?N/D 2017 N/D 2019**BTL1 Voltage sags are considered the most common power quality problem. These can be caused by the utility or by customer loads. When sourced from the utility, they are most commonly caused by faults on the distribution system. These sags will be from 3 to 30 cyclesand can be single or three phase. Depending on the design of the distribution system, a ground fault on 1 phase can cause a simultaneous swell on another phase.

6	**Define momentary interruption and components of waveform distortion.**BTL2 N/D 2017 Momentary interruption is said to occur when the RMS voltage decrease less than 0.1 per unit for time duration of 0.008333 second to 3 second. **Causes:** Utility re-closer operation, faulty circuit breakers, bad wiring connections. **Effects:** Lost data, destruction of files, damaged hard disk. <u>Components of waveform distortion:</u> ☐ DC offset ☐ Notches ☐ Flickering ☐ Harmonics ☐ Noises ☐ Inter-harmonics
7	**How can power quality problems be detected?A/M 2016**BTL4 ➢ A piece of equipment misoperates at the same time of a day. ➢ Circuit breakers trip without being overloaded. ➢ Equipment fails during a thunderstorm. ➢ Automated systems stop for no apparent reason.
8	**Comment "harmonics affect the electrical system".A/M 2016 N/D 2017**BTL2 Harmonics cause magnetic portions of the electrical system to overheat such as transformers, line reactors, magnetic relays and power factor capacitors.
9	**How do harmonics affect the load?**BTL2 The effect of harmonics on loads varies a great deal and is dependent on the load itself. Most loads are not affected by moderate levels of harmonics. Exceptions to this are loads that perform electrical measurements in the frequency domain of the harmonics.
10	**How do you measure power quality?A/M 2015** BTL2 It requires power quality measurement equipment to measure, record and diagnose harmonic problems. Power quality instruments offer a service of characterizing all aspects of power quality and determining if it is acceptable to the load.
11	**Classify the types of power quality solutions available on the market today.**BTL1 There are hundreds of manufacturers making thousands of different Power Quality solutions today. The categories of these solutions are: ➢ Utility based solutions for the substation level. ➢ User based solution for whole facility protection. ➢ User load level solutions for specific loads. ➢ Designed in solutions, built in by the equipment manufacturer to reduce the sensitivity to Power Quality problems.
12	**Why is power conditioning needed? A/M 2016** BTL2 Effective power conditioning will prevent the erosion of your equipment and by filtering out these harmful properties will substantially enhance its reliability.
13	**What types of equipment are affected by power line noise?**BTL2 Any equipment based on semiconductor technology can be affected which includes all computers, telecommunications PBXs and key systems, automated manufacturing and design systems, computerized medical equipment and point of sale terminals.

14	**What represent quality of power?**BTL2 This term covers technical aspects as well as non-technical aspects like the interaction between the customer and the network operator. Eg. The speed with which the network operator reacts to complaints, etc.
15	**Comment transients or noise on the power line causing problems now.**BTL4 Advances in digital logic technology have produced smaller and more sophisticated devices. This new generation of micro-circuitry is extremely dense and substantially more susceptible and transient damage.
16	**What are the power quality issues?**BTL1 Power frequency disturbances, power system transients, grounding and bonding, electromagnetic interference, power system harmonics, electrostatic discharge, power factor.
17	**Classify power quality events in short duration events A/M 2019.**BTL1 ➢ Sag ➢ Swell ➢ Interruption.
18	**Mention the types of sag.**BTL1 ➢ Instantaneous sag ➢ Momentary sag ➢ Temporary sag
19	**Mention the types of swell.**BTL1 ➢ Instantaneous swell ➢ Momentary swell ➢ Temporary swell
20	**List the types of interruption.**BTL1 ➢ Sustained interruption ➢ Momentary interruption ➢ Temporary interruption
	PART –B
1.	**Explain the major power quality issues in detail. (13 M)AU DEC-2015 N/D 2019** BTL2 **Answer: Page:1.8 - C.Ravichandran** ➢ **Power Frequency Disturbances (2 M)** (a) Low frequency phenomena that results in voltage sags or swells. (b)Source or load generated due to faults or switching operations. ➢ **Power System Transients (2 M)** (a)Fast and short duration events that produce distortions such as notching, ringing etc. ➢ **Grounding and Bonding(2 M)** (a)The fundamental objective of grounding is safety. (b)The second objective is to provide a low impedance path. (c)The third use of grounding is to create a ground reference plane. ➢ **Electromagnetic Interference (2 M)** (a)Interaction between electric and magnetic fields and sensitive electronic circuits and devices. (b)High frequency phenomenon.

	➢ **Power System harmonics (2 M)** (a) Low frequency phenomena characterized by waveform distortion. ➢ **Electrostatic discharge (1 M)** (a) Very common and unlikable occurrence. (b) Uncomfortable nuisance we are subjected to when we open the door of a car or the refrigerated case in the supermarket. ➢ **Power Factor (2 M)** (a) Power factor is an economic issue in the operation of a power system. (b) As utilities are increased faced with power demands that exceed generation capability, the penalty for low power factor is expected to increase.
2.	**Explain the following: (13 M)AU DEC-2016 A/M 2019**BTL2 **(a) Total harmonic distortion (7 M)** **(b) Total demand distortion(6 M)** **Answer: Page:1.45 - C.Ravichandran**. **(a)Total Harmonic Distortion (7 M)** **Definition**: (**2 M**) Used to describe the net deviation of a non-linear waveform from ideal sine wave characteristics. **Expression & Explanation**: (**5 M**) $\mathrm{THD}=\sqrt{\frac{\sum_{n=3,5,7,\ldots}V_n^2}{V_1^2}}$ Where V_1 – Fundamental Component, V_h– harmonic component, h – harmonic order **(b) Total Demand Distortion: (6 M)** **Definition**: **(2 M)** The square root of the sum of the squares of the RMS value of the currents from 2nd to the highest harmonic divided by the peak demand load current and is expressed as percent. **Expression & Explanation**: **(4 M)** TDD = I_{RMS} distorted / Maximum demand load current (I_d max) Two ways to measure ➢ $I_{d\ max}$ – Average maximum demand current readings for the preceding time period with a load already present in the system. ➢ Estimated based on the predicted load profiles for a new facility.

3.	**Enlist the various IEEE and IEC power quality Standards.(13 M)A/M 2016 N/D 2017,2018** BTL2 **Answer: Page: 1.54 - C.Ravichandran** **IEEE Standards: (7 M)** ➢ IEEE Std 141 – 1993 ➢ IEEE Std 142 – 1991 ➢ IEEE Std 241 – 1990 ➢ IEEE Std 242 – 1986 ➢ IEEE Std 399 – 1990 ➢ IEEE Std 446 – 1987 ➢ IEEE Std 487 – 1992 ➢ IEEE Std 493 – 1990 ➢ IEEE Std 518 – 1982

IEC Standards: (6 M)

IEC 61000 Series Electromagnetic Compatibility defines for the following

- Part 1 – Definitions and methodology
- Part 2 – Environment
- Part 3 - Limits
- Part 4 – Tests and measurements
- Part 5 – Installation and mitigation
- Part 6 – Generic immunity and emissions

4. **Explain power quality and also explain the reasons for increased concern in power quality. (13 M)AU DEC-2016** BTL2

Answer: Page:1.2 - C.Ravichandran

Power Quality:(1 M)

- Any abnormal behavior on a power system arising in the form of voltage/current which adversely affects the normal operation of electrical (or) electronic equipment.
- Any deviation of the current or voltage waveform from its normal sinusoidal wave shape. These disturbances include sag, under voltage, interruption, swell, over voltages, transients, harmonics, voltage flicker and any other distortions to the sinusoidal waveform.
- Occurrence of one (or) more of such disturbances is called a power quality event.

Major reasons for the increased concern in power quality: (4 M)

- Newer generation load equipment is more sensitive to power quality variations
- Consequences from the failure of any component in an integrated process.
- Increased awareness of power quality issues.
- Increasing harmonic levels on power systems.

Increased interest in power quality:(5 M)

- Poor power quality can affect the accuracy of utility metering.
- Poor power quality can cause protective relays to malfunction.
- Poor power quality can result in equipment downtime and/or damage, resulting in a loss of production.
- Poor power quality can result in increased costs due to the preceding effects.
- Poor power quality can result in problems with electromagnetic compatibility and noise.

Various types of power quality are :(3 M)

1.Short duration Variation
- Sag
- Swell
- Interruption

2.Long duration Variation
- Under Voltage
- Over Voltage
- Sustained Interruption

3.Transients
- Impulsive Transients
- Oscillatory Transients

4.Waveform Distortion
- Harmonics
- Notching

- Flicker
- DC offset

PART*C

1. **With a waveform sketch, explain the terms. (15 M) AU DEC-2017** BTL 4

- **(a) Voltage Sag (3 M)**
- **(b) Voltage interruption (3 M)**
- **(c) Voltage swells (3 M)**
- **(d) Sag with harmonics (3 M)**
- **(e) Transients (3 M)**

Answer: Page:1.13 - C.Ravichandran

(a)Voltage Sag:(3 M)

Decrease in the RMS voltage at the power frequency for periods ranging from a half cycle to a minute.

Types:

Instantaneous (0.5 – 30 cycles), Momentary (30 cycles – 3s) , Temporary (3s – 1 min)

(b) Voltage interruption:(3 M)

Supply voltage decreases to less than 0.1 pu for a period of time not exceeding 1 min.

Types:

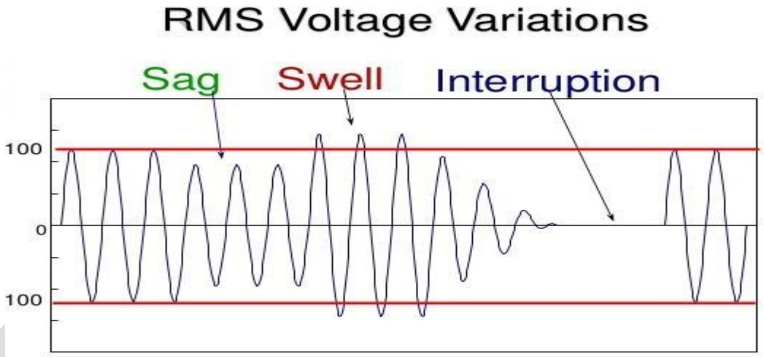
Momentary (0.5 – 30 cycles), Temporary (30 cycles – 3 s)

(c) Voltage Swell:(3 M)

Increase up to a level between 1.1 and 1.8 pu in RMS voltage at the power frequency.

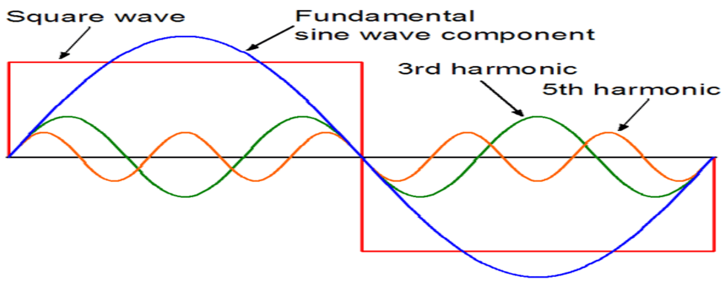
Types:

Instantaneous (0.5 – 30 cycles), Momentary (30 cycles – 3s) , Temporary (3s – 1 min)



(d) Sag with harmonics:(3 M)

Harmonics are sinusoidal currents and voltages with frequencies that are integral multiples of the fundamental power line frequency.

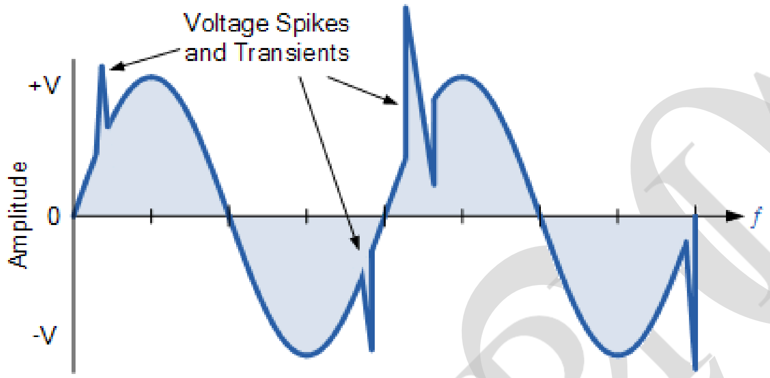


(e)Transients:(3 M)

Disturbances that occur for a very short duration.

Types:

Impulsive – occurs due to lightning, Oscillatory – occurs due to switching



2. **Discuss about the CBEMA curves. Explain about the events described in the curve. (15 M)**

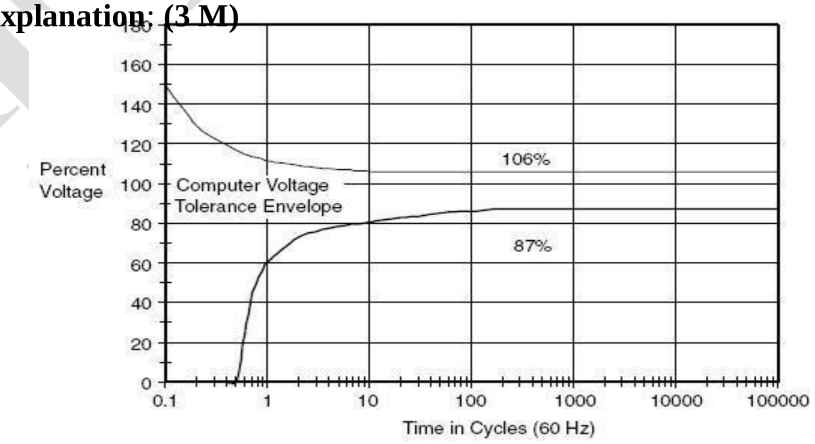
AU DEC-2015, 2017 BTL5

Answer: Page:1.48 - C.Ravichandran

Definition: **(2 M)**

- CBEMA stands for Computer & Business Equipment Manufacturers Associations (CBEMA).
- CBEMA developed the curve employing historical data from mainframe computer operations showing the range of acceptable power supply voltages for computer equipment.

Curve and its explanation: (3 M)



- Horizontal axis – Duration of sag or swell

- Vertical axis – percent change in line voltage

Events – 7 types(10 M)

- Steady-State Tolerances
- Line Voltage Swell
- Low-Frequency Decaying Transient Ring wave
- High-Frequency Impulse and Ring wave
- Voltage sags
- Dropout
- No Damage Region
- Prohibited Region

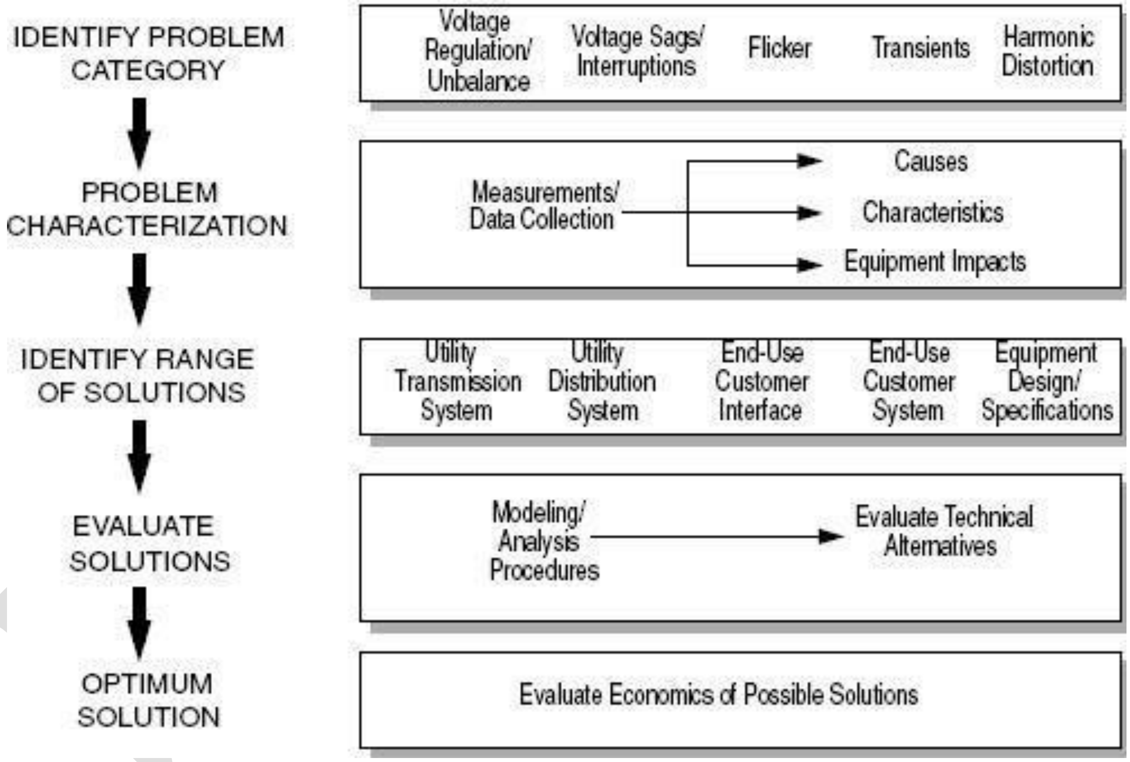
3. What is the need of power quality evaluation procedure? Explain the basic process involves it. (15 M)BTL 2 A/M 2018

Answer: Page:1.52 - C.Ravichandran

Need: (3 M)

To improve the power quality and equipment performance the quality evaluation procedure is explained through a chart below.

Explanation: (7 M)



General Procedure includes the following: (5 M)

- Evaluation
- Measurements
- Solutions

	UNIT II - VOLTAGE SAG AND SWELL
	Estimating voltage sag performance - Thevenin’s equivalent source - Analysis and calculation of various faulted condition - Estimation of the sag severity - Mitigation of voltage sag, Static transfer switches and fast transfer switches. - Capacitor switching – Lightning - Ferro resonance - Mitigation of voltage swell.
	PART*A
1.	**When does sag lead to interruption?** BTL4 Voltage sag is a reduction in voltage for a short time. The voltage reduction magnitude is between 10% and 90% of the normal root mean square (RMS) voltage at 50 Hz/ 60 Hz. An interruption is a complete loss of voltage, or a drop to less than 10% of nominal voltage in one or more phases.
2.	**What is voltage sag?** BTL2 A sag or dip is a decrease in RMS voltage or current at the power frequency for durations from 0.5 cycles to 1 minute, reported as the remaining voltage. Typical values are between 0.1 pu and 0.9 pu.
3.	**What are the causes of sag?** BTL2 ➢ Voltage sags are usually associated with voltage sag. ➢ Equipment sensitive to both the magnitude and duration of voltage sag. ➢ Equipment sensitive to have characteristics other than magnitude and duration.
4.	**What are the three levels of possible solutions to voltage sag and momentary interruption problems?**BTL2 ➢ Power System Design ➢ Equipment design ➢ Power conditioning equipment.
5.	**List some industry standards associated with voltage sags.**BTL1 ➢ SEMI F47-0200 ➢ CBEMA curve
6.	**What are the sources of sags and interruption?**BTL2 ➢ A sudden increase in load results in a corresponding sudden drop in voltage. ➢ Any sudden increase in load, if large enough will cause a voltage sag in motors, faults, switching. ➢ Recloser operation.
7.	**Give some economic impacts due to sag.** BTL1 ➢ Process outrages ➢ Damaged products ➢ Lost time for restarting.
8.	**What is the importance of estimating sag performance?**BTL2 It is important to understand the expected voltage sag performance of the supply system so that facilities can be designed and equipment specifications developed to assure the optimum operation of production facilities.

9.	**What are the various factors affecting the sag magnitude due to faults at a certain point in the system?** BTL1 ➢ Distance to the fault ➢ Fault impedance ➢ Type of fault ➢ Pre-sag voltage level ➢ System configuration ➢ System impedance ➢ Transformer connections
10.	**Name the different motor starting methods.** BTL1 ➢ Resistance and reactance starters ➢ Autotransformer starters ➢ Star-Delta starters
11.	**What are the causes for voltage sags due to transformer energizing?** BTL2 ➢ Normal system operation, which includes manual energizing of a transformer. ➢ Reclosing actions.
12.	**How voltage sag can be mitigated?** BTL4 Voltage sag can be mitigated by voltage and power injections into the distribution system using power electronics based devices which are also known as custom power devices.
13.	**Name the three levels of possible solutions to voltage sag and momentary interruption problems.** BTL1 ➢ Equipment Design ➢ Power conditioning equipment ➢ Power system design
14.	**Name any four types of sag mitigation devices. A/M 2018 2019**BTL1 ➢ Dynamic Voltage Restorer(DVR) ➢ Active Series Compensators ➢ Distribution Static Compensator(DSTATCOM) ➢ Solid State Transfer Switches(SSTS)
15.	**Define Dynamic Voltage Restorer (DVR).** BTL2 A DVR is a solid state power electronics switching device consisting of either GTO or IGBT, a capacitor bank as an energy storage device and injection transformers. It is connected in series between a distributed system and a load.
16.	**What is the important role of a DVR?** BTL2 The basic idea of a DVR is to inject a controlled voltage generated by a forced commuted converter in series to the bus voltage by means of an injecting transformer.
17.	**Define active series compensation devices.** BTL2 A device that can boost the voltage by injecting a voltage in series with the remaining voltage during a voltage sag condition.
18.	**What is the purpose of DSTATCOM?** BTL2 It allows effective control of active and reactive power exchanges between the DSTATCOM and the ac system.
19.	**What is the main function of DSTATCOM?** BTL2 ➢ Voltage regulation and compensation of reactive power ➢ Correction of power factor

	➢ Elimination of current harmonics.
20.	**Write the role of SSTS.** BTL2 ➢ Can be used very effectively to protect sensitive loads against voltage sags, swells and other electrical disturbance. ➢ It ensures continuous high quality power supply to sensitive loads by transferring , within a time of milliseconds , the load from a faulted bus to a healthy one.
	PART * B
1.	**What is the need of estimating sag performance? Explain the different methods of estimating voltage sag performance. A/M 2019(13 M)** BTL4 **Answer: Page: 2.12 - C.Ravichandran** **Need:(3 M)** To design the facilities and equipment specifications to assure the optimum operation of production facilities. **General procedure: (5 M)** ➢ Determine the number and characteristics of voltage sags that result from transmission system faults ➢ Determine the number and characteristics of voltage sags that result from distribution system faults ➢ Determine the equipment sensitivity to voltage sags ➢ Evaluate the economics of different solutions **Methods:(5 M)** ➢ Data Required for Estimation – System parameter & Fault event-related parameter ➢ Voltage sag Magnitude – Analysis of fault need accurate information of all the impedances ➢ Duration Determination – Determining the duration of the voltage sag need complete information of the type, location and settings of the protective relays.
2.	**Explain the principle of DVR operation used for sag mitigation. (13 M)**BTL2 **Answer: Page: 2.20 - C.Ravichandran** **Principle & Diagram: (6 M)** ➢ Consists of either GTO or IGBT, a capacitor bank as an energy storage device and injection transformers. ➢ Basic idea - to inject a controlled voltage generated by a forced commutated converter in series to the bus voltage by means of an injecting transformer.

Explanation: (7 M)

- Normal operating condition - DVR injects only a small voltage to compensate for the voltage drop of the injection transformer and device losses.
- Voltage sag condition - the DVR control system calculates and synthesizes the voltage required to maintain output voltage to the load
- This is done by injecting a controlled voltage with a certain magnitude and phase angle into the distribution system to the critical load.

3. **Explain the procedure for estimating the sag severity indices. A/M 2019(13 M)**BTL4 **Answer: Page: 2.18 - C.Ravichandran**

Procedure: (8 M)

Step 1: Obtain sampled voltages with a certain sampling rate and resolution
Step 2: Calculate event characteristics
Step 3: Calculate single-event indices
Step 4: Calculate site indices from the single-event indices
Step 5: Calculate system indices from the site indices

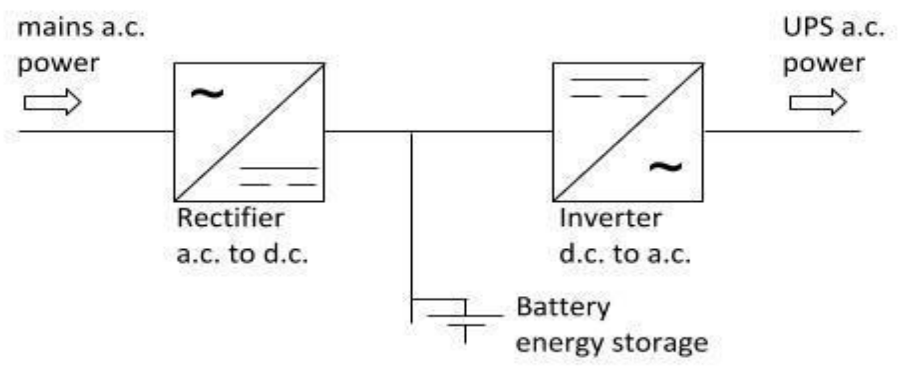
Flowchart: (5 M)

PART*C

1. **Explain the following sag mitigation technique. (15 M)**BTL4

(a)Static UPS with minimal energy storage (5 M)
(b) Backup storage energy supply (BSES) (5 M)
(c)Flywheel with UPS system (5 M)
Answer: Page: 2.42 - C.Ravichandran

Static UPS with minimal energy storage:(5 M)



- To maintain supply during supply interruptions.
- During aninterruption the load is fed from the battery through dc/ac converter.

Backup storage energy supply(BSES):(5 M)

- Disconnects a protected load from the utility supply within milliseconds after a disturbance.

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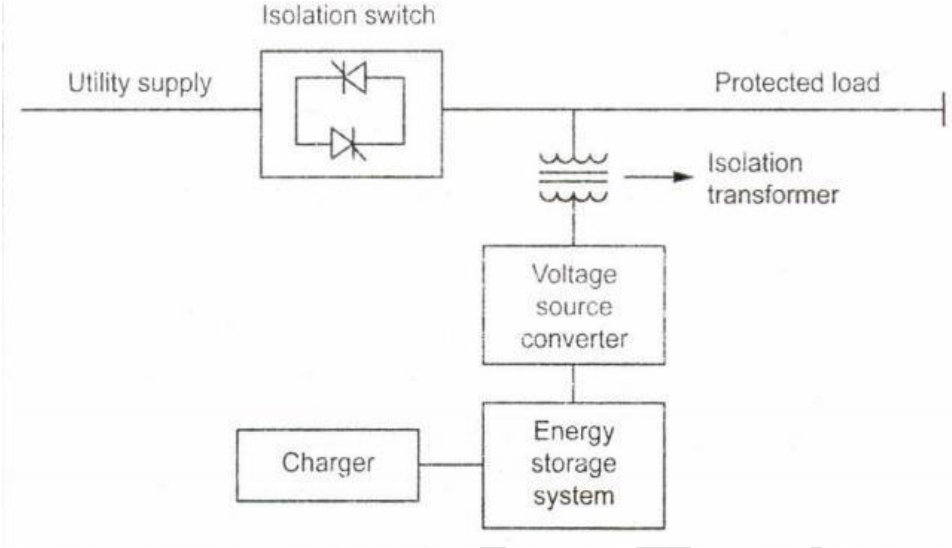
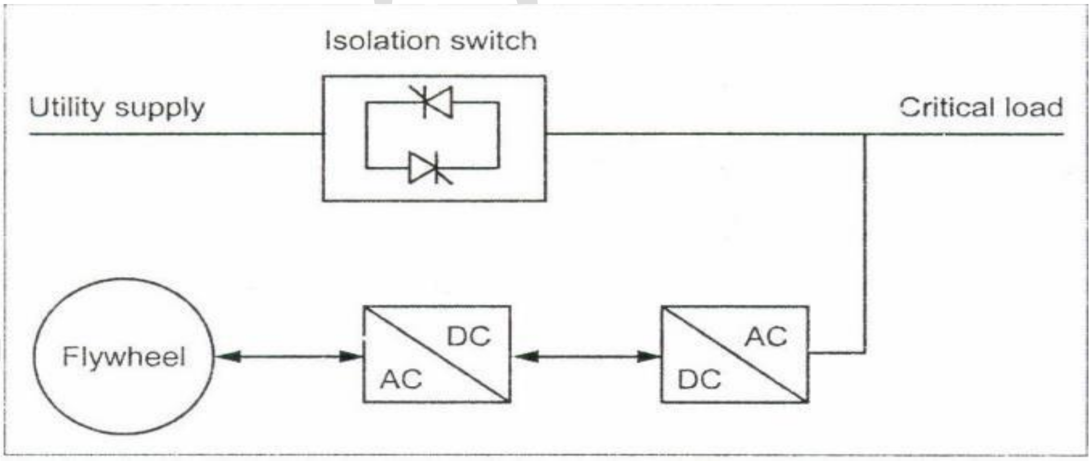
- Supplies the entire load using stored energy



Flywheel with UPS system: (5 M)



- The flywheel with UPS integrates the function of a motor, flywheel rotor and generator into a single integrated system.
- Modern flywheels provide energy storage for many seconds of ride through support in the event of a disturbance.

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Explain the solid state transfer switch with the transfer operation.(15 M)BTL5
Answer: Page: 2.38 - C.Ravichandran
Definition: (3 M)
Solid transfer switches use solid state devices, thyristors (SCR) to perform their fast transfer function.
Transfer Function: (2 M)
Two approaches – Open transition & Closed transition
Open transition: (5 M)

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	Break before make operation where the current to the load is interrupted for a brief period of time Advantages: No need of synchronizing gear, No paralleling of sources Disadvantages: Requirement of new source, De-energization of load **Closed transition: (5 M)** Make before break operation where the current to the load is not interrupted during the transfer. Advantages: Seamless transition, No in-rush currents Disadvantages: Requirement of synchronizing and paralleling equipment, Problems on one source transferred to the other.

	UNIT III – HARMONICS
	Harmonic sources from commercial and industrial loads - Locating harmonic sources – Power system response characteristics - Harmonics Vs transients. Effect of harmonics – Harmonic distortion - Voltage and current distortions - Harmonic indices - Inter harmonics – Resonance Harmonic distortion evaluation, IEEE and IEC standards.
	PART*A
1.	**Define transient over voltages.**BTL2 A transient over voltage can be defined as the response of an electrical network to a sudden change in network conditions, either intended or accidental, (e.g. a switching operation or a fault) or network stimuli (e.g. lightning strike).
2.	**What are the types of transient over voltages?** BTL1 1) Impulsive 2) Oscillatory
3.	**Define impulsive transients. Give example for impulsive transient over voltages.** BTL2 ➢ An impulsive transient is a sudden, non-power frequency change in the steady state condition of the voltage and/or current waveforms that is essentially in one direction, either positive or negative, with respect to those waveforms. ➢ The most common cause of this type of transient is lightning.
4.	**Give examples for oscillatory transient over voltages.** BTL1 Switching operations within the distribution network are a major cause of oscillatory transient over voltages. Such operations include (a) Switching of utility capacitor banks. (b) Switching of circuit breakers to clear network faults. (c) Switching of distribution feeders to rearrange the network for maintenance or Construction.

	but they can produce problems at a user facility. ➢ Severe over voltages can appear on user facility capacitors through a phenomenon known as voltage magnification.
6.	**What are the causes of voltage magnification on network?** BTL2 The voltage magnification will not result in capacitor damage. The problem that usually occurs is the failure or mis-operation of sensitive loads in the facility where the low voltage capacitors are installed.
7.	**Define voltage magnification phenomena.** BTL2 The highest transient voltages occur at the low voltage capacitor bank when the characteristic frequency of the switching transient is nearly equal to the resonant frequency of the low voltage system and when the switched capacitor is ten or more times the size of the low voltage capacitor.
8.	**Mention the two important concerns for capacitor bank switching transients.** BTL1 Voltage transients at the capacitor bank substation and neighbouring substations Power quality impact on sensitive customer loads due to variations in voltage when energizing capacitor banks.
9.	**Give the various aspects of equipment specific design and protection issues for the capacitor switching transients.** BTL4 ➢ Phase-to-ground and phase-to-phase insulation switching withstand to voltage stresses. ➢ Controlled closing for circuit breakers. (Pre-insertion resistors/reactors or synchronous switching) ➢ Capacitor bank and substation Circuit breakers. (ANSI/IEEE C37 requirements / Current limiting reactor requirements)
10.	**What specify the IEEE standard for shunt power capacitors causing transient over voltages?** BTL4 The IEEE Standard for Shunt Power Capacitors, ANSI/IEEE Std. 18-1992, specifies that capacitors "may reasonably be expected to withstand" transient over-voltages from 205% to 354% of rated peak voltage, depending on the number of times a year the overvoltage occurs.
11.	**What are the various causes of over voltages?** BTL2 Over voltages, i.e. brief voltage peaks (transients, surges, spikes) can be attributed to the following main causes: 1.Atmospheric discharges i.e. lightning (LEMP - Lightning Electro-Magnetic Pulse) 2.Switching operations in the public grid and low-voltage mains, 3.Electrostatic Discharges(ESD). 4.Ferroresonance.
12.	**Give the basic principles of overvoltage protection of load equipment**.AM 2019 BTL2 ➢ Limit the voltage across sensitive insulation. ➢ Divert the surge current away from the load. ➢ Block the surge current entering into the load. ➢ Bonding of equipment with ground
13.	**What is the need of surge arrestors?**BTL2 ➢ A surge arrester is a protective device for limiting surge voltages on equipment by discharging or bypassing surge current. ➢ Surge arresters allow only minimal flow of the 50Hz/60Hz power current to ground.

14.	**Differentiate between transient voltage surge suppressors (TVSS) and surge arrestors.** BTL4 ➢ Arresters and TVSS devices protect equipment from transient over-voltages by limiting the maximum voltage, and the terms are sometimes used interchangeably. However, TVSSs are generally associated with devices used at the load equipment. ➢ A TVSS will sometimes have more surge-limiting elements than an arrester.
15.	**Mention the types of surge arrestors** BTL1 ➢ Metal-oxide varistor type ➢ Gapped silicon - carbide type
16.	**What is metal-oxide surge-arrester?** BTL2 A metal-oxide surge-arrester (MOSA) utilizing zinc-oxide block provides the best performance, as surge voltage conduction starts and stops promptly at a precise voltage level, thereby improving system protection
17.	**Give any two advantages of metal-oxide arresters over conventional silicon carbide distribution class arresters.** BTL2 ➢ Improved Surge Duty Capability ➢ Improved Temporary Overvoltage Capability
18.	**What is the need of Transmission Line Arresters?** BTL2 Transmission Line Surge Arresters conduct lightning surges around the protected insulator so that a lightning flashover is not created. They are designed to be installed functionally in parallel with the line insulator. The arrester conducts the lightning surges around the protected insulator so that a subsequent 50Hz / 60 Hz fault on the circuit is not created.
19.	**Mention the Benefits of Transmission Line Surge Arresters.** BTL1 Lowers initial cost of new or transmission line upgrades by making construction more compact and transmitting more energy in the same right of way. ➢ Reduces the height of transmission lines by eliminating shield wire. ➢ Improves outage statistics by eliminating back flashover from the tower ground lead to the phase conductor.
20.	**What is the role of surge arrestor on shielded and unshielded transmission line?** BTL2 ➢ On shielded transmission lines or under-built distribution circuits, the arrester prevents tower to phase insulator back-flashovers during a lightning strike. ➢ On unshielded sub transmission or distribution circuits, the arrester prevents phase-to-ground flashover.
21.	**What is the need of low pass filter in transient protection?** BTL2 ➢ This LC combination provides a low impedance path to ground for selected resonant frequencies. ➢ Low-pass filters employ pi principle to achieve better protection even for high-frequency transients.
22.	**What is the need of Shunt protectors or surge reduction filters?** BTL2 ➢ An in-line filter specifically designed to reduce the rate of voltage rise (dv/dt) of the preclamped waveform. ➢ It gives some series impedance between input and output terminals. This type of product is highly recommended for the protection of sensitive electronic equipment

23. **What is the application of Power Conditioners in transient protection?N/D 2019** BTL2

Low-impedance power conditioners are used primarily to interface with the switch-mode power supplies found in electronic equipment. Low-impedance power conditioners differ from isolation transformers in that these conditioners have much lower impedance and have a filter as part of their design when on the device to position the power conditioners to avoid voltage swells.

24. **Differentiate between TVSS, Filter and Data/signal protection devices.** BTL2

- **Transient**: focus on limiting high-voltage spikes to an acceptable level.
- **Filtering**: protect against low-energy transients and high frequency noise.
- **Data/signal protection devices**: Products that guard sensitive instrumentation against what we refer to as 'back door' transients and noise.

25. **Define lightning phenomena.** BTL2

Lightning is an electrical discharge in the air between clouds, between different charge centre within the same cloud, or between cloud and earth (or earthed object). Even though more discharges occur between or within clouds, there are enough strokes that terinate on the earth to cause problems to power systems and sensitive electronic equipment.

PART*B

1. **Write short notes on the following:(13 M)**BTL2A/M 2019

(i) **Ferro resonance (7 M)**
(ii) **Low pass filter (6 M)**

(i)Ferro resonance: (7 M)

Answer:Page:3.22 - C.Ravichandran

Definition: (2 M)

Ferroresonance is a special case of series LC resonance where the inductance involved is nonlinear and it is usually related to equipment with iron cores.

Causes: (2 M)

- It occurs when line capacitance resonates with the magnetizing reactance of a core while it goes in and out of saturation.
- It occurs when a non-linear inductor is fed from a series capacitor.
- The non-linear inductor in power system can be due to bank type transformer, core type transformer, Shell type transformer etc.

Problems associated with Ferro resonance: (3 M)

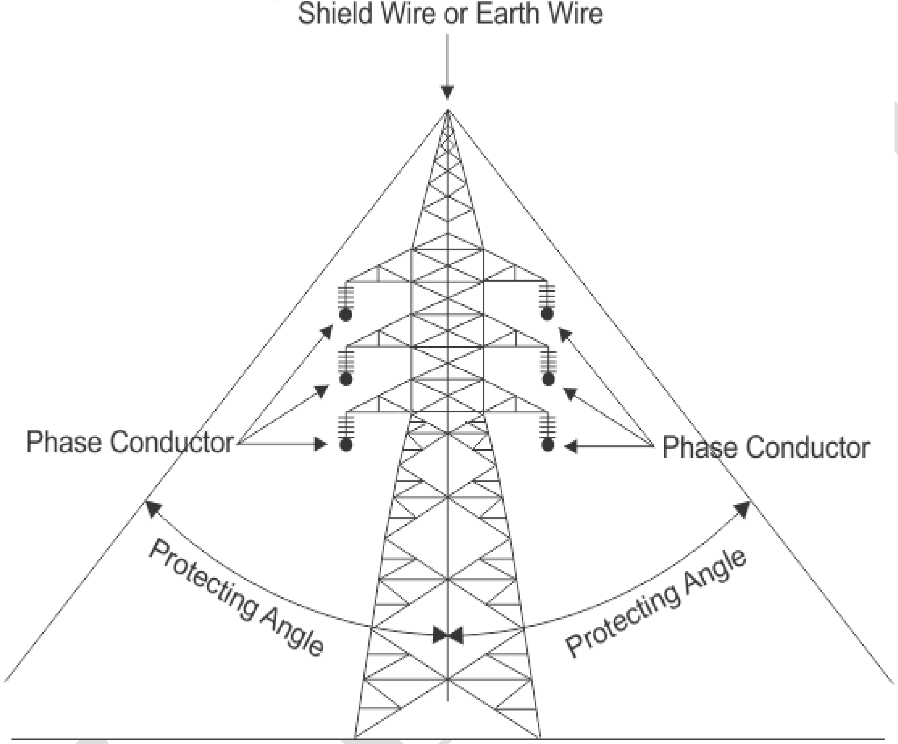
- Overheating
- Audible noise
- High overvoltages and surge arrester failure.

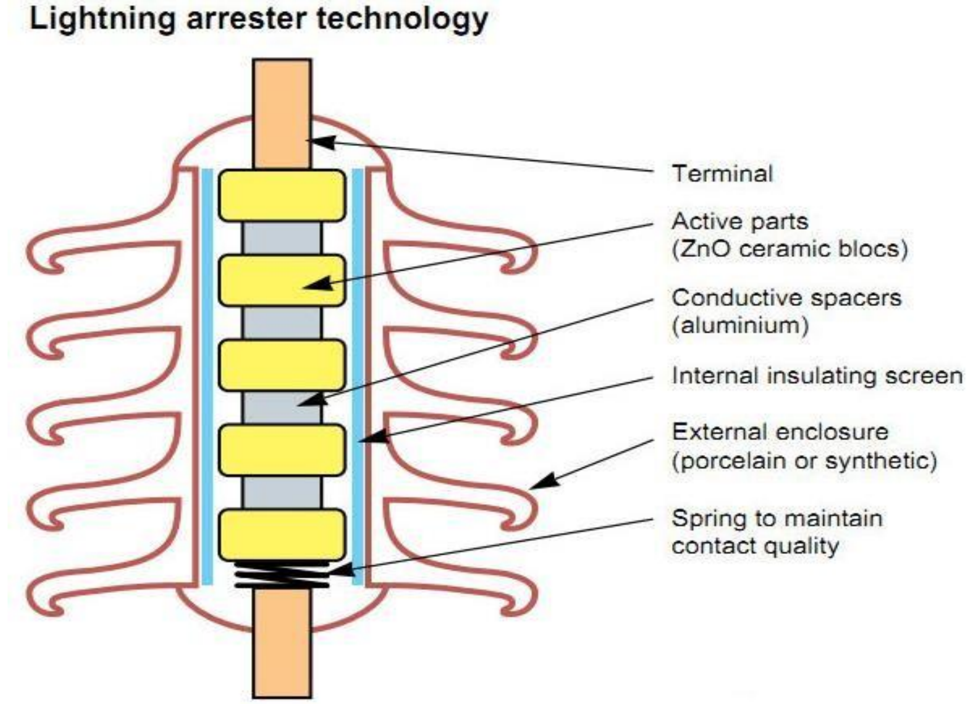
(ii) Low pass filter: (6 M)

Answer:Page:3.35 - C.Ravichandran

Definition: (2 M)

- Low pass filters are composed of series inductors and parallel capacitors in general electric circuits.
- This LC combination provides a low impedance path to ground for selected resonant frequencies.

	Explanation: (4 M) ➢ It combines two surge suppressors and a low pass filter to provide maximum protection. ➢ It uses a gap-type protector on the front end of line to provide maximum protection.
2.	**Explain the various methods of protection against lightning. (13 M)**BTL4 **Answer:Page:3.37 - C.Ravichandran** **Line shielding**: **(6 M)** **Explanation & Diagram: (3+3 M)** The line with shield wire can reduce the number of flashovers in open ground and number of flashovers with nearby objects  **Surge Arrestors**: **(7 M)** **Explanation & Diagram: (3+4 M)** ➢ Transmission Line surge arresters conduct lightning surges around the protected insulator so that a lightning flashover is not created. ➢ They are designed to be installed functionally in parallel with the line insulator. ➢ The arrester becomes a low ohmic path for the surge as voltage across it increases.

	
3.	**Explain in detail about each method used for protection of transformers. N/D 2019(13 M)** BTL2 **Answer: Page: 5.11 – S.Thirukkovai** **Two methods: (3 M)** ➢ Use transformers with interlaced secondary windings ➢ Apply surge arresters in the secondary tappings. **Transformer with interlaced secondary winding: (4 M)** ➢ It is a design not characteristic of the transformer and it cannot be changed once the transformer has been made. ➢ If the transformer does not have interlaced section windings the only option is to apply arresters to the low-voltage side. **Surge arresters:** **Diagram: (2 M)** **Explanation: (4 M)** ➢ The primary arrester is mounted directly on the tank with very short lead lengths. ➢ It can also have another secondary arrester. ➢ Secondary arresters can be adapted as external mounting on transformers. Internally mounted arresters are also available. ➢ Arrester rating of 40KA discharge current is recommended. ➢ Voltage discharge is typically 3 to 5 KV.
	PART*C
1.	**Explain the role of PSCAD/EMDTC in transient analysis with example models. (15 M)**BTL5 **Answer:Page:3.50 - C.Ravichandran**

Role of PSCAD: **(3 M)**

- PSCAD stands for Power System Computer Aided Design
- PSCAD is a powerful and flexible graphical user interface to the EMTDC solution engine.
- PSCAD enables the user to schematically construct a circuit, run a simulation, analyze the results, and manage the data in a completely integrated, graphical environment.

Transient studies: (1 M)

Transient over voltage studies, Line energizing, Breakers re-strike etc.

Transformers: (1 M)

Inrush current issues, Saturation, Representing different core types etc.

Faults: (1 M)

Preparing the simulation to perform a sequence of events, DC offset in fault current.

Protection systems: (1 M)

Detailed CT saturation models, Modeling a simple relay scheme

Power Quality: (1 M)

Voltage dips, swells and interruptions, Induction motor starting, system faults.

Induction machines: (1 M)

Large induction motors starting issues including flicker and voltage dip problems.

Power Electronics Basics: (1 M)

Using power electronic modules and designing simple firing systems, PSCAD Interpolation method.

FACTS Devices:(1 M)

SVC, STATCOM, Active Filters

Synchronous machines: (1 M)

Controls including governors, exciters

Example models: (3 M)

Surge arrestor model, Transmission line model.

2. **Explain in detail about various methods to mitigate voltage swells. (15 M)**BTL4

Answer:Page:3.26 - C.Ravichandran

Basic principles: (6 M)

- Limit the voltage across sensitive insulation
- Divert the surge current away from the load
- Block the surge current entering into the load
- Bonding of equipment with ground
- Prevent surge current flowing between grounds
- Design a low pass filter using limiting and blocking principle

Circuit Diagram: (4 M)

Various methods used are: (5 M)

- Surge Arrestors and Surge Suppressors – Protective device for limiting surge voltages on equipment by discharging or bypassing surge current.
- Transient Voltage Suppressors – Semiconductor devices designed to provide protection against voltage and current transients.

	➢ Over Voltage protection – Low Voltage Crowbar (LVC) LVC offers a quick, economical fix to the problem and it is installed inside a power supply or between the power supply and sensitive equipment.
3.	**Explain the following:**BTL4 **(a)Pre-insertion Impedance (5 M)** **(b) Synchronous closing control (5 M)** **(c)MOV Arresters (5 M)** **Answer: Page: 5.20 – S.Thirukkovai** **Pre-insertion Impedance: (5 M)** ➢ Provides a means for reducing the transient currents and voltages associated with the energization of a shunt capacitor bank. ➢ The impedance is “shorted-out” (bypassed) shortly after the initial transient dissipates, thereby producing a second transient event. ➢ The insertion transient typically lasts for less than one cycle of the system frequency. ➢ Performance evaluated using both the insertion and bypass transient magnitudes. **Synchronous closing control: (5 M)** ➢ Synchronous closing is independent contact closing of each phase near a voltage zero. ➢ Apply a switching device that maintains a dielectric strength sufficient to withstand system voltages until its contacts touch. ➢ Success of a synchronous closing scheme is often determined by the ability to repeat the process under various conditions. **MOV Arresters: (5 M)** ➢ MOV stands for Metal oxide varistors. ➢ Limit the transient voltages to the arrester’s protective level at the point of application. ➢ The primary concern is the energy duty during a restrike event. ➢ In addition, remote arresters may be subjected to severe energy duties if voltage magnification occurs.

	UNIT IV – PASSIVE POWER COMPENSATORS
	Principle of Operation of Passive Shunt and Series Compensators, Analysis and Design of Passive Shunt Compensators Simulation and Performance of Passive Power Filters- Limitations of Passive Filters Parallel Resonance of Passive Filters with the Supply System and Its Mitigation. Fundamentals of load compensation – voltage regulation & power factor correction.
S.No.	**PART*A**
1	**What are the important concepts to bear in mind to understand power system harmonics?**BTL1 There are two important concepts to bear in mind with regard to power system harmonics. The first is the nature of harmonic current producing loads (nonlinear loads) and the second is the way in which harmonic currents flow and how the resulting harmonic voltages develop.
3	**Define true power factor.**BTL2 **True power factor** is calculated as the ratio between the total active power used in a circuit (including harmonics) and the total apparent power (including harmonics) supplied from the source. **True power factor = Total active power (P) / apparent power (S)**
4.	**What is the reason for existence of harmonic distortion?**BTL2 Harmonics distortion exists due to the nonlinear characteristics of the devices and loads on the power system. These devices act as current sources that inject harmonic currents into the power system.
5	**Differentiate between linear loads and non-linear loads.**BTL4 **Linear load:** Any load that draws current at supply fundamental frequency only is a linear load. The current drawn does not contain any harmonics (multiples of the supply frequency). Motors, resistors, inductors and capacitors are all linear loads. **Non Linear load:** Any load that draws harmonic currents from the supply is a nonlinear load. The current waveform of such non-linear loads, is discontinuous and non-sinusoidal because of the presence of harmonics.
6.	**What is voltage and current distortion?**BTL2 ➢ Voltage distortion is any deviation from the nominal sine waveform of the AC line voltage. ➢ Current distortion is any deviation from the nominal sine waveform of the AC line

	current.
7.	**Mention the commonly used indices used for measuring harmonic component of waveform.**BTL1 The two most commonly used indices for measuring the ham10nic content of the waveform are the total harmonic distortion (THD) and total demand distortion (TDD). 1. If a generator produces a non-ideal sinusoidal waveform, the voltage waveform will contain a certain amount of harmonics 2. In motors, decreased efficiency, excessive heating, and vibration are symptoms of harmonic voltage distortion.
8.	**Mention at least two causes of harmonics made on distribution systems.**BTL1 ➢ In the distribution system, transformers are capable of producing harmonics due to magnetic core saturation. This is more prevalent at a lighter loading of the transformer. ➢ Large load currents in the neutral wires of a 3 phase system. Theoretically the neutral current can be up to the sum of all 3 phases therefore causing overheating of the neutral wires. Since only the phase wires are protected by circuit breakers of fuses, this can result in a potential fire hazard.
9.	**What is harmonic index? State its significant.**BTL2 The power quality industry has developed certain index values that help us assess the quality of service as it relates to distortion caused by the presence of harmonics. These values, or harmonic indices, serve as a useful metric of system performance. The two most commonly used indices under harmonic studies are (a) Total harmonic distortion (THD) (b) Total demand distortion (TDD)
10.	**Mention the problems created by harmonics.**BTL1 A large load current flows in the neutral Wires of a 3 phase system. Theoretically the neutral current can be up to the sum of all 3 phases therefore causing overheating of the neutral wires. Poor power factor conditions that result in monthly utility penalty fees for major users (factories, manufacturing, and industrial) with a power factor less than 0.9.
11.	**Mention the harmonic effects on devices and loads Insulation stress (voltage effect).** BTL1 ➢ Thermal stress (current effect) ➢ Load ruptures (abnormal operation)
12.	**What is the effect on transformer due to Harmonics?**BTL2 The primary effect of power system harmonics on transformers is the additional heat generated by the losses caused by the harmonic contents generated by the load current.
13.	**Mention the harmonic sources from commercial loads.** BTL1 ➢ Single phase loads such as Switch mode power supplies, fluorescent lighting and UPS systems ➢ Three phase loads such as high voltage AC drives system
14.	**Mention the harmonic sources from industrial load.**BTL1 ➢ Three phase converter with Adjustable speed drives (DC drives and AC drives) ➢ Arcing Devices (Arc furnaces, welders, Discharge lamps etc) ➢ Saturable devices (transformer, electromagnetic devices etc with steel core)
15.	**What is the advantage of three phase converter?**BTL2 Three-phase electronic power converters do not generate third-harmonic currents mainly when compared with single-phase converters. This is a great advantage because the third harmonic current is the largest component of harmonics shown in harmonics spectrum

<table>
<tr><td>16</td><td>What is the disadvantage of 12 pulse drive?BTL2
The disadvantages of the l2-pulse drive are that there is more cost in control design and an extra transformer is usually required.</td></tr>
<tr><td>17.</td><td>State the different types of inverters. BTL1
➢ Variable voltage inverter (VVI)
➢ Current source inverter (CSI)
➢ Pulse width modulated (PWM)</td></tr>
<tr><td>18.</td><td>What is Variable Voltage Inverter?BTL2
The variable voltage inverter (VVI), or square-wave six-step voltage source inverter (VSI), receives DC power from an adjustable voltage source (either from thyristor converter or DC-DC converter fed by Diode Bridge) and adjusts the frequency and voltage.</td></tr>
<tr><td>19.</td><td>What is current Source inverter?BTL2
The current source inverter (CSI) receives DC power from an adjustable current source and adjusts the frequency and current.</td></tr>
<tr><td>20.</td><td>What is the need of locating harmonic sources?BTL4
When harmonic problems are caused by excessive voltage distortion on the supply system, it is important to locate the sources of harmonics in order to develop a solution to the problem.</td></tr>
<tr><td></td><td>PART*B</td></tr>
<tr><td>1.</td><td>Explain in detail the various causes and effects of harmonics in distribution power system.(13 M)
BTL2
Answer: Page:4.32 - C.Ravichandran
Causes of Harmonics: (6 M)
There are many causes of harmonics on a power system.
➢ Harmonics can arise in the generating system, in the distribution system, and from the loads connected to the network.
➢ If a generator produces a non-ideal sinusoidal waveform, the voltage waveform will contain a certain amount of harmonics.
➢ The greatest production of harmonics is the harmonic current generation from non-linear loads. The problems of power system harmonics have increased considerably with the use of static power converters.
➢ Switching actions result in harmonics.
➢ Harmonic producing loads are treated a current source.
➢ Group of harmonic that produces harmful effects are called third harmonics.
Effects of Harmonics:(7 M)
➢ Insulation stress – Voltage effect.
➢ Thermal stress – current effect.
➢ Load rupture – abnormal operation.
➢ Effect on transformers: Additional heat generated by the losses.
➢ Effect on motors: Increased losses.
➢ Effect on circuit breakers: Mis-operation of blowout coils.</td></tr>
<tr><td>2.</td><td>Explain the need of locating harmonic sources and the identification procedure on the basis of Thevenins equivalent circuit. (13 M)BTL2
Answer: Page: 4.63 - C.Ravichandran
Need:(2 M)
When harmonic problems are caused by excessive voltage distortion on the supply system, it is</td></tr>
</table>

	important to locate the sources of harmonics in order to develop a solution to the problem. **Two approaches: (2 M)** ➢ Compare the time variations of the voltage distortion with specific customer and load characteristics. ➢ Monitor flow of harmonic currents on the feeder with capacitor banks off. **Thevenins Equivalent circuit:(4 M)** **Identification Procedure**: **(5 M)** ➢ If $\|V_U\| > \|V_C\|$ - Harmonic source is at the utility side. ➢ If $\|V_C\| > \|V_U\|$ - Harmonic source is at the customer side. Where V_U - Thevenins voltages for utility. V_C – Thevenins voltage for customer.
3.	**Explain the devices for controlling harmonic distortion. (13 M)**BTL2 **Answer: Page: 4.90 - C.Ravichandran** **Series Reactors: (1 M)** Connected in series upstream of a non-linear load **Zigzag Transformers: (1 M)** To control zero-sequence harmonic components **Specially connected Transformers: (1 M)** Inhibits propagation of third-order harmonic currents and their multiples **Using 6-pulse Diode Rectifier: (2 M)** Consists of 6 uncontrollable rectifiers or diodes and an inductor, which together with a DC capacitor forms a low-pass filter for smoothing the DC current. **Using 12-pulse or 24-pulse Diode Rectifier**: **(1 M)** Formed by connecting two 6-pulse rectifiers in parallel to feed a common DC-bus **Using Phase Controlled Thyristor Rectifier: (1 M)** Accomplished by replacing the diodes in a 6-pulse rectifier with thyristors **Using IGBT Bridge**: **(2 M)** Control the Dc voltage level and displacement power factor regardless of the power flow direction **Using a Larger DC or AC Inductor: (1 M)** Connected in its AC input or DC bus **Harmonic Filters: (3 M)** Active and Passive Filters
	PART*C
1.	**Explain for the following: (15 M)**BTL4 **1.Harmonic sources from commercial loads. (5 M)** **2.Harmonic sources from industrial loads. (5 M)** **3.Harmonic sources from residential loads. (5 M)** **Answer: Page: 4.43 - C.Ravichandran** **Harmonic sources from commercial loads**: **(5 M)** In commercial buildings, sources of harmonic current generation are generally small in size and large in number. Two categories: ➢ Single phase loads. ➢ Three phase loads.

	Harmonic sources from industrial loads: **(5 M)** ➢ Three phase converter with adjustable speed drives (DC and AC drives) ➢ Arcing Devices (Arc furnaces, Welders, Discharge lamps etc.) ➢ Saturable devices (Transformers, electromagnetic devices etc. with steel core) **Harmonic sources from residential loads**: **(5 M)** ➢ It is mostly from the devices like Uninterruptible power supplies, Electronic fluorescent lighting ballasts etc. ➢ Harmonics depends on the diversity of the different load types.
2.	**Design Harmonic Source Identification Procedure for two source systems. (15 M)** BTL6 **Answer: Page: 4.66 - C.Ravichandran** Identification of harmonic sources at the point of Common Coupling based on voltage indices. **Procedure:** Step 1: Measure harmonic voltage and current at Point of Common Coupling (PCC). (3 M) Step 2: Calculate I_U and Z_U and also I_C and Z_C. (3 M) Step 3: Calculate voltage at the utility and customer side. (3 M) Step 4: Compare the measured harmonic voltage at PCC, Voltage at the utility and the customer side. (3 M) Step 5: Identify the source of harmonics.(3 M)
3.	**Analyze the power system response characteristics under the presence of harmonics. (15 M)**BTL4 **Answer: Page: 4.66 - C.Ravichandran** The response of the power system at each harmonic frequency determines the true impact of the nonlinear load on harmonic voltage distortion. Three important variables affecting the power system response characteristics are: **(a) The system impedance characteristics: (5 M)** ➢ Parallel Resonance - High impedance path to the flow of current. ➢ Series Resonance – Low impedance path to the flow of current. **(b) The presence of a capacitor bank causing resonance: (5 M)** ➢ Parallel Resonance – shunt capacitor banks appear to the harmonic source as being in parallel with the system source reactance. ➢ Series Resonance – Capacitor appears to be in series with line impedance. **(c) The amount of resistive loads in the system: (5 M)** ➢ When the resistive load increases, the overall damping factor of the circuit increases and the sharpness of the resonance decreases. ➢ When the resistive load decreases, the damping factor also decreases but the sharpness of the resonance increases. ➢ The sharpness of the resonance determines the impedance that is seen by the harmonic currents.

UNIT V – POWER QUALITY MONITORING & CUSTOM POWER DEVICES

Monitoring considerations - Monitoring and diagnostic techniques for various power quality problems - Quality measurement equipment - Harmonic / spectrum analyzer - Flicker meters Disturbance analyzer - Applications of expert systems for power quality monitoring. Principle& Working of DSTATCOM – DSTATCOM in Voltage control mode, current control mode, DVR Structure – Rectifier supported DVR – DC Capacitor supported DVR -Unified power quality conditioner

PART*A

Q.No.	Questions
1	**What is the importance of power quality monitoring?**BTL2 Power Quality Monitoring is necessary to- detect and classify disturbance at a particular location on the power system. PQ monitoring assists in preventive and predictive maintenance. Problems can be detected before they cause widespread damage by sending automated alerts. PQ Monitoring can be used to determine the need for mitigation equipment.
2	**What are the monitoring objectives**?BTL1 ➢ Continuous evaluation of the electric supply system for disturbances and power quality variations. ➢ Document performance of power conditioning equipment, such as static switches, UPS systems, other ride through technologies, and backup generators.
3	**What are the purposes of power quality monitoring system?**BTL1 ➢ Preventive maintenance. ➢ Load analysis. ➢ Equipment diagnostics. ➢ Long-time surveys.
4	**What is proactive monitoring**?BTL1 The traditional approach to power quality monitoring is reactive. We need to know when a problem is going to occur before it happens. Permanent power quality monitoring systems are designed tohelp proactively identify conditions and events that may cause problems should be addressed. This iscalled proactive monitoring.
5	**List out the steps involved in power quality monitoring/D 2019**.BTL1 ☐ Planning for the monitoring. ☐ Preparing for the monitoring. ☐ Inspecting the site. ☐ Monitoring the power. ☐ Analysing, monitoring and inspecting data. ☐ Applying corrective solutions.
6	**Mention the requirements of monitoring for a voltage regulation and unbalance.** BTL1 ☐ 3 phase voltages ☐ RMS magnitudes ☐ Continuous monitoring with periodic maximum/minimum/average samples

7	**What are the requirements of monitoring for a harmonic distortion?**BTL1 ➢ Currents for response of equipment. ➢ 3 phase voltages and currents. ➢ Waveform characteristics. ➢ 128 samples per cycle minimum. ➢ Synchronized sampling of all voltages and currents.

	➢ Configurable sampling characteristics.
8	**What are the Characteristics of power quality monitoring equipment?**BTL2 **Harmonic Analysis** Harmonic analyses are usually conducted by obtaining and interpreting measurements of waveforms. Equipment normally required to perform a harmonic study consists of a harmonic analyzer, an oscilloscope, and an RMS responding voltmeter and ammeter. Spectrum analysis is usually performed up to the 50th harmonic (3 kHz).
9	**What are the Characteristics of power line monitors?** BTL1 ☐ Portable, rugged, lightweight ☐ Simple to use, with proper training ☐ Designed for long-term unattended recording ☐ Definition of line disturbance parameters varies between manufacturers
10	**Classify the Types of power quality measurement equipment**.BTL1 ☐ Hand-held single-phase power quality monitors ☐ Portable three-phase power quality monitors ☐ Harmonic analyzers ☐ Distortion analyzers ☐ Multimeters
11	**Mention the factors that should be considered for selecting the instrument.**BTL1 ☐ Number of channels (voltage and/or current) ☐ Temperature specifications of the instrument ☐ Input voltage range (e.g., a to 1000 V) ☐ Ability to measure three-phase voltages
12	**Write the use of oscilloscope?**BTL1 Oscilloscopes with fast sampling rates and automatic triggering function can be very useful for trace of transients.
13	**What is the use of spectrum analyzer?**BTL1 A spectrum analyzer can be used for trace of high frequency harmonics.
14	**What is the use of simple single phase hand-held power quality monitor?**BTL1 Power quality problems like measuring the occurrence of harmonics or checking the voltage level or the power frequency can easily be made by using a simple single phase hand-held power quality monitor.
15	**Mention the Instruments used for the analysis of non-sinusoidal voltage and currents?**BTL1 ☐ Oscilloscope ☐ Spectrum analyzer ☐ Harmonic analyser
16	**Mention the basic categories of instruments for harmonic analysis?** BTL1 ☐ Simple meters ☐ General-purpose spectrum analyzers ☐ Special-purpose power system harmonic analyzers ☐ Digital Harmonics Measuring Equipment ☐ Distortion Analyzers ☐ Data Logger
17	**What is Spectrum analyzer?**BTL2N/D 2019 An instrument used for the analysis and measurement of signals throughout the electromagnetic

	spectrum. Spectrum analyzers are available for sub audio, audio, and radio-frequency measurements, as well as for microwave and optical signal measurements.
18	**What is the operation of spectrum analyzer?**BTL2 A spectrum analyzer separates the signal into two components: amplitude (displayed vertically) and frequency (displayed horizontally). In some low frequency analyzers, phase information can also be displayed. Low-frequency analyzers are sometimes called as **"Harmonic analyzers".** Vertical scale displays the amplitude and horizontal scale displays the frequency.
19	**What is Swept heterodyne technique?**BTL2 Any signal at the input, at a frequency such that the difference between its frequency and the local oscillator is within the bandwidth of an intermediate- frequency filter, will be detected and will vertically deflect the spot on the display by an amount proportional to the amplitude of the input signal being analyzed.
20	**What is Swept heterodyne technique?**BTL2 Any signal at the input, at a frequency such that the difference between its frequency and the local oscillator is within the bandwidth of an intermediate- frequency filter, will be detected and will vertically deflect the spot on the display by an amount proportional to the amplitude of the input signal being analyzed.
21	**What are the advantages of FFT**?BTL1 ➢ FFT technique is much faster. ➢ Measurement is virtually real time.
22	**What are the disadvantages of FFT**?BTL1 □ Restricted to lower frequencies. □ Complex due to need of A/D converter.
23	**What is the use of digital storage**?BTL2 Digital storage gives the effect of a constant display, even though a very slow sweep may have been used to acquire the displayed data.
24	**What is tracking generator**?BTL2 The tracking generator enhances the applications of spectrum analyzers. Its output delivers a swept signal whose instantaneous frequency is always equal to the input tuned frequency of the analyzer.
25	**What is harmonic analyzer**?BTL2 Spectrum analyzers covering up to typically 100 kHz can also be called harmonic analyzers.
	PART*B
1.	**(i) Draw the block diagram of advanced power quality monitoring systems. Explain it in details.(6M)**BTL2N/D 2019 **Answer: Page: 5.3 – T.Srianandа Ganesh** **Block Diagram: (3M)** **Explanation: (3M)** ➢ Monitoring as part of a facility site survey ➢ Determining what to monitor ➢ Choosing monitoring locations ➢ Options for permanent power quality monitoring equipment (a)Digital Fault Recorders (b) Smart Relays and other IEDs (c) Voltage Recorders

(d) Implant power monitors
(e) Special purpose power quality monitors
(f)Revenue meters

(ii) Analyze the equipments used for power quality monitoring. (7 M)BTL4

Answer: Page: 5.11 – T.Sriananda Ganesh

Types of Instruments: (3 M)

- Wiring and grounding test devices
- Multimeter
- Oscilloscopes
- Disturbance Analyzers
- Harmonic / spectrum analyzers
- Combination of Disturbance and Harmonic analyzers
- Flicker meters
- Energy monitors

Explanation: (4 M)

The following are the important factors to be considered when choosing the instrument:

- Number of channels (voltage and/or current)
- Temperature specifications of the instrument
- Ruggedness of the instrument
- Input voltage range (e.g., 0 to 600 V)
- Power requirements
- Ability to measure three-phase voltages
- Input isolation (isolation between input channels and from each input to ground)
- Ability to measure currents
- Housing of the instrument (portable, rack-mount, etc.)
- Ease of use (user interface, graphics capability, etc.)
- Documentation
- Communication capability (modem, network interface)

2. **Illustrate the importance of power quality monitoring and also enlighten the role of the power quality monitoring instruments. (13 M)**BTL4

Answer: Page: 5.1 & 5.8 – T.Sriananda Ganesh

Importance of power quality monitoring:

The monitoring objectives determine the choice of monitoring equipment, triggering thresholds, methods for data acquisition and storage, and analysis and interpretation requirements.

1.Monitoring to charactering system performance: (2 M)

- A power produces may find this objective important if it has the need to understand its system performance and then match that system performance with the needs of customer
- System characterization is a proactive approach to power quality monitoring.

2.Monitoring to characterize specific problem: (2 M)

This is a reactive mode of power quality monitoring, but it frequently identifies the cause of equipment incompatibility, which is the first stage to a solution.

3.Monitoring as part of an enhanced power quality service: (2 M)

These services offer differentiated levels of power quality to match the needs of specific customers.

4. Monitoring as part of predictive or just in time maintenance:(2 M)

- Power quality data gathered over time can be analyzed to provide information relating to specific equipment performance.
- Equipment maintenance can be quickly ordered to avoid catastrophic failure

<u>Role of the power quality monitoring instruments:</u>

1. Monitor Connections: (2 M)

- To provide input power to the monitor from a circuit other than the circuit to be monitored.
- Grounding of the power disturbance monitor is an important consideration. The disturbance monitor will have a ground connection for the signal to be monitored and a ground connection for the power supply of the instrument.

2. Setting Monitors Thresholds: (1 M)

The best approach for selecting threshold is to match them with the specifications of the equipment that is affected. This may not always be possible due to lack of specifications or application guidelines.

3. To measure Quantities and Duration: (1 M)

- Current measurements are used to characterize the generation of harmonic by non-linear loads on the system.
- Voltage measurements helps characterize the system response to gathered harmonic currents.

4. Finding the source of a disturbance: (1 M)

- Identifying the source of a disturbance is to correlate the disturbance waveform with possible causes.
- Identification becomes more straight forward when the cause has been determined.

3. **Discuss in detail about IEEE flicker meter and also explain the statistical analysis of long term and short term flicker evaluation. (13 M)**BTL4

Answer: Page: 5.22 – T.Sriananda Ganesh

Definition: (2 M)

A flicker meter is a device that demodulates the flicker signal, weighs it according to established flicker curves and performs statistical analysis on the processed data.

Block diagram: (4 M)

Explanation: (4 M)

<u>Two parts:</u>

- Simulation of the response of the lamp eye brain chain.
- Online statistical analysis of the flicker signal and presentation of the results.

These meters can be divided into 3 sections

First section – The input waveform is demodulated, thus removing the carrier signal.

Second section – Removes the unwanted terms using filters

Third section – Statistical analysis of the measured flicker

<u>Six Blocks:</u>

Block 1: Input voltage adaptor

Block 2: Square low demodulator

Block 3: Two filters

Block 4: Squaring multiple and sliding mean filter

Block 5: Statistical Analysis of the instantaneous flicker level.

Flicker Standards: (3 M)

- IEEE Standard 141 – 1993
- IEEE Standard 519 – 1992
- IEC standard 61000 – 4 – 15 (formerly IEC 868)

PART*C

1. **Explain in detail the applications of expert system for power quality monitoring.(15 M)** BTL6

Answer: Page: 5.27 – T.Sriananda Ganesh

Diagram: (5 M)

Explanation: (5 M)

The development of an autonomous expert system calls for many approached such as Signal processing and rule – based techniques along with the knowledge – discovery approach commonly known as data mining.

The process of turning raw measurement data into knowledge involves the following operations:

- Selection and preparation
- Information extraction from selected data
- Information assimilation
- Report presentation

Steps: (5 M)

- The first step in the knowledge discovery is to select appropriate measurement quantities and disregard other types of measurements that do not provide relevant information.
- The data selection task is responsible for ensuring that all required phase voltage and current waveform data are available before proceeding to the next step.
- The second step attempts to represent the data and project them onto domains in which a solution is more favorable to discover.
- The data are already projected on other spaces or domains that are ready to extract the desired information.
- A simpler harmonic frequency extracting process might be accomplished by first computing the noise level in the frequency domain – signal. Any magnitude higher than the threshold number may indicate the presence of harmonic frequencies.
- The data mining step usually results in scattered pieces of information.
- The last step in the chain is interpretation of knowledge and report presentation.

2. **Explain the function of active filters and how it overcomes the drawbacks of passive filter in controlling harmonics. (15 M)**BTL4

Answer: Page: 5.28 – T.Sriananda Ganesh

Explanation: (7 M)

Filters are used where effective reduction or elimination of certain harmonics is required. It is generally classified as

- Passive Filters
- Active Filters

The application of passive tuned filters introduces new system resonances which depend on specific system conditions.

Passive filters are required to be significantly overrated in order to account for possible harmonic absorption from the power system and also the ratings must synchronize with reactive power requirements of the loads. Therefore it is often difficult to design such filters to avoid leading power factor operation for some loading conditions.

A flexible and reliable solution to voltage or current quality problems is provided by active power filters. Active filters have the advantage of compensating harmonics without frequency reactive power concerns.

They are based on PWM converters and are connected to low and medium voltage distribution power system in shunt or in series.

Drawbacks of Passive filter: (4 M)

- Insufficient fitness for large bands of harmonic frequencies, which insists the use of more number of filters.
- Possibility of series and parallel resonance with the grid which may cause dangerous amplification of neighboring frequency harmonics.
- Highly dependent on the grid, load parameters and main frequency.
- Bulky equipment.
- Very low flexibility for load variations which implies new filter design for each load variation.

Advantages of Active filter: (4 M)

The active filters present many advantages over traditional methods for harmonic compensation such as:

- Adaptation with the variation in the loads.
- Possibility of selective harmonic compensation.
- Limitations in the compensation power.
- Possibility of reactive power compensation.
- Do not resonate with the power system
- Operate autonomously with respect to the system impedance characteristics.

3. **Briefly discuss the common objectives of power quality monitoring. (15 M)**BTL2

Answer: Page: 5.1 – T.Sriananda Ganesh

The monitoring objectives determine the choice of monitoring equipment, triggering thresholds, methods for data acquisition and storage, and analysis and interpretation requirements.

1.Monitoring to charactering system performance: (3 M)

- A power produces may find this objective important if it has the need to understand its system performance and then match that system performance with the needs of customer
- System characterization is a proactive approach to power quality monitoring.

2.Monitoring to characterize specific problem: (3 M)

This is a reactive mode of power quality monitoring, but it frequently identifies the cause of equipment incompatibility, which is the first stage to a solution.

3.Monitoring as part of an enhanced power quality service: (3 M)

These services offer differentiated levels of power quality to match the needs of specific customers.

4.Monitoring as part of predictive or just in time maintenance: (3 M)

- Power quality data gathered over time can be analyzed to provide information relating to specific equipment performance.
- Equipment maintenance can be quickly ordered to avoid catastrophic failure

5.To measure Quantities and Duration: (3 M)

- Current measurements are used to characterize the generation of harmonic by non-linear

	loads on the system. ➢ Voltage measurements helps characterize the system response to gathered harmonic currents.