

**1000+**

**Electrical  
Maintenance  
Question  
and  
Answers**

1. What is static electricity?

Static electricity means electricity at rest. If we join a charged conductor to another conductor, electricity flows from one to the other. This way an electric current is produced, which lasts for a moment only. Static electricity is no use. Rubbing of two different materials having different electrons produces this.

2. What is current?

Flow of electrons in any conductor is called electric current. Its symbol is 'I' and measuring unit is Ampere measured by ammeter or ampere meter.

3. What is electro-motive force (emf) or voltage?

It is the pressure that moves the electrons to flow in any conductor. It is also known as electromotive force voltage. Its symbol is 'E' or 'V' and measuring unit is volt measured by voltmeter.

4. What is potential difference (P.D)?

The difference of potential between two points in a circuit is the voltage required to drive the current between them or the voltage drop between those two points is called the potential difference.

$$P.D = R * I \text{ volts.}$$

5. What is terminal voltage ( $V_T$ )?

It is the voltage available at the terminal of the source of supply. It's symbol is  $V_T$ .

$$V_T = \text{emf} - P.D$$

6. What is resistance?

Resistance is the property of a substance, which gives opposition to flow of electrons through itself. Its measuring unit is ohm and measured by ohmmeter, multi meter, wheat stone bridge, and post office box. There are two types of resistances and they are fixed resistance and variable resistance.

7. What is ampere?

The international ampere is defined as that steady current which, flowing through a solution of silver nitrate, deposits silver at the rate of 0.001118 gm/sec.

8. What is volt?

The international volt is defined as 1/1.0183 of the emf of a Weston cadmium cell. It is that difference of potential which, when applied to a conductor whose resistance is 1 (one) international ohm, will cause a current of 1 (one) international ampere to flow.

9. What is matter?

The matter is defined as anything, which possesses weight and occupies space and can be in any of three forms solid, liquid or gaseous. The matter consists of three ingredients, which are protons, neutrons and electrons.

10. What is the speed of electricity or electrons?

The speed of electricity or electrons is 297842 km (186000 miles) per second.

11. How we get electric shock?

On all alternators, transformers neutral is earthed. Human body is conductor and when touched to the live conductor it completes its shortest path through the body and the body gets electric shock in which its nervous system, the heart, respiratory system may cease to function.

12. What is fuse and what materials used for fuse wire?

Fuse is a weakest point in an electrical circuit, which melts when the excess current flows through it in the electrical circuit.

The materials, which can be used in fuses, are tin, lead, zinc, silver, antimony, copper, and aluminium, etc.

13. What is fusing factor?

The ratio of minimum fusing current and the current rating of fusing element is called the fusing factor.

Fusing factor = minimum fusing current / current rating of fusing element. Its value is always more than 1 (one).

14. What is soldering and what is brazing?

Soldering is the process of joining two metals with an alloy whose melting point is less than that of the materials to be soldered.

Soldering at high temperature using brass as solder is called brazing or hard soldering.

The composition of the fine solder (soft solder) is tin 60% and lead 40%. Its melting point is 190°C and is widely used.

15. What are the sources of electricity?

- a. Battery (chemical source)
- b. Generator (magnetism)
- c. Thermocouple (heat generated)
- d. Light (photo electric or solar cell)
- e. Pressure (piezo electricity)
- f. Friction (static electricity)

16. What are the effects of electric current?

- a. Physical effect.
- b. Chemical effect.
- c. Magnetic effect.
- d. Heating effect.
- e. X-ray effect.

17. What is fire?

Destructive burning of any material is called the fire. Fire is the result of combining fuel, oxygen and heat. If any one among three is separated the fire will come to end.

18. On what factor resistance of the substance depends (Laws of resistance)?

- a. The resistance of the conductor is directly proportional to the length of the conductor.
- b. The resistance of the conductor is inversely proportional to the cross-section of the conductor.
- c. The resistance of the conductor depends on the nature of the material by which it is made. That is specific resistance of the material.
- d. The resistance of the conductor depends on its temperature.

The formula to find the resistance of the substance is below.

$$R = \frac{\rho L}{A} \Omega$$

Where  $\rho$  is the constant for the material called its specific resistance or resistivity.

19. What is specific resistance or resistivity of the material?

Specific resistance of the material is the resistance of a piece of unit length and unit cross-section (unit cube of that material). That is the resistance between the opposite faces of unit cube of the material.

Or the specific resistance of any material is the resistance offered by the opposite face of that material.

The unit of specific resistance is  $\Omega/\text{cm}^3$ ,  $\Omega/\text{inch}^3$ ,  $\Omega/\text{m}^3$ .

20. What is the temperature co-efficient of resistance?

Temperature co-efficient of the resistance of any substance is, change in its original resistance due to the change in temperature. The temperature co-efficient of resistance of material is the ratio of increase in resistance of 1°C rise in temperature to the original resistance of the material (strictly at 0°C).

Formula for the resistance measurement is,

$$R_t = R_0 (1 + \alpha t)$$

Where  $R_t \rightarrow$  Resistance at  $t^\circ\text{C}$ .

$R_0 \rightarrow$  Resistance at  $0^\circ\text{C}$ .

$\alpha \rightarrow$  Temperature co-efficient.

$t \rightarrow$  Temperature rise.

21. What are the effects of temperature on resistance?

The effects of temperature on resistance are

- In certain pure metals such as gold, copper, silver, aluminium etc. the resistance increases with increasing temperature at fairly regular manner. Such metals possess positive temperature co-efficient of resistance.
- In certain materials (alloys) such as eureka, nichrome etc. the change in resistance due to increasing temperature is irregular and negligible for a considerable range of temperature.
- In case of certain materials belongs to insulators, electrolytes such as paper, rubber, glass, mica, carbon, acids, alkalies etc. the resistance decreases with increasing temperature at fairly regular manner. Such materials possess negative co-efficient of resistance.

22. What are the classifications of voltages?

- Low voltage: Voltage not exceeding 250V. That is 0 – 250V.
- Medium voltage: Voltage above 250V upto 650V comes under medium voltage.
- High voltage: Voltage above 650V upto 33 kV comes under high voltage.
- Extra high voltage: Above 33 kV voltages are extra high voltages.

23. What is coulomb?

It is the unit of charge. One (1) coulomb is the quantity of electricity, which is circulated by a current of one (1) ampere in one second. The letter Q denotes it.

So that 1 coulomb = 1 amp \* 1 second.

24. What is farad?

Farad is the unit of capacitance and the letter F denotes it. A condenser has a capacitance of one (1) farad, if it is capable to maintain a charge of one coulomb under a potential difference of one volt between its plates.

1 farad = 1 coulomb / 1 volt. =  $Q/V$ .

25. What is henry?

It is the unit of inductance and the letter H denotes it. A circuit has inductance of one henry, if an electro-motive force of one volt is induced in that circuit, when the current in that circuit changes at the rate of one ampere per second.

1 henry = 1 volt sec / ampere.

26. What is the least count of out-side micrometer?

The least count of out-side micrometer is 0.01mm.

## 27.State symbols for quantities and units.

| Sl.No | Name of the quantity    | Symbol | Name of the unit           | Symbol              |
|-------|-------------------------|--------|----------------------------|---------------------|
| 1     | Volume                  | V      | Cubic meter                | m <sup>3</sup>      |
| 2     | Time                    | T      | Second                     | S                   |
| 3     | Frequency               | F      | Hertz                      | Hz                  |
| 4     | Rotational frequency    | N      | Reciprocal second          | S <sup>-1</sup>     |
| 5     | Slip                    | S      |                            |                     |
| 6     | Speed, Velocity         | V      | Meter per second           | m/s                 |
| 7     | Mass                    | M      | Kilogramme                 | Kg                  |
| 8     | Density                 | P      | Kilogramme per cubic meter | Kg / m <sup>3</sup> |
| 9     | Momentum                | P      | Kilogram meter per second  | Kg m/S              |
| 10    | Force                   | F      | Newton                     | N                   |
| 11    | Weight                  | G      | Newton                     | N                   |
| 12    | Torque                  | T      | Newton meter               | Nm                  |
| 13    | Pressure                | P      | Newton per square meter    | N/ m <sup>2</sup>   |
| 14    | Work                    | W      | Joule                      | J                   |
| 15    | Energy                  | E,W    | Joule                      | J                   |
| 16    | Power                   | P      | Watt                       | W                   |
| 17    | Efficiency              | η      |                            |                     |
| 18    | Electric charge         | Q      | Coulomb                    | C                   |
| 19    | Emf, Voltage, PD        | E      | Volt                       | V                   |
| 20    | Electric flux           | ψ      | Coulomb                    | C                   |
| 21    | Capacitance             | C      | Farad                      | F                   |
| 22    | Electric current        | I      | Ampere                     | A                   |
| 23    | Magneto motive force    | Fm     | Ampere turns               | AT                  |
| 24    | Magnetic flux density   | B      | Telsa                      | T                   |
| 25    | Magnetic flux           | φ      | Weber                      | Wb                  |
| 26    | Self inductance         | L      | Henry                      | H                   |
| 27    | Mutual inductance       | Lmm, m | Henry                      | H                   |
| 28    | Resistance              | R      | Ohm                        | Ω                   |
| 29    | Resistivity             | ρ      | Ohm meter                  | Ωm                  |
| 30    | Conductance             | G      | Mho                        |                     |
| 31    | Reluctance              | S      | Reciprocal henry           | H <sup>-1</sup>     |
| 32    | Impedance               | Z      | Ohm                        | Ω                   |
| 33    | Reactance               | X      | Ohm                        | Ω                   |
| 34    | Admittance              | Y      | Mho                        |                     |
| 35    | Active power            | P      | Watt                       | W                   |
| 36    | Reactive power          | Q      | VAR                        | VAR                 |
| 37    | Apparent power          | S      | Volt-ampere                | VA                  |
| 38    | Number of turns         | N      |                            |                     |
| 39    | Speed                   | N      | Rotation per minute        | r.p.m               |
| 40    | Number of phases        | M      |                            |                     |
| 41    | Number of pair of poles | P      |                            |                     |
| 42    | Luminous intensity      | L      | Candela                    | Ca                  |
| 43    | Luminous flux           | φ      | Lumen                      | lm                  |
| 44    | Quantity of light       | Q      | Lumen second               | lm S                |

|    |              |   |     |    |
|----|--------------|---|-----|----|
| 45 | Illumination | E | Lux | lx |
|----|--------------|---|-----|----|



## 28. State Greek alphabets and what for they are used?

| Sl.No | Symbol    | Name        | Used for to indicate                          |
|-------|-----------|-------------|-----------------------------------------------|
| 1     | $\alpha$  | Alpha       | Angle, temperature co-efficient of resistance |
| 2     | $\beta$   | Beta        | Angle                                         |
| 3     | $\gamma$  | Gamma       | Angle, conductivity                           |
| 4     | $\delta$  | Delta       |                                               |
| 5     | $\eta$    | eta         | Efficiency                                    |
| 6     | $\theta$  | Theta       | Angle, temperature                            |
| 7     | $\lambda$ | Lambda      | Wave length                                   |
| 8     | $\mu$     | Mu          | Amplification factor                          |
| 9     | $\pi$     | Pi          | 22/7                                          |
| 10    | $\rho$    | Rho         | Specific resistance, resistivity              |
| 11    | $\sigma$  | Sigma       | Charge density, fractional slip               |
| 12    | $\phi$    | Phi         | Phase angle                                   |
| 13    | $\varphi$ | Capital phi | Magnetic flux                                 |
| 14    | $\Psi$    | Psi         |                                               |
| 15    | $\psi$    | Capital psi | Electric flux                                 |
| 16    | $\omega$  | Omega       | Angular velocity                              |

## 29. What is conductance?

Conductance is the property of the conductor, which allows the flow of electric current through it. Conductance is denoted by the letter G and is reciprocal of resistance. The unit of conductance is mho. A substance, which possesses conductance as its major property can be called as a good conductor.

## 30. What do you mean by insulator? What are the qualities of good insulator?

A substance, which will not allow the flow of electric current to pass through it is called the insulator. The conductance and conductivity is zero in insulators. Insulators are used to isolate the electric current from neighbouring parts. Insulators will not allow the leakage of current, short-circuiting current, shock to the operator and isolate the electric current safely without any diversion to any other place.

Qualities of good insulator

- It should be flexible
- It should have good mechanical strength
- It should easily moulded into any shape
- It should not be effected by acid
- It should be non-inflammable
- It should have very high specific resistance to prevent leakage current
- It should be withstand high temperature. Because insulators possess negative temperature co-efficient of resistance. That is resistance decreases with increasing temperature
- It should have high dielectric strength

31. What is electrode?

A conducting element used for converging (centering) current to and from a medium is called electrode. There are two types of electrode. A positive and other is negative.

**32. What is force?**

Force is that which change or tends to change a body state of rest or uniform motion through a straight line. The unit of force is Newton.

**33. What is Newton?**

One Newton is that amount of force which acting on one-kilogram mass for one second gives an acceleration 1 meter/sec/sec.

**34. What is weight?**

Weight is the gravitation force by which a body attracted to the earth. Gravitational unit of force in M.K.S system is kilogram weight or 9.81 Newton.

Weight is the force with which 1-kilogram mass is attracted by the earth towards its center.

**35. What is bayer?**

Bayer is the C.G.S unit of pressure and is equal to 1-dyne/cm<sup>2</sup>.

**36. What is conductor?**

Substances such as metals, which have large number of free electrons are said to offer a low resistance to the flow of electrons under the influence of emf and hence are called conductors.

Conductors are used to conduct electricity from one place to another place due to its major property conductance. Conductors are classified into three main groups.

- a. Good conductors.
- b. Semi conductors.
- c. Fair conductors.

**37. What are the properties of good conductor?****Properties of good conductor**

- a. It posses very low resistance or specific resistance.
- b. It posses more conductance and there by conducts electricity readily through it.
- c. It is a good conductor of heat.
- d. It is highly resistance to corrosion by liquid.
- e. It must be malleable and ductile.
- f. It must be flexible.
- g. It posses better tensile strength.
- h. It should not react with climatic conditions.
- i. It can be drawn in very fine wires.
- j. It must be readily joinable.
- k. It must be very low in cost.
- l. It must available in plenty.

37. What are the common conductors in sequence with high conductivity?

- a. Silver
- b. Silver copper alloy
- c. Copper (Hard drawn and Annealed)
- d. Gold
- e. Zinc
- f. Platinum
- g. Tin
- h. Aluminum
- i. Iron
- j. Brass
- k. Phosphorous bronze
- l. Nickel
- m. Lead
- n. Germanium silver
- o. Antimony
- p. Platinoid
- q. Mercury
- r. Bismuth
- s. Platinum iridium

38. What is semiconductor?

Semiconductors possess less conductivity (conductance) than good conductors. That is semiconductors give opposition (resistance) to the flow of free electrons than that of good conductor.

Examples for semiconductor are

- a. Dilute acid
- b. Metallic ores
- c. Sea water
- d. Moist earth
- e. Silicone
- f. Germanium

39. What is fair conductor?

Fair conductors are the materials, which have less conductivity than that of semiconductor. Fair conductor gives more opposition to the flow of free electrons than that of semiconductors.

Examples for fair conductors are

- a. Charcoal
- b. Coke
- c. Carbon
- d. Plumbago

40. What is resistor?

Resistors possess high resistance, but less conductance. This property is well utilized to convert electrical energy into heat energy. Common application of resistors is production of heaters. Examples are eureka, carbon, nichrome, tungsten, manganin, germanium, and tantalum. In case of heaters, electrical iron and soldering iron etc the heating element are made of nichrome, but in lamps filament is made of tungsten.

41. What is the difference between resistor, rheostat and potential divider?

Resistor: a fixed resistance connected permanently in the circuit for limiting the current to definite value is called the resistor.

Rheostat: a variable resistance by sliding contacts on it the current can be varied is called rheostat.

Potential divider: when a resistance is used to develop a voltage drop it is called a potential divider.

42. What is solder?

Solder is an alloy of lead and tin mixed in different proportion as per the work to be done. In some cases certain % of bismuth and cadmium is also added to decrease the melting point of the solder. Antimony increases the melting point of the solder.

Bismuth has a special quality in comparing to most of other metals. That is it expands when it cools. This property helps to shrink the solder and thereby it allows the joint become firm.

The quality of the solder depends on the % of tin in the solder. To get stronger joint add more tin in the solder.

For electrical work fine solder of 1½ part tin and 1 part lead is used and for sheet metal works soft solder of 1 part tin and 1 part lead is used.

43. What is flux?

Flux is a cleanser and is used to remove and prevent oxidation of the metals, allowing the solder to flow from and to, to unite the solder more firmly with the surface to be joined.

44. What is skin effect?

Electricity has affinity (fondness) to pass through peripheral surface of the conductor. This effect of electricity flowing through the peripheral surface of the conductor is known as skin effect.

45. What are the advantages of stranded cables?

- a. It gives flexibility.
- b. It prevents skin effect.
- c. Increases current carrying capacity.
- d. It provides easy in soldering joint.
- e. If one strand breaks the other will carry the load current.

## 46. State the Ohm's law.

In a closed electrical circuit, at a constant temperature, the ratio between the resulting unvarying current or direct current and applied voltage is a constant. That constant is known as resistance.

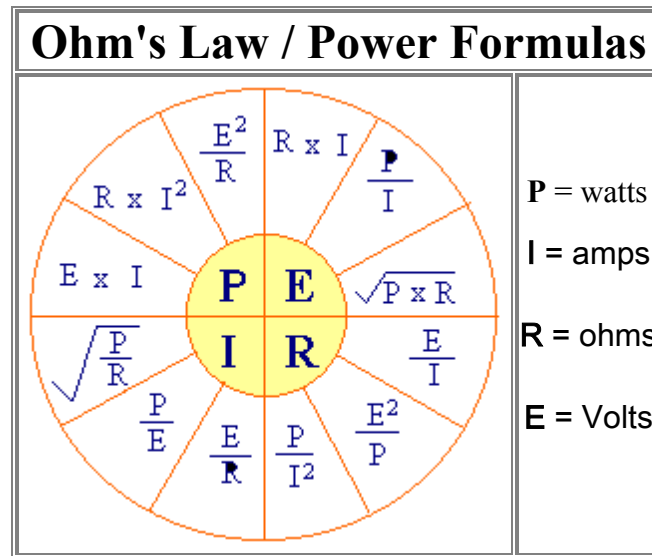
OR

In simple manner Ohm's law says that, in a closed electrical circuit the current is directly proportional to the voltage and inversely proportional to the resistance of the circuit.

$$I = V/R \text{ or}$$

$$R = V/I \text{ or}$$

$$E = IR.$$



## 47. What is series circuit? What are the characteristics of series circuit?

It is that circuit where two or more electrical consuming devices are connected so as to provide only one path to the flow of current.

Characteristics of series circuit

- It has only one path for the flow of current.
- If any breakage happens the whole system will be out of that circuit.
- It is very difficult to find the fault.
- Individual voltage drop depends on individual resistance ( $V = I r_n$ ).
- The total resistance of a series circuit is the sum of the individual resistance.
- Addition of the resistance increases total resistance and decreases the current.
- Individual device will not get its full efficiency.

48. What is parallel circuit? What are the characteristics of parallel circuit?

It is that circuit where two or more electrical consuming devices are connected so as to provide as many parallel paths to the flow of current.

Characteristics of parallel circuit

- a. As many parallel paths as there are devices.
- b. Individual devices will get its full efficiency.
- c. Breakage in one circuit will not affect the other circuit.
- d. Current in each device is different according to the resistance of the device.
- e. If the individual resistance increases the total resistance will decrease  
 $(1/R = 1/r_1 + 1/r_2 + 1/r_n)$
- f. The reciprocal of total resistance is equal to the sum of the reciprocal of individual parallel resistances  $(1/R = 1/r_1 + 1/r_2 + 1/r_n)$ .
- g. Individual conductance is inversely proportional to the individual resistance.
- h. If two same value resistors are connected in parallel circuit the total resistance is the resistance of one resistor. And the total of parallel circuit resistance will be less than the least resistance in that circuit.

49. What is capacitor? On what factor capacity of a capacitor depends?

Capacitor or condenser is a device to store electrical energy and to release it into the circuit of which the capacitor forms a part.

Capacity of a capacitor depends on following factors

- a. Capacity of the capacitor is directly proportional to the area of the plate.
- b. Capacity is inversely proportional to the distance between the plate. That is if the distance is more the capacity decreases or if the distance is less the capacity more.
- c. It depends on the nature of dielectric constant.

50. On what factor voltage rating of the capacitor depend?

The voltage rating of the capacitor depends on the distance between the plates of the capacitor. If the voltage exceeds, the electrons across the space between the plates can result in permanent damage to the capacitor.

51. What are the types of capacitor?

- a. Paper capacitor.
- b. Rolled plastic cover or polyester type capacitor.
- c. Mica capacitor.
- d. Silver mica capacitor.
- e. Ceramic capacitor.
- f. Electrolytic capacitor.

52. What is the resultant capacitance in series and parallel circuit?

In series circuit the resultant capacitance  $1/C_T = 1/c_1 + 1/c_2 + 1/c_n$  farad.

In parallel circuit the resultant capacitance  $C_T = c_1 + c_2 + c_n$  farad.



53. What is the formula to find the capacitance in a circuit?

$$C = Q/E \text{ farad.}$$

## 54. What is work?

Work is said to be done, when the point of application of the force moves. Work done is equal to force \* distance. The unit of work is Newton (M.K.S system) and joule (1 Newton Meter).

## 55. What is power?

Power is the rate of doing work or power is the work done per second.

Power = Work / time.

Unit of electrical power is watt. One mechanical horsepower is equal to 746 watts (British) and 735.5 watts (metric) or 735.5 joules/sec. So 1 kW is equal to 1.34 horsepower (British) and 1.36 horsepower (metric).

## 56. What is energy?

Energy is the capacity to do the work. The unit of energy is joule or watt-second or watt-hour or kilo watt-hour.

## 57. Define Joule's law.

The heat generated in conductor (resistance) while the flow of current is directly proportional to the square of the current, the resistance of the conductor and time for which the current flows.

$H = I^2 R t$  / J calories.

Where J is mechanical equivalent of heat is equal to 4.2 Joules.

In electricity  $H = 0.24 I^2 R t$  calories.

## 58. What is electrolysis?

When current passes through an acid or a salt, it de-composes and the two de-composed portions tend to move in opposite direction. This process is called the electrolysis.

Or the process of decomposing a liquid by the passage of electric current (DC) through it is called the electrolysis or electric analysis.

## 59. What are the Faradays laws of electrolysis?

**First law**

The mass ions liberated at an electrode are directly proportional to the quantity of electricity (coulomb Q) which has passed through the electrolyte. That is  $M \propto Q$  or  $M \propto I t$ .

And  $M = Z I t$ .

Where Z is electro chemical equivalent.

**Second law**

If the same quantity of electricity passes through several electrolyte the masses of the ions liberated are proportional to their respective chemical equivalent.

60. What is electro plating?

The process of depositing a metal on the surface of another metal by electrolysis is known as electro plating. Usually the plating material will be silver, chromium etc.

61. What are the applications of electrolysis?

- a. Electro plating.
- b. Purification of copper and extraction of number of metals and number of commercial compounds like sodium, hydrogen, hydroxide, oxygen etc.
- c. Electro typing.
- d. Determination of DC polarity.
- e. Electro refining of metals.

62. State the laws of magnetism.

- a. Magnet imparts its magnetic properties to other metals.
- b. When a magnet is suspended freely horizontally, it stands at geographical north and south.
- c. Every magnet has a north and its associated separable South Pole.
- d. If a magnet broken in any number of pieces, each piece will act as a separate magnet having north and south poles.
- e. ***Like poles repulse and unlike poles attracts.***
- f. ***The amount of attraction or repulsion is directly proportional to the pole strength and inversely proportional to the square of the distance between them. This is some times known as inverse square law.***

63. What is flux density?

It is the flux passing per unit area in a substance through a plain at a right angle to the flux. The letter 'B' denotes it and it is measured in Weber/cm<sup>2</sup>.

$$B = \Phi/a \text{ Weber/cm}^2.$$

64. What is magneto motive force?

The force, which drives the magnetic flux through a magnetic circuit, is called the magneto motive force.

65. What is permeability?

Permeability of a substance is the conducting power for lines of force of magnetic material as compared with the air.

66. What is reluctivity?

It is the specific reluctance of a magnetic circuit or magnetic material as in the case of resistivity in an electric circuit.

67. What is reluctance?

It is the property of a magnetic material, which opposes the establishment of magnetic flux in it, as in the case resistance in an electric circuit.

68. What is permeance?

It is the reciprocal of reluctance, which helps to develop or establish magnetic flux easily in a magnetic material as in the case of conductivity in an electrical circuit.

69. What are the methods of magnetization?

- a. Tough method
- b. By means of electric current
- c. Induction method

70. How the polarity of the magnet can be determined?

Polarity of the magnet can be determined by 'End rule' and 'Palm rule'.

71. What are the advantages of electro magnetism?

- a. Electro magnets can be magnetised very easily by sending DC through it.
- b. Changing the direction of the current through the coil can change the polarity of the poles.
- c. The strength of the magnet can be controlled by the electric current.
- d. Electro magnets can be made in any shape depending upon the need.
- e. The magnetic strength remains constant as long as the current is constant.

72. State 'Cork screw rule' and 'Right hand thumb rule'.

Cork screw rule

Direction of magnetic lines of force around a straight current carrying conductor can be determined by these rules.

'Cork screw rule' says that, the direction of magnetic lines of force around a straight current carrying conductor is the same as that in which the cork screw must be rotated to cause to an advance in the direction of the current in conductor.

Right hand thumb rule

Grasp the conductor with right hand in such a way that the extended thumb must be in the direction of current in the conductor. Then the folded fingers or encircling fingers must be in the direction of magnetic lines of force around the conductor.

73. Who discovered electro magnetism?

'Orsted' a denish scientist discovered that whenever an electric current passes through a conductor, a magnetic field will be produced around that conductor in concentric circle. In addition to that heat will be produced in that conductor.

74. State the faraday's laws of electro magnetic induction.

In 1831 Faraday discovered the production of electric current in electric conductor by converting magnetism. Faraday has mentioned two laws known as faraday's laws of electro magnetic induction.

First law

Whenever a conductor causes to cut the magnetic lines of force an emf will be induced in that conductor.

Second law

The quantity of electricity or the value of the emf produced in that conductor is directly proportional to the rate of change of flux linked with that conductor.

## 75. How we can find the direction of induced emf?

The direction of induced emf can be found out by the 'Fleming's right hand rule', and 'Lenz's law'

Fleming's right hand rule

Fleming's right hand rule states that, if one extends the thumb, fore finger and middle finger of the right hand at right angle to each other in such a way that the thumb point in direction of motion of the conductor, the fore finger in the direction of flux (from north to south pole), then the middle finger indicates the direction of the induced emf in the conductor.

Lenz's law

The Lenz's law states that, electro magnetically induced current always flows in such a way or direction that the action of magnetic field set up by induced current tends to oppose the root cause which produces it.

## 76. What is eddy current?

Eddy currents are those which are produced or induced in the mass of metal whenever the metal is moved in magnetic field of the magnetic field is moved across the mass metal so as to link it. The direction of this eddy current is always in opposite direction to the cause to produce them as per Lenz's law.

Eddy current can be calculated by following equation

$$W_e = k B_{\max}^2 f^2 t^2 v \text{ watt.}$$

Where  $k$  – Constant

$B_{\max}$  – Maximum flux density

$f$  – frequency of magnetic reversal

$t$  – thickness of each lamination

$v$  – volume of the armature core or mass metal.

Development of eddy current is made use in energy meters to provide controlling torque and also in form of automatic starters in moving coil measuring instruments.

## 77. What is magnetic Hysteresis?

Lagging of magnetization or induction flux density 'B' behind the magnetising force 'H' is known as magnetic hysteresis.

## 78. What are the types of induced electro motive force?

a. Dynamically induced emf.

b. Statically induced emf.

Statically induced emf can be further divided into two groups.

a. Mutually induced emf.

b. Self induced emf.



79. What are the use of mutual induction and self-induction?

Use of mutual induction

- a. Transformers are works on this principle.
- b. An inductance furnace makes use of it.
- c. Used in ignition coils of motor car, motor cycles, scooters etc.

Use of self-induction

- a. In regulators to give reduced voltage to the fans.
- b. In fluorescence tube light to give high voltage at the time of starting and to give low voltage at its normal working time.
- c. Used in welding plant rectifiers to keep arc stationary by smoothing choke.

80. What are the different methods used to measure the resistance?

The different methods developed to measure the resistances are as follows.

- a. Wheat stone bridge.
- b. Slide wire bridge.
- c. Post office box.
- d. Ohm meter.
- e. AVO meter or multi meter.
- f. Bridge megger.
- g. Megger.

81. What is generator? What are the essential parts of the generator?

Generator is a machine, which converts mechanical energy into electrical energy.

A generator works on under the principle of faraday's laws of electro magnetic induction.

Its essential parts are conductor, magnetic field and the movement of either the conductor or the magnetic field so as to create a rate of change of flux linkage with the conductor by the action of applied mechanical energy.

82. What is the equation used to find out frequency of number of cycles of induced emf?

$$f = NP/120$$

83. What are the types of generators?

There are two types of generator.

- a. Permanent magnet generator.
- b. Electro magnet generator.

In electro magnet generator there are two types.

- a. Self excited generator.
- b. Separately excited generator.

84. What are main types of DC generator?

Mainly there are three types.

- a. Series generator or series wound generator.
- b. Shunt generator or shunt wound generator.
- c. Compound generator.

There are different types of compound generator.

- a. Short shunt commulative compound generator.
- b. Short shunt differential compound generator.
- c. Long shunt commulative compound generator.
- d. Long shunt differential compound generator.

Depending upon the terminal voltage characteristics there are three types of compound generator.

- a. Under compound generator.
- b. Flat or level compound generator.
- c. Over compound generator.

85. What is the emf equation for generator?

$$\text{emf} = \frac{P \cdot \phi \cdot Z \cdot N}{A \cdot 60}$$

Where,

$\phi$  = Flux per pole in Weber.

Z = Total number of armature conductors.

P = Number of poles.

A = Number of parallel paths in armature.

N = Speed in rpm.

emf = emf generated in one parallel path and it is the emf generated of that generator.

For a wave wound generator there are only two (2) parallel paths in the armature. In such cases  $A=2$  and in lap wave wound armature parallel paths is equal to the number of poles in the armature winding.

86. What are the losses in DC generator?

There are two main losses.

- a. Copper losses or electrical losses.
- b. Stray losses or rotational losses or constant losses.

Copper losses includes following losses

- a. Armature copper losses ( $I_a^2 r_a$ ).
- b. Field copper losses ( $I_{se}^2 r_{se}$ ) or ( $I_{sh}^2 r_{sh}$ ).
- c. Losses in brush.

Stray losses are as follows

- a. Magnetic losses (Iron loss or core loss).
- b. Mechanical losses.

87. What is efficiency of generator?

$$\begin{aligned}\text{Efficiency} &= \text{Out put} / \text{input} \\ &= \text{Out put} / \text{out put} + \text{losses}\end{aligned}$$

**88. What is armature reaction?**

Armature reaction is the effect of armature flux on the main field flux.

The effects of armature reaction are follows.

- a. Armature reaction destroys (cross magnetizes) and weakens the main field flux produced by the main pole.
- b. It causes to reduce the induced emf in the armature.
- c. It causes to reduce the efficiency of machine.
- d. It causes to produce sparking at the brushes due to the shifting of M.N.A (magnetic neutral axis).
- e. At short-circuited loads or at very heavy loads, in case of self-excited generators de-magnetising of pole cores (wiping of residual magnetism) may takes place.

**89. What are the remedies for armature reaction?**

- a. Brushes have to shift to new M.N.A position in the direction of rotation of armature.
- b. To over come the weakening of the field extra turns have to be added in armature.
- c. Pole shoes have to modify at trailing pole tip side to increase the reluctance.
- d. Pole shoes have to modify to increase the reluctance.
- e. In big machines there is chance of load fluctuation, a compensating winding to be placed at the pole shoes and it is connected in series with the armature winding such that the current in that winding is opposite to the armature winding.

**90. What is commutation?**

Usually the width of the brush is equal to the two segments of the commutator. Whenever a brush contacts two or more commutator segments, the connected to those segments are short-circuited. After the period of short-circuiting the current on those coils changes their current direction in it. The change that takes place in the coil after the period of short-circuiting of that coil is called commutation.

When that changes take place slowly, that commutation is known as smooth commutation and when that changes take place suddenly, that commutation is known as rough commutation.

If the commutation is not smooth, the spark may be more and that will damage the commutator surface, commutator segments and so the winding.

The remedies for rough commutation are resistance commutation method and emf commutation method.

**91. What are the characteristics of DC generator?**

There are three main characteristics of DC generator and they are,

- a. No load saturation characteristics or OCC or magnetic characteristics ( $E_0/I_f$ ).
- b. Internal or total characteristics ( $E/I_a$ ).
- c. External characteristics ( $V/I$ ).

## 92. What is motor? How DC motor works?

A motor is a machine, which takes electrical energy and converts that electrical energy into mechanical energy.

DC motor works under the principle, that whenever a current carrying conductor placed in a magnetic field, a mechanical force will be acts upon that conductor and the conductor tends to rotate, if it is arranged freely to rotate.

The direction of the force or rotation can be determine by “Fleming’s left hand rule”

## 93. What is torque?

Whenever a current carrying conductor placed in a magnetic field, a mechanical force will be acts upon that conductor and the conductor tends to rotate, if it is arranged freely to rotate. This rotation is due to the turning or twisting force acted on that conductor. This turning or twisting movement of a force about an axis is called torque ‘T’.

**$T = \text{force} * \text{radius}$  Newton-meter.**

Work done per revolution = force \* distance covered in one revolution.

$\therefore$  Work done per revolution = force \*  $2\pi r$ .

Work done per second = force \*  $2\pi r$  N (r.p.s)

Work done per second =  $2\pi N T$  ( $\because T = F * r$ )

So power developed in metric horsepower is equal to force  $2\pi NT/735.5$  hp.

## 94. What are the classifications of DC motor?

- a. DC series motor.
- b. DC shunt motor.
- c. DC compound motor.

There are two types of DC compound motor.

- a. Differential compound motor.
- b. Commulative compound motor.

## 95. What are the losses in DC motor?

The losses in DC motor are same as that of DC generator. They are copper losses, magnetic losses and mechanical losses.

## 96. What are the characteristics of DC motor?

The characteristics of DC motor shows the relation between armature current ( $I_a$ ), speed (N) and torque (T).

- a. Torque and armature current characteristics. It is also known as electrical characteristics.
- b. Speed and armature current characteristics.
- c. Speed and torque characteristics.

97. What is the necessity of DC motor starter?

$$E_b = V - I_a r_a.$$

$$\therefore I_a = (V - E_b) / r_a.$$

At the time of starting from the rest there is no any back emf ( $E_b$ ) in the armature. So a large current flows through the armature based on  $V / r_a$ . This very large current blow out the fuses and before to that it will damage the commutator, commutator brushes and winding. To avoid this difficulties a proper resistance has to be introduce in series with the armature till the motor reaches it's rated speed or till development of  $E_b$  in the armature to reduce the starting large current to safe value. This starting resistance is gradually cut out as the motor gains speed and the develops back emf ( $E_b$ ) which regulates it's speed and armature current. This can be achieved by the help of starter.

98. What are the types of DC motor starter?

- a. DC two point starter for series motor.
- b. DC three point starter for shunt motor.
- c. DC four point starter for compound motor.

99. How speed control of DC motor can be achieved?

Induced emf in the armature  $E = P * \phi * Z * N / A * 60$  volts.

Where Z and A are constant.

$$N \propto E_b / \phi$$

$$N \propto (V - I_a r_a) / \phi.$$

We can consider that the  $I_a r_a$  drop is very small and there by in the place of  $V - I_a r_a$  we can consider only V. If it so then  $N \propto V / \phi$ .

So speed may be varied by varying either applied voltage to the armature and by varying field flux or field strength per pole or total field flux.

100. What is cell?

Cell is one unit for converting chemical energy into electrical energy. A cell essentially requires two electrodes, electrolyte and container.

101. What is battery?

The combination of two or more cells is called the battery.

102. What are the classifications of cell?

- a. Primary cells.
- b. Secondary cells.

103. What are the differences between primary cell and secondary cell?

Primary cells are those cells, which cannot be re-charged after the substances (electrolyte, electrode and container) used in it becomes useless.

The common primary cells in use are,

- a. Simple voltaic cell (one fluid cell).
- b. Daniel cell (two fluid cell).
- c. Leclanche cell (two fluid cell).
- d. Dry cell.
- e. Standard cell or Weston cadmium cell.

Secondary cells are those cells, which can be re-charged and use again once they discharged or used for the work for number of times with out re-newing it's materials.

Most commonly used secondary cells are,

- a. Lead acid cell.
- b. Nickel iron alkaline cell.
- c. Nickel cadmium alkaline cell.

104. What is polarization? What is local action?

Polarization

The hydrogen bubbles which are clinging over the surface of copper electrode (anode) becomes a thin film of hydrogen over the copper electrode. This hydrogen film increases the internal resistance and reduces the emf of the cell and hence the cell soon becomes inactive. This effect is known as polarization.

Local action

In voltaic cell it is observed that, when the cell is not connected to the load and not supplying any current zinc will continuously dissolving in the electrolyte. This is due to the impurities (copper, iron, tin, and lead) in the commercial zinc. So that whenever commercial zinc is used as a electrode, separate small cells are developed between the impurities and zinc with the presence of electrolyte. These local cells consume always zinc and the emf developed by those local cells are always opposite to the main emf. The action of these cells is known as local action.

105. What are the advantages of secondary cells over primary cell?

- a. It gives high current capacity.
- b. Its internal resistance is very low.
- c. It gives a constant current.
- d. It posses very high efficiency.
- e. It posses fairly constant emf.
- f. It posses good mechanical strength.
- g. It posses large storage capacity.

- h. It can be renewed by charging after it is discharge.
- i. It is durable.



106. What is Plante plate and Faure plate?

There are two types of positive plate preparation. They are Plante plate and Faure plate.

Plante plate

As per plante process positive plate  $\text{PbO}_2$  are prepared by a process of repeated charging and discharging of pure lead. Positive plates, which are made by this process, are also called 'formal plates'. This process of positive plate preparation required very long time for its manufacturing and so it is very costly.

Faure plate

Faure plates are generally made up of rectangular lead grid into which the active material lead peroxide  $\text{PbO}_2$  is filled in the form of paste.

107. How negative plate is made up of?

The negative plate of a lead acid cell is made up of spongy lead 'Pb'. The negative plates are also of rectangular lead grid and the active material Pb in the form of paste is held firmly in this lead grid.

108. Why negative plates are one more than positive plates?

Negative plates are one more than positive plates so as to get negative plates on both the sides of positive plates. This is to prevent the buckling action of the lead on positive plate in the multi plate lead acid cell. The other reason is that both the sides of positive plates will become active and the efficiency of the positive plate and the cell will increase.

109. What is electrolyte?

Electrolyte is the medium through which the current produces chemical changes. Electrolyte is a mixture of sulphuric acid of 1.85 specific gravity (concentrated sulphuric acid) diluted with distilled water in the ratio of 1:3 approximately, so the specific gravity of the dilute sulphuric acid is 1.280.

110. What are the types of grouping of cells?

There are three main ways of grouping.

- a. Series grouping.
- b. Parallel grouping.
- c. Series parallel grouping.

### 111. What are the advantages of series grouping and parallel grouping?

#### Advantages of series grouping.

- The total emf increases and is equal to ' $nE$ '. Where  $n$  – total number of cells in series and  $E$  – emf of one cell.
- The internal resistance ' $r$ ' also increases and equal to ' $nr$ '. So total resistance of the circuit also increases and is equal to  $R + nr$  ohms. Where  $R$  – external load resistance.
- Total current is equal to one cell current. That is there is no current increase. If the internal resistance is negligible or less then current will be maximum.

#### Advantages of parallel grouping.

- In parallel grouping emf of one cell will be the total emf of the grouping.
- Total internal resistance of the parallel group is equal to  $r/n$ .
- Total resistance of the group is equal to  $R + r/n$ .
- Total current =  $E / (R + r/n)$  amps.

So we can understand that parallel useful when the external resistance is small as compared to internal resistance of the parallel group. But at the same time series grouping is useful when the internal resistance is small compared to the external resistance of the group.

### 112. What are the methods of charging of battery.

Mainly there are three types of charging of battery.

- Constant current charging system.

In this system the charging current is kept to constant by varying the supplied DC voltage by the help of rheostat or filament lamps in series with the battery, so as to overcome the increased back emf of the battery or of the cell.

Charging current =  $V - E_b / R + r$  amps.

- Constant voltage or potential charging.

In this system the voltage is kept to constant, so the charging current in the beginning will be high when the back emf or counter emf of the battery is low and current will be small when the back or counter emf increases as the battery gets charge.

- Trickle charging system.

The continuous charging of a battery at a very low rate for keeping the battery ready in good working condition is called the trickle charging. This is to maintain the losses occurring at the idle period. The value of the trickle charging current is approximately 2% of the full charging current of the battery.

113. What are the factors on which the capacity of the battery depends?

The capacity of the battery is measured in ampere-hour. The capacity of the battery depends upon the following factors.

- a. Number and area of the positive plate.
- b. Discharge voltage. A cell should not be discharged below 1.8 V. If it is discharged below 1.8 V it may cause to reduce the capacity.
- c. Discharge rate. Capacity decreases with increase rate of discharge.
- d. Specific gravity of electrolyte. With rapid rate of discharge causes to weaken the electrolyte so the chemical action also weakens and there by the capacity decreases. When the specific gravity increases the capacity of the battery increases.
- e. Quantity of electrolyte. Electrolyte level should be at the top plate level.
- f. The design of separator. The design of the separator should be thin.
- g. Temperature. When the temperature increases the resistance of the battery decreases and the capacity increases.

114. Explain Kirchhoff's laws.

Kirchhoff's laws are used in complex network circuits to determine the equivalent total resistance and the current flowing in various conductors of that circuit.

Mainly there are two laws.

- a. Point law or current law.
- b. Mesh law or voltage law.

Point law or current law.

The point law states that, the algebraic sum of the currents meeting at any point or junction or node of a network is zero. In other words the sum of the currents flowing towards the junction or node or any point of network is equal to the total current flowing away from that junction.

Mesh law or voltage law.

The mesh law states that, in any closed electrical circuit the algebraic sum of the potential drops is equal to the sum of the impressed emf's acting in that close circuit. In this the important factor is to determine the emf sign to calculate the total emf.

115. What are the types of wiring?

Mainly there are two types of wiring systems.

- a. Tree system.
- b. Distribution system.

116. What are the systems of wiring?

Following are the general systems of domestic wiring and industrial wiring.

- a. Cleat system wiring.
- b. Casing and capping system wiring.

- c. Lead sheathed system wiring.
- d. C.T.S, T.R.S, P.V.C sheathed system wiring.
- e. Conduit system wiring.

117. What are the testing of wiring installation?

Following are the tests to be done after installation of wiring.

- a. Polarity test.
- b. Short circuit test.
- c. Continuity test.
- d. Insulation test between conductors and conductors to the earth.
- e. Earth continuity test.

118. What are the advantages of AC over DC?

- a. For the same capacity alternators are cheaper than DC generators, because alternator is not having commutator arrangement and there by small in size.
- b. Alternating current produces pulsating magnetic field and there by it posses the property of inductance and capacitance.
- c. Alternating current can be step-up or step-down by static transformer.
- d. AC can be transmitted with very less cost in comparing to DC transmission.
- e. Alternating line losses are very less comparing to DC line losses.
- f. An alternators and AC motor requires very less maintenance.
- g. Charge per unit for AC is less than DC.

119. Define AC.

Alternating current is that type of electric current, which changes it's magnetude and direction periodically.

120. What is cycle?

One complete set of changes in value and direction of alternating quantity and emf or current is called a cycle.

121. What is periodic time?

Periodic time is the time taken to complete on cycle. Its symbol is 'T'. For example Indian standard frequency is 50 cycles per second. So the periodic time  $T = 1/50$  seconds. That is equal to 20 m seconds.

122. What is frequency?

Number of cycles per second is called frequency.

123. What is amplitude value or peak value?

It is the maximum value of an alternating quantity that can be obtained in any one direction.

124. What is instantaneous value?

The value of an alternating quantity at a particular instant is called instantaneous value.

125. What is average value or mean value?

Average of all instantaneous values of emf or current over a half cycle is known as average value or mean value.

$$\text{Average value} = 0.637 * E_{\max} \text{ or } I_{\max}$$

126. What is root mean square value (R.M.S)?

The R.M.S value is also known as effective value or virtual value. The instantaneous value of both the directions will all be squared up and will be added together. Then divide to get the average with the number of instantaneous values and find the square root of this average to calculate the R.M.S value of the emf or current.

Or

The R.M.S value of an alternating current or emf is equal to the same value of direct current (DC), which produces the same amount of heat with the same time when applied the DC through the same circuit as AC is produced.

$$\text{R.M.S value} = \text{maximum value} / \sqrt{2} = 1/\sqrt{2} = 0.707.$$

$$\therefore \text{R.M.S value or effective value} = 0.707 * E_{\max} \text{ or } I_{\max}$$

127. What is form factor?

The ratio of the R.M.S value to the average value is called the form factor.

$$\begin{aligned} \therefore \text{Form factor} &= 0.707 * E_{\max} \text{ or } I_{\max} : 0.637 * E_{\max} \text{ or } I_{\max} \\ &= 0.707 * E_{\max} \text{ or } I_{\max} / 0.637 * E_{\max} \text{ or } I_{\max} \\ &= 1.11 \end{aligned}$$

$$\text{So that R.M.S value} = \text{average value} * 1.11$$

$$\text{Or average value} = \text{R.M.S value} / 1.11$$

128. What is crest factor or peak factor?

The ratio of maximum value to the R.M.S value is known as crest factor. So the crest factor = maximum value / R.M.S value.

$$\begin{aligned} &= E_{\max} \text{ or } I_{\max} / (E_{\max} \text{ or } I_{\max} / \sqrt{2}) \\ &= E_{\max} \text{ or } I_{\max} * \sqrt{2} / E_{\max} \text{ or } I_{\max} = \sqrt{2} = 1.414 \end{aligned}$$

129. What is vector quantity and what is scalar quantity?

Vector quantity

A quantity, which has both the direction and magnitude is said to be a vector quantity. Examples are force, emf, current etc.

Scalar quantity

A scalar quantity is that, which has only magnitude but no direction. Examples are temperature, mass, volume etc.

130. What is phase?

The development of an AC quantity through different stages is known as Phase.

The term phase refers to the number of separate individual voltage setup in an AC circuit.

131. What is in-phase?

When those two vectors (voltage and current) attain (reaches) their maximum and minimum values simultaneously (at the same time), then those two quantities are said in-phase. Here between those quantities there is no angle.

132. What is out of phase?

When two alternating quantities voltage and current do not reach their maximum and minimum values simultaneously, then they are called out of phase.

133. What is phase angle?

Phase angle is an angular displacement between two alternating quantities. Phase angle is measured in electrical degrees or radians.

134. What is quadrature quantity?

When the phase angle between two vectors is  $90^\circ$  electrical, then they are said to be quadrature quantity.

135. What anti-phase quantity?

When two quantities are out of phase by  $180^\circ$  electrical, then they are said to be anti-phase quantities.

136. What is leading quantity?

The alternating quantity that reaches its maximum value earlier than the other quantity is known as the leading quantity.

137. What is lagging quantity?

The alternating quantity that attains its maximum value later than the other quantity is called the lagging quantity.

138. What is the relation between voltage and current in AC circuit containing only resistance?

Current (I) is in-phase with the voltage.

$$I = V/R \text{ amps.}$$

$P = I * V * \cos\phi$  or  $I^2 R$  watts. (Where  $\cos\phi$  is zero because the voltage and current are in-phase. So  $\cos\phi 0^\circ$  (zero) = 1)

139. What is the relation between voltage and current in AC circuit containing only inductance?

Current (I) lags behind the voltage by  $90^\circ$ .

$$I = V/X_L \text{ amps.}$$

$$X_L = 2\pi fL \text{ ohms.}$$

$P = I * V * \cos\phi$  watts. (Where  $\cos\phi$  is 0 because current lags behind voltage by  $90^\circ$ . So  $\cos\phi 90^\circ = 0$ )

$$\therefore P = I * V * 0 = 0 \text{ watts.}$$



140. What is the relation between voltage and current in AC circuit containing only capacitance?

Current (I) is leading the voltage by  $90^\circ$ .

$$I = V/X_C \text{ amps.}$$

$$X_C = 1/2\pi fC \text{ ohms.}$$

$P = I * V * \cos\phi$  watts. (Where  $\cos\phi$  is 0 because current is leading the voltage by  $90^\circ$ . So  $\cos\phi 90^\circ = 0$ )

$$\therefore P = I * V * 0 = 0 \text{ watts.}$$

141. What is inductance and inductive reactance?

#### Inductance

A coil carrying alternating current produces an alternating flux, which causes to link with same coil and produces an emf in the coil, which opposes the applied emf. This property is known as inductance. The unit for measurement is henry.

#### Inductive reactance

The opposition or the reactance offered by the property of inductance in the circuit is known as inductive reactance and denoted by the letter  $X_L$ . The unit for measurement is ohm.

142. What is capacitance and capacitive reactance?

#### Capacitance

The property of a capacitor to store electrical energy in it, when it is connected to an electric supply is called capacitance. Unit for measurement is farad. Capacitor store an electric energy in the unit of charge and the unit of charge is coulomb.

#### Capacitive reactance

The opposition due to capacitance of capacitor in an electric circuit is called capacitive reactance and it denoted by the letter  $X_C$ . The unit for measurement is ohm.

143. What is impedance?

The total opposition offered by an AC circuit for the flow of current through it is called Impedance. The letter 'Z' denotes it and the unit is ohm.

$$\therefore Z = \sqrt{R^2 + (X_L \sim X_C)^2}$$

$$Z = \sqrt{R^2 + (X)^2}$$

Where  $\sim$  indicates the difference of  $X_L$  and  $X_C$  and denoted in the letter X (net reactance of the AC circuit).

144. What is ohm's law for AC circuit?

$$I = V/Z \text{ amps.}$$

$$Z = V/I \text{ ohms.}$$

$$V = I * Z \text{ volts.}$$



145. What is the current and power in an AC circuit?

### Current

AC circuit contains resistance 'R' and reactance 'X'.

In resistive circuit  $I_R = I \cos\phi$ . Because resistance current ( $I_R$ ) is in-phase with voltage ( $E_R$ ).

In reactance circuit  $I_X = I \sin\phi$ . Because reactance current will lead or lag the voltage ( $E_R$ ) by  $90^\circ$ .

So the resultant current (I) is the vector sum of  $I \cos\phi$  and  $I \sin\phi$ . So that circuit current  $I = \sqrt{(I \cos\phi)^2 + (I \sin\phi)^2}$  amps.

$I \cos\phi$  is some times known as power component of current or the power current or energy current and the  $I \sin\phi$  is known as reactive component of current or watt-less current. Because  $I \sin\phi$  is not taking any energy from the circuit.

### Power

Power in watts = terminal voltage \* power component of current.

a. **True power** =  $E * I * \cos\phi$  watts.

This true power is some times known as energy component or active component or watt-full component. Because this is the power used to produce torque in motor and supplies heat, light etc. or this true power is the power consumption of all source of electric circuit.

b. **Reactive power** =  $E * I * \sin\phi$  watts.

This reactive power is some times known as reactive or in-active component or watt less component or VARS.

c. **Apparent power** =  $E * I$  watts.

The terminal voltage multiplied by the actual resultant current (I) is called the apparent power or volt-ampere or VA.

146. What is power factor?

So from the above power explanation,

$$\cos\phi = \text{true power} / \text{apparent power} = E * I * \cos\phi / E * I.$$

So that power factor is equal to

- Cosine of angle of lead and lag of the resultant current with the applied voltage.
- The ratio of R/Z.
- The ratio of true power to the apparent power.

## 147. What is resonance in series circuit?

If in an AC circuit inductive reactance  $X_L$  and capacitive reactance  $X_C$  is equal the voltage across both will be equal and are  $180^\circ$  out of phase. So that each will cancel each other and the current limiting component will be the resistance of the circuit.

If we are in a position to alter the frequency of supply voltage at a particular frequency named as 'resonant frequency', AC series circuit's  $X_L = X_C$  and the net reactance will be zero. So the current in the circuit is in-phase with the voltage. Because the controlling component of the circuit is resistance only and the current is maximum and equal to  $V/R$  amps.

This above said condition is called 'series resonance' and the frequency at which it occurs is called resonant frequency and the resonant frequency ( $F_R$ ) is equal to  $(F_R) = 1/2\pi\sqrt{LC}$  cycles per second.

## 148. What is Q-factor?

The ratio of  $V_L/V$  or  $V_C/V$  at the resonant frequency is called the voltage magnification denoted as Q-factor.

$$\text{Q-factor} = \frac{1}{R} \sqrt{L/C}$$

## 149. What is Admittance?

Admittance: Admittance is the reciprocal of impedance. It is denoted by the letter 'Y' and the unit of measurement is mho.

$Y = I/E = \text{RMS current} / \text{RMS voltage}$ .

Equation used in admittance

a. Conductance 'G' =  $Y * \cos\phi = 1/Z * R/Z = R/Z^2$  mho.

b. Susceptance 'B' =  $Y * \sin\phi = 1/Z * X/Z = X/Z^2$  mho.

c. Admittance 'Y' =  $\sqrt{G^2 + B^2}$  mho.

d. In special cases when  $X = \text{zero}$ , then  $G = 1/R$  and  $R = \text{zero}$ , then  $B = 1/X$ .

## 150. What is the resonance frequency equation for parallel circuit?

In parallel circuit when  $X_C = X_L$ , the circuit is called the parallel resonance circuit.

That is  $2\pi fL = 1/2\pi fC$ .

In term ( $F_R$ ) =  $1/2\pi\sqrt{1/LC - R^2/L^2}$  cycles per second.

If 'R' is negligible, then ( $F_R$ ) =  $1/2\pi\sqrt{LC}$  cycles per second.

## 151. What is poly phase?

A system with two or more the two phases is known as poly phase system.

## 152. What is phase sequence?

The sequence of attaining the maximum value of the induced emf in each set of winding among those three sets is known as phase sequence. This phase sequence is usually indicated by the letters R, Y, B.

153. What is phase voltage?

The voltage between one of the phase and neutral is known as phase voltage and it is denoted by  $V_{ph}$ .

154. What is line voltage?

The voltage across any two phases of the supply system is called line voltage and it is denoted by the letter  $V_L$ .

155. What is phase current?

The current flowing through any of the phase winding is known as phase current and it is denoted by  $I_{Ph}$ .

156. What is line current?

The current flowing between any two phases of the winding is called line current and it is denoted by the letter  $I_L$ .

157. What is balanced load and unbalance load?

Balanced load

In a three-phase system the power factors and the phase current or line currents of the 3-phase are equal, then that load is called balanced load.

Unbalance load

If the three-phases have different power factors and the phase current, then the load is called the unbalance load.

158. What is phase power and total power?

Phase power

The power measured between a phase and neutral is known as phase power.

Total power

The total power measured between the three phases is called total power.

159. What are the methods of connecting 3-phase windings?

There are two methods.

- a. Star or wye (Y) connection.
- b. Delta or mesh ( $\Delta$ ) connection.

160. What are the value of voltage and current in star connection and in delta connection?

Star connection

- a.  $I_L = I_{Ph}$ .
- b.  $V_L = \sqrt{3} V_{Ph} \therefore V_{Ph} = V_L / \sqrt{3}$ .

Note: in star connection we are getting neutral point and we can able to measure the phase as well as line voltage.

Delta connection

- a.  $V_L = V_{Ph}$ .
- b.  $I_L = \sqrt{3} I_{Ph} \therefore I_{Ph} = I_L / \sqrt{3}$ .



161. What is the power in 3-phase supply system?

In a single-phase system power ' $P$ ' =  $V_{ph} * I_{ph} * \cos\phi$  watts.

In 3- $\phi$  system power ' $P$ ' =  $3 * V_{ph} * I_{ph} * \cos\phi$  watts.

In **Star** connection,  $I_L = I_{ph}$  and  $V_{ph} = V_L/\sqrt{3}$ . Substituting the value of  $I_{ph}$  and  $V_{ph}$  in the above 3- $\phi$  power equation,

$$P = 3 * V_{ph} * I_{ph} * \cos\phi \text{ watts.}$$

$$P = 3 * V_L/\sqrt{3} * I_L * \cos\phi \text{ watts.}$$

$$P = \sqrt{3} * V_L * I_L * \cos\phi \text{ watts.}$$

In **Delta** connection,  $V_L = V_{ph}$  and  $I_{ph} = I_L/\sqrt{3}$ . Substituting the value of  $I_{ph}$  and  $V_{ph}$  in the above 3- $\phi$  power equation,

$$P = 3 * V_{ph} * I_{ph} * \cos\phi \text{ watts.}$$

$$P = 3 * V_L * I_L/\sqrt{3} * \cos\phi \text{ watts.}$$

$$P = \sqrt{3} * V_L * I_L * \cos\phi \text{ watts.}$$

So that the power in three phase supply system whether star connected or delta connected is same and power  $P = \sqrt{3} * V_L * I_L * \cos\phi$  watts.

$$\text{So } \cos\phi = P / \sqrt{3} * V_L * I_L .$$

162. What are the advantages of rotating field system?

- For rotating field alternators only two slip rings and brush gear assembly are required irrespective of number of phases.
- The DC excitation voltage is low and it is very easy to insulate. This intern reduces the size of the machine.
- Out put current can be taken directly from the fixed terminals on the stator. It is easy to insulate high voltage stationary stator (armature).
- The armature winding can be easily braced to prevent any deformation produced by the mechanical stress set as a result of short circuit current and the high centrifugal brought into play.

163. What are the types of alternator?

Depending upon the speed there are three types.

- Low speed.
- Medium speed.
- High speed.

Depending on rotation there are two types.

- Armature rotating
- Field rotating.

Depending on number of phases there are two types.

- Single phase
- Poly phases.

With respect to excitation there are two types.

- Self excited
- Separately excited.





164. What is the voltage equation for alternator?

165. What is voltage regulation?

166. How alternators are rated?

Alternators are rated in kVA.

167. What are the losses in an alternator?

Losses in alternators are same as DC generator and they are as follows.

a. Copper losses includes following losses

Armature copper losses ( $I_a^2 r_a$ ).

Field copper losses ( $I_{fe}^2 r_f$ ).

Losses in brush.

b. Stray losses are as follows

Magnetic losses (Iron loss or core loss and pole shoes loss).

Mechanical losses includes bearing friction, slip ring friction and friction due to windage.

168. When the efficiency of the alternator is maximum or on what factor the efficiency of the alternator depends?

Efficiency of an alternator depends on its load power factor for a given load. As the power factor decreases  $I_a$  increases and the copper losses increases and thus efficiency decreases. The efficiency for given load is maximum only when the power factor is unity and it decreases as the power factor fall.

169. What are the methods of synchronizing?

a. Lamp method.

Dark lamp method and bright lamp method.

b. Synchroscope method.

170. What is synchroscope?

Synchroscope is an instrument, which shows the phase relationship of emf of the incoming alternator and at the same time it also indicates whether it is running slow or fast. This instrument works on the principle of rotating magnetic fields. It consists of a small motor with rotor and stator. Both wound for two phase. A potential transformer connected to two of the main bus-bar give supply to the stator 'A' winding and another potential transformer of same type connected to the corresponding terminals on the incoming machine supply to the stator 'B' winding. The rotor rotates if the stator resultant flux in the 'A' and 'B' is different and the exact time of synchronizing is the stand still position of the rotor. That means the both the voltages in winding 'A' and 'B' are same and there is no resultant flux to rotate the rotor. The speed of the rotor depends on the frequency of the alternator

and is too fast when alternator (incoming machine) speed is more and less when alternator is too slow.

## 171. What is transformer?

Transformer is a static device by which AC power at one voltage in one circuit will be transformed into AC power of same frequency at another (decreased or increased voltage) or same voltage to an another circuit, which is in mutual inductive influence with the previous circuit and it is based on mutual electro magnetic induction.

## 172. What are the purposes or advantages of transformer?

**Purposes**

- a. Electrical energy may be transmitted economically over long distance by stepping up of voltages to reduce the line losses.
- b. To distribute the low voltages at consumer side by stepping down the voltages.

**Advantages**

- a. Transformer is a static machine and losses are very less. There by efficiency is high and about 95 to 98%.
- b. Practically maintenance is very less.

## 173. What is the working principle of transformer?

A transformer works under the principle of mutual electro magnetic induction (Faraday's laws of Electro-magnetic induction). It says that, when ever a changing flux links with a coil an emf is induced in it and this induced emf is proportional to the rate of change of flux and the number of turns in the coils linking the flux.

## 174. What are the types of transformer core?

- a. Core type transformer core.
- b. Shell type transformer core.
- c. Berry type transformer core.
- d. Spiral type transformer core.

## 175. What is the transformation ratio in transformer?

Equation for transformation ratio is,

$$E_2/E_1 = N_2/N_1 = k$$

$k = >1$  in step up transformer, where secondary turns are more and thus voltage is more to reduce the transmission current.

$k = <1$  in step down transformer, where secondary turns are less than primary and low voltage for consumer use.

If we include the current in transformation ration the equation is,

$$E_2/E_1 = N_2/N_1 = I_1/I_2 = k$$

## 176. What is the use of conservator in the transformer?

It is a drum type cylinder mounted on the top of the transformer through a small pipe. ... of the conservator is kept empty. To indicate the level of oil in the

transformer an indicator is fixed. Conservator will help the oil inside the tank by providing sufficient space to expand and to contract as its temperature varies without exposing much surface area. That is it limits the air with oil due to its less surface area.

177. What is the use of breather in the transformer?

Breather is a bottle shaped steel tube, which is attached to one side of conservator to allow the air to pass in and out of the tank or conservator through the calcium chloride and silica gel, which is filled in it to absorb the moisture contained in the air. When the silica gel absorb the moisture its colour changes from blue to pink.

178. What is the use of buchholz relay in the transformer?

It's a protection relay used in oil immersed transformer to protect the transformer from insulation failure, core heating or any other type of internal faults, which may cause the heating of winding beyond the specified temperature. This relay is placed in between the pipe connecting the conservator and the tank. Generally used in power transformer of above 500 kVA.

It consists of two operating floats and is operated by two mercury switches separately provided for the alarm and trip. Due to internal fault (collection of gases) or leakage of oil if the oil level comes down the alarm relay first operates and then the trip relay operates to isolate the transformer from the circuit.

179. What is the use of explosion vent in the transformer?

It is also a safety device of a transformer, which protects the transformer tank from the high consequences of the high-pressure gases induced or developed by any type of short circuit in the transformer by allowing the gas to escape by puncturing the diaphragm.

180. What is the emf equation for transformer?

Always maximum flux reaches from zero to maximum in one quarter of the cycle. That is in ... of second. That is equal to  $1/200$  second.

$$\begin{aligned}\text{Average rate of change of flux} &= Q_m / \dots f. = Q_m * 4 * f. \\ &= 4 f Q_m \text{ Weber / second.}\end{aligned}$$

As the coil has N turns the average emf induced in the coil =  $4 f Q_m N$  volts.

But the rms. Value = average value \* form factor.

$$\begin{aligned}\therefore \text{rms. Value of emf} &= 1.11 * 4 f Q_m N \text{ volts.} \\ &= \mathbf{4.44 f Q_m N \text{ volts.}}\end{aligned}$$

181. What are the losses in transformer?

In transformer there are losses due to,

1. Resistance of the winding (copper losses).
2. Eddy current and Hysteresis in the iron parts and core (core and iron losses)
3. Losses due to leakage reactance (leakage flux).

At No load the copper losses and leakage flux losses are negligible due to the very less primary current.

At loaded condition copper losses and leakage flux losses will exist in considerable manner. Copper losses are variable and can be calculated by  $I_p^2 * r_p$  and  $I_s^2 * r_s$ .



182. What are the types of cooling in transformer?

1. Natural cooling.
  - a. Air natural cooling (Dry type).
  - b. Oil immersed natural cooling.
  - c. Oil immersed, forced oil circulation with natural cooling.
2. Artificial cooling.
  - a. Oil immersed forced air circulation with air blast cooling.
  - b. Oil immersed blast cooling.
  - c. Air blast cooling.
3. Artificial cooling (water).
  - a. Oil immersed water cooling.
  - b. Oil immersed forced oil circulation with water cooling.
4. Mixed cooling (water).

This is the method of cooling combining oil natural, water, air natural, air blast and forced oil.



**183. State the type transformers?**

Transformers can be classified into different groups and types based on the following factors.

1. Type of core.
  - a. Core type transformer core.
  - b. Shell type transformer core.
  - c. Berry type transformer core.
  - d. Spiral type transformer core.
2. Method of cooling.
  - a. Natural cooling transformer.
  - b. Artificial cooling transformer.
  - c. Artificial cooling (water) transformer.
  - d. Mixed cooling transformer.
3. As per transformer ratio.
  - a. One to one transformer.
  - b. Step down transformer.
  - c. Step up transformer.
4. Based on number of phases.
  - a. Single-phase transformer.
  - b. Two-phase transformer.
  - c. Three phase transformer.
5. As per winding connection.
  - a. Star-star connected.
  - b. Star-delta connected.
  - c. Delta-delta connected.
  - d. Delta-star connected.
  - e. Open delta connected.
  - f. Scott connected.
6. As per the size of the transformer.
  - a. Distribution transformer (upto 500 kVA).
  - b. Power transformer (above 500 kVA).
7. Based on function and utilization.
  - a. Auto transformer.
  - b. Potential transformer (instrument transformer).
  - c. Current transformer (instrument transformer).

**184. What is the humming of transformer?**

Humming is a sound, which is produced due to the vibration of the cores in the transformer. The vibrations are produced due to the change in polarity of an alternating current or voltage and by the loose of lamination of the core. Both can be minimised by tightening the core of the transformer.

185. What are the types of AC three phase motors?

Mainly there are two types.

**1. Synchronous motors.**

- a. Plain synchronous motors.
- b. Auto synchronous motors.

**2. A-synchronous motors.**

*a. Induction motors.*

1. Single phase motors
  - Shaded pole motor.
  - Capacitor start capacitors run motor.
  - Capacitor start induction's run motor.
  - Split face motor.
2. Three phase motors.
  - $3\phi$  single squirrel cage motor.
  - $3\phi$  double squirrel cage motor.
  - Squirrel deep bar induction motor.
  - Slipring induction motor.

*b. Commutator motors.*

1. Single phase commutator motors.
  - Plain repulsion motor.
  - Repulsion start induction's run motor.
  - Repulsion induction motor.
  - *Series motor or universal motor.*
2.  $3\phi$  commutator motors.
  - $3\phi$  series motor
  - Charge motor.
  - Compensated motor.

186. What is the working principle of  $3\phi$  induction motor?

When  $3\phi$  supply is given to stator, a rotating magnetic field of constant magnitude is produced. This rotating magnetic field produces induced emf in the rotor winding as per faraday's laws and this induced emf causes to circulate a heavy induced current in the rotor winding due to very small resistance of rotor. At the initial moment the frequency of induced emf is equal to the frequency of the stator supply voltage, when the rotor is stationary as in the case of secondary of a transformer. The rotor induced current according to lenz's law flows in such a direction that it opposes the cause, which is inducing it. In this case the cause producing the rotor current is the relative speed between the rotating magnetic field if stator and the rotor and is maximum when the rotor is stationary. Hence to reduce this relative speed rotor conductor (rotor) starts to rotate in the same direction in

which the stator field is rotating and tries to catch it up. The rotation of this rotor is developed due to the torque developed in the rotor by interaction between the rotating magnetic field of stator and the field produced by the rotor current.

## 187. What is torque?

As said above torque is a turning or twisting moment of a force about an axis and it is measured by the product of force \* radius at which the force acts.

There are two types of torques.

- Starting torque: This is the torque, which is required to start the motor at load or no-load.
- Running torque: This is the torque, which is required to run the motor at normal speed and at normal load.

The letter 'T' denotes torque in induction motor and torque is proportional to

$$I_r \phi \cos\phi_r.$$

That is  $T \propto I_r \phi \cos\phi_r$ .

Where  $I_r$  = rotor current.

$\phi$  = Flux = stator flux per pole in Weber.

$\cos\phi_r$  = rotor power factor.

## 188. What is slip?

The difference in speed of stator magnetic speed ' $N_s$ ' (synchronous speed) and rotor speed ' $N_r$ ' is called slip or absolute slip and it is denoted by the letter 'S'.

$$\therefore S = N_s - N_r / N_s.$$

Slip has no unit. Percentage of slip of induction motor varies from 4 to 5% in small motors and 1.5 to 2.5% in big motors.

In other words slip ' $S$ ' =  $f_r / f$ . Where  $f_r$  is rotor frequency and  $f$  is stator frequency.

## 189. What is the working principle of double squirrel cage induction motor?

In double squirrel cage motor outer cage rotor winding is of high resistance and low reactance. Inner cage winding is of high reactance and low resistance.

At the time of starting rotor frequency is equal to the stator frequency and there by the reactance of the inner cage winding is comparatively high ( $X_L = 2\pi fL$ ) because it is linking more inner winding than the outer winding. So the impedance of inner cage winding is very high. Hence the current flow through inner cage winding is very less comparing to the outer cage winding. That is a very high ratio of current is passing through the outer cage winding at the time of starting and there by produces very high starting torque.

When the rotor starts running the speed of the motor can be increased and the slip will be decreased and there by the rotor frequency (' $S$ ' =  $f_r / f$ ). So that in the running condition the reactance of the inner cage decreases to the lowest value and hence the Impedance ( $X_L = 2\pi fL$ ). So the current in inner cage winding will be comparatively more than the outer cage winding at the time of running. So now

inner cage winding produces more torque than outer cage at the time of running and the motor running torque is good enough.

190. Why starter is necessary to start the AC motor?

- a. At the time of starting motor starting current is high (4 to 5 times). Therefore if motor is directly started the supply voltage may be disturbed.
- b. By the help of starters starting and stopping of motors can be made easily as we required. Because starters provides overload tripping difficulties.
- c. The help of starters can protect motor against the single phasing by the action of overload arrangements.
- d. Protect the motor from no-voltage and its difficulties.
- e. Permits automatic control when required.

191. What are the types starters used for starting of induction motor?

- a. Direct on line starter (air break) mechanically.
- b. Direct on line starter (air break or oil immersed) electrically.
- c. Star delta starter.
- d. Slipring motor starter.
- e. Auto transformer starter.

192. What are the speed control methods of induction motor?

- a. By controlling the supply voltage.
- b. By controlling the supply frequency ( $N_s = 120f / P$ ).
- c. By varying the number of poles ( $N_s = 120f / P$ ).
- d. By rotor rheostatic control (for small speed variation).

193. What is magnetic locking or cogging effect of induction motor?

In squirrel cage induction motor some times the rotor and stator core teeth or slots are comes face to face or parallel at stationary condition. If we are starting the motor at this condition the motor get hesitated to start or run due to the attraction developed between those rotor and stator teeth or slots. This is known as the magnetic locking or cogging effect of a squirrel cage induction motor. This type of magnetic locking in squirrel cage induction motor can be avoided either by skewing the rotor slot or by selecting the rotor slot, such that there is no common factor between the rotor slot and stator slots.

194. What is skewing?

Skewing can be done by turning the rotor slots about  $15^\circ$  from the parallel position of slots with the shaft.

That is rotor slots are not in parallel with the shaft but there is an angle of about  $15^\circ$  with the shaft.

195. What are the losses in induction motor?

- a. Stator losses (stator copper losses, stator iron losses).
- b. Rotor losses (rotor copper losses, rotor iron losses).
- c. Windage and friction losses.

196. What is synchronous motor?

An alternator, which is running as a motor can be called as synchronous motor and it runs at synchronous speed while it converts electrical energy into mechanical energy. It requires both AC for armature and DC supply for field.

197. What are the advantages and dis-advantages of synchronous motor?

Advantages

- a. It's a constant speed motor and is equal to synchronous speed from no load to full load.
- b. It has good efficiency higher than induction motor.
- c. It can be run as a motor and also as an alternator as per the requirement. More over it can be used as synchronous condenser.

Dis-advantages

- a. It can not be used as a varying speed motor. Because its speed can not be varied.
- b. As a motor it is not self-starting type and it can not be started on load.
- c. It requires both AC and DC supply.
- d. Hunting is also produced in this motor.

198. What are the applications of synchronous motor?

- a. These motors are used in powerhouses, in sub stations for the improvement of power factor by connecting it in parallel to the supply and it is run without load under over excitation of field.
- b. Used in big industries where many induction motors are installed to improve the power factor.
- c. Used for constant mechanical loads.

199. What is hunting effect?

When the load is varied to the motor the oscillation being setup in the rotor about the position of equilibrium corresponding to change of load condition. So the damper winding acts the magnetic lines of force and causes to create the opposite torque, which keeps the rotor in the same position of the particular load. This oscillation of the rotor is known as Hunting or Phase swinging. To reduce this hunting damper winding is helpful.

200. What is synchronous condenser or phase advancer?

An over excited synchronous motor takes leading current just like a condenser and gives leading power factor. A synchronous motor, which I used only for the purpose of improving power factor, can be called as synchronous condenser or phase advancer.

201. Why single-phase motors are not self-starting?

When a  $1\phi$  supply is given to the single winding of the single phase motor, the field produced by it changes in magnitude and direction sinusoidally (pulsating flux).



Such and alternating field is equivalent to two fields of equal magnitude and speed rotating in opposite direction. Such rotating magnetic fields produces two torque's on the rotor. So the rotor can not rotate in any direction. Because the net torque developed by the motor is equal to zero. So a single-phase motor is not self-starting.

202. What are the methods to self-starting of single-phase motor?
- a. Splitting one phase into two phases.
  - b. By using capacitor.
  - c. By using repulsion method.
  - d. By shading the poles.
  - e. By connecting the field in series with the rotor having winding with commutator (AC series motor or universal motor).
203. What are the methods to control the speed of single-phase motor?
- In AC single-phase motors speed control can not be achieve as smooth as in DC motor. There are following few methods of speed control.
- a. By changing the number of poles of stator.
  - b. By changing the applied voltage to the stator.
  - c. Frequency control method.
  - d. Rotor rheostat control.
  - e. By operating two motors in concatenation or cascade or tandem method.
  - f. By injecting an emf in the rotor circuit.
  - g. By changing slip.
204. What are the classifications of electrical measuring instruments?
- a. Absolute instruments. These instruments give the value of the quantity to be measure in terms of the constant of the instrument and their deflection only. There is no any calibrated scale.
  - b. Secondary instruments. Secondary instruments are those, which are calibrated in comparison with some absolute instrument so as to indicate the electrical quantity to be measured with the deflection of needle or pointer of that meter over a calibrated scale.
205. What are the operating principles of electrical measuring instruments?
- a. Magnetic effect.
  - b. Electro dynamic effect.
  - c. Electro magnetic effect.
  - d. Thermal effect.
  - e. Chemical effect.
  - f. Electro static effect.
206. What are the classifications of secondary instruments?
- a. Indicating instruments.
  - b. Recording instruments.

c.Integrating instruments.

207.What are the essentials of indicating instrument?

- a.Deflecting torque or force (effect of electricity).
- b.Controlling torque or force (spring control and gravity control).
- c.Damping torque or force (air friction, eddy current and fluid friction).

208. What are the possible errors in induction (energy meter) measuring instruments?

- a. Phase error: Field flux in induction meter does not lag  $90^\circ$  behind the supply voltage due to its resistance. This can be adjusted by copper shading rings, which are placed at the central limb of the shunt magnet.
- b. Speed error: An error in speed, which is tested on the non-inductive load, can be eliminated by correctly adjusting the position of the brake magnet.
- c. Friction error: It can be reduced very much by providing two copper shading at the both outer limbs.
- d. Creeping error: Some time slow, continuous rotation of the disc (rotor) when only the pressure coil is excited, but no current flowing in the circuit (no current in current coil) may happen. It may be caused due to incorrect friction compensator, stray magnetic field, and excess voltage. This can be rectified by drilling two holes in the disc on the opposite sides of the spindle. This causes sufficient distortion of the field to prevent rotation, when one of the holes comes under one of the pole of the shunt magnet.

209. What is illumination?

The quantity of a light emitted by a lighting source is known as illumination. Heating effect of electric current is used in producing illumination. When a solid or vapour is heated it begins to radiate energy in the surrounding media.

Lux is the unit for illumination. Lux is the illumination produced by a uniform source of candle power on the inner surface of a sphere of radius one (1) meter.

210. What are the laws of illumination?

- a. Illumination 'E' is directly proportional to the luminous intensity 'I' of the source. ie  $E \propto I$ .
- b. Inverse square law: The illumination of the surface is inversely proportional to the square of the distance of the surface from the source. ie  $E \propto 1/d^2$ .
- c. Illumination 'E' is directly proportional to the cosine of angle made by the normal to the illumination surface and the direction of the incident light and is known as lam pod's cosine angle.

211. What are the factors to be considered for correct illumination?

- a. Nature of work.
- b. Determine the foot-candle illumination required after studying the nature of work. Example for precision work - 100 foot candle, for fine engraving - 50 foot candle, for reading, typing, drawing, fine machine works 25 foot candle etc.
- c. Design of apartment using for the proper projection of illumination for better work or purpose.

212. What are the types of lighting?

- a. Direct lighting: light directly comes from the source to the surface.
- b. Indirect lighting: light reflects from the wall, reflector or ceilings etc.
- c. Semi direct lighting: light comes through the shade.

213. What are the properties of good illumination?

- a. It should have sufficient light.
- b. It should not strike the eyes.
- c. It should not produce glares.
- d. Light should be uniform.
- e. It should be of harmonious.
- f. It should be of correct type as needed.
- g. It should have suitable shade and reflector.
- h. Economically productive.

214. What are the sources of light?

- a. Incandescent lamps.
- b. Carbon arc lamps.
- c. Gas discharge lamps.

215. What are the materials used in Neon sign tube lamps for different colors?

Following are the materials used in neon sign tubes for different colors.

For, Red - Neon gas.

Reddish orange - Neon gas + Argon gas.

Blue - Vapour of mercury.

Golden - Neon gas + Helium gas.

Green - mixture of Neon gas and mercury in yellow glass tube.

By depositing fluorescent powder on the inner surface of the tube varying colors in intensity can be made.

216. What is the material used in fluorescent tube?

The fluorescent tube is filled with argon gas at low pressure and some mercury after evacuating the tube. This argon gas gives initial starting at quick manner. Initially the mercury is in the form of globules on the inside of the tube surface. As the temperature increases the liquid takes globules mercury changes into vapour form and takes over the conduction of the current.

217. What are the importances of conversion of AC into DC?

- a. For traction purpose a DC series motor is most important. Examples in railways, in electrical lifts etc.
- b. For electrolytic and electro chemical processes such as electro plating, electrolysis, electro refining only DC is essential.
- c. DC is essential for battery charging, running arc lamp torch, cinema projector and for arc welding.

d. It is required for operating relays, timer, telephone, circuit breakers etc.

218. What is rectifier? Write few types of rectifiers.  
Rectifier is a device which converts AC supply into DC.  
Following are the types of rectifiers generally used.
- Copper oxide rectifier.
  - Selenium rectifier.
  - Electrolytic rectifier.
  - Mercury arc rectifier.
  - Tungar rectifier.
219. What are the parts of paper insulated lead covered cable?
- Core.
  - Insulation of cable.
  - Metallic sheath.
  - Bedding.
  - Armouring.
  - Serving.
220. What are the factors considered for selecting a cable?  
Following factors considered for the selection of the cable.
- System voltage.
  - Condition of installation.
  - Continuous current to be carried.
  - Maximum operating conductor temperature ( $70^{\circ}$ ).
  - Ambient air temperature ( $40^{\circ}$ ).
  - Thermal resistivity of soil.
  - Depth of laying.
  - Short circuit current.  $I_{sh} = Ka / (t/2)$ . Where 'K' is constant ( $K = 109$  for copper cables), 'a' is area and 't' is time duration of short circuit in seconds.
221. What are the advantages of high voltage transmission?
- Saving in conductor materials.
  - Low power loss ( $I^2R$ ) of transmission lines due to decrease in current.
  - Better efficiency of line due to fewer losses.
  - Better voltage regulation due to less voltage drop in line due to less transmission current.
  - Due to the less cross section of conductor distance between the poles increases and the cost decreases and the labour cost also decreases.
222. What are the types of distribution system?
- Radial distribution system.
  - Ring distribution system.
  - Grid distribution system.



223. What are types of distribution of supply?

- a. Over head distribution system.
- b. Under ground distribution system.

224. What are the main items used in over head distribution system?

- a. Conductor material.
- b. Pole.
- c. Cross arm.
- d. Insulators.
- e. Strain insulator.
- f. Post insulator.
- g. Stay wire.
- h. Support with insulator and stay lightner.

225. Write types of lightning arrestor.

- a. Horn gap lightning arrestor.
- b. Oxide film lightning arrestor.
- c. Pellet lightning arrestor.
- d. Thyrite lightning arrestor.

226.

***Motor, Generator and Exciter.***

1. What are the main classifications of alternator?

- a. Salient pole.
- b. Non – salient pole.

2. What is the emf equation of alternator?

Flux cut per second by each conductor =  $2 \phi_m f$

Average emf generated in each conductor =  $2 \phi_m f Z$

Average emf generated per phase =  $k_d k_c 2 \phi_m f Z$

r.m.s emf generated per phase =  $k_f k_d k_c 2 \phi_m f Z$

For sinusoidal waveform when  $k_f$  is 1.11 then emf generated

=  $1.11 * 2 k_d k_c \phi_m f Z$

=  $2.22 k_d k_c \phi_m f Z$

$k_f \rightarrow$  form factor

$f \rightarrow$  Frequency

$\phi_m \rightarrow$  Flux maximum

$Z \rightarrow$  Turns per phase

$k_d \rightarrow$  Breadth factor or distribution factor

$k_c \rightarrow$  Coil span

3. Why conductors in alternator are transposed?

To reduce eddy current losses.

4. What is the effect of frequency and high voltage at the start of motor.

For a constant load if frequency decreases motor current will increase and at the start if voltage is more motor current also increases.

5. What is the minimum voltage required for starting of 6.6 kV motors?

Minimum 80% of rated voltage.

6. What are the limits of vibration measurement for motors?

50 microns for displacement and 5 mm/second for velocity.

7. What you mean by SPDP?

Screen protected drip proof.

8. What is the current in single phasing?

2 times of rated current.

9. What is the impedance per phase of delta connected motor?

1.5 times the total impedance.

10. What is the slip of an induction motor during normal running?  
More than zero.

11. What is the effect of increased load on power factor of induction motor?

Power factor of an induction motor increases with loading.

12. Explain the behavior of generator when operating alone and operating parallel with grid.

***Generator operating alone.***

- a) The power factor of generator depends on load power factor.
- b) The terminal voltage decreases when generator is loaded.
- c) Governor decides the frequency of generator.
- d) Increase in excitation increases the terminal voltage of the generator.

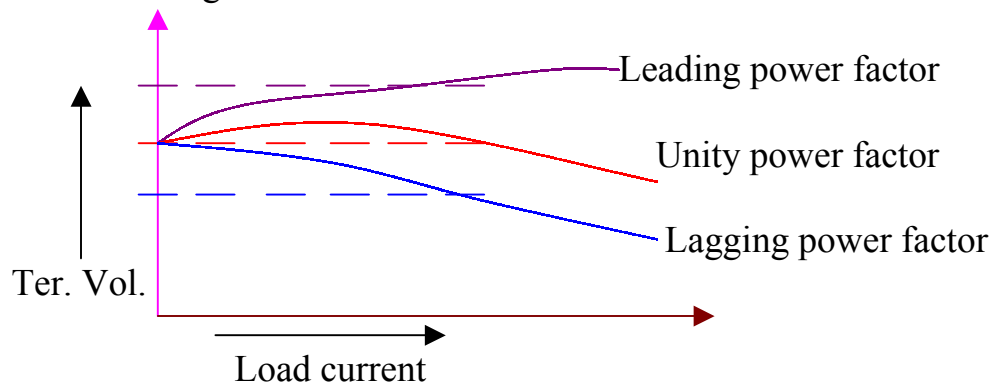
***Generator parallel with grid.***

- a) If we increase the steam input to the generator the frequency of the generator will not change. It will remain practically constant as same as grid frequency. That is grid decides the frequency of the generator.
- b) Increase in the excitation will not increase the terminal voltage. Instead the reactive power out put of the generator increases. This reactive power supplies for the magnetizing current of motors, transformers and etc.
- c) Increase in the steam input increases the active power of the generator.
- d) If generator is under excited it will draw leading reactive current from the grid.

13. Draw and explain following.

a) *Load current Vs terminal voltage at different power factors.*

1. At leading power factor as the load current increases the terminal voltage also increases.
2. At lagging power factor as the load current increases the terminal voltage drops.
3. At unity power factor as the load current increases there is slight drop in terminal voltage.



b) *Torque Vs slip characteristics of induction motor.*

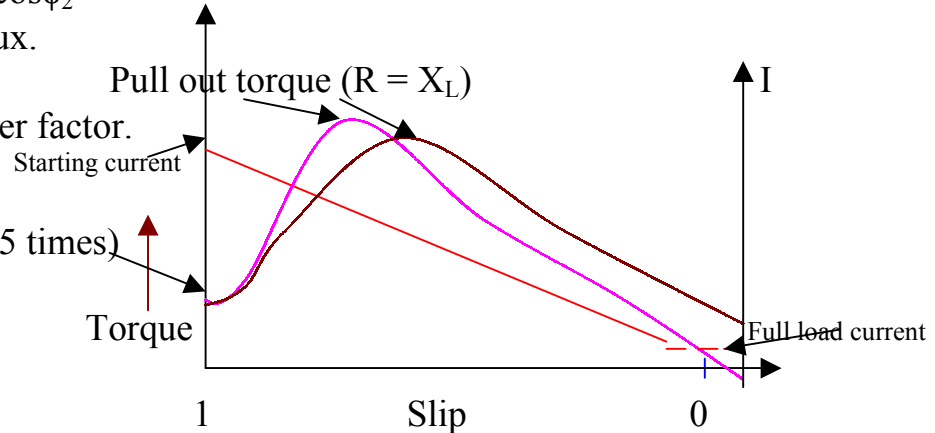
$$\text{Torque (T)} = \phi I_2 \cos\phi_2$$

Where  $\phi$  - main flux.

$I_2$  – rotor current

$\cos\phi_2$  – rotor power factor.

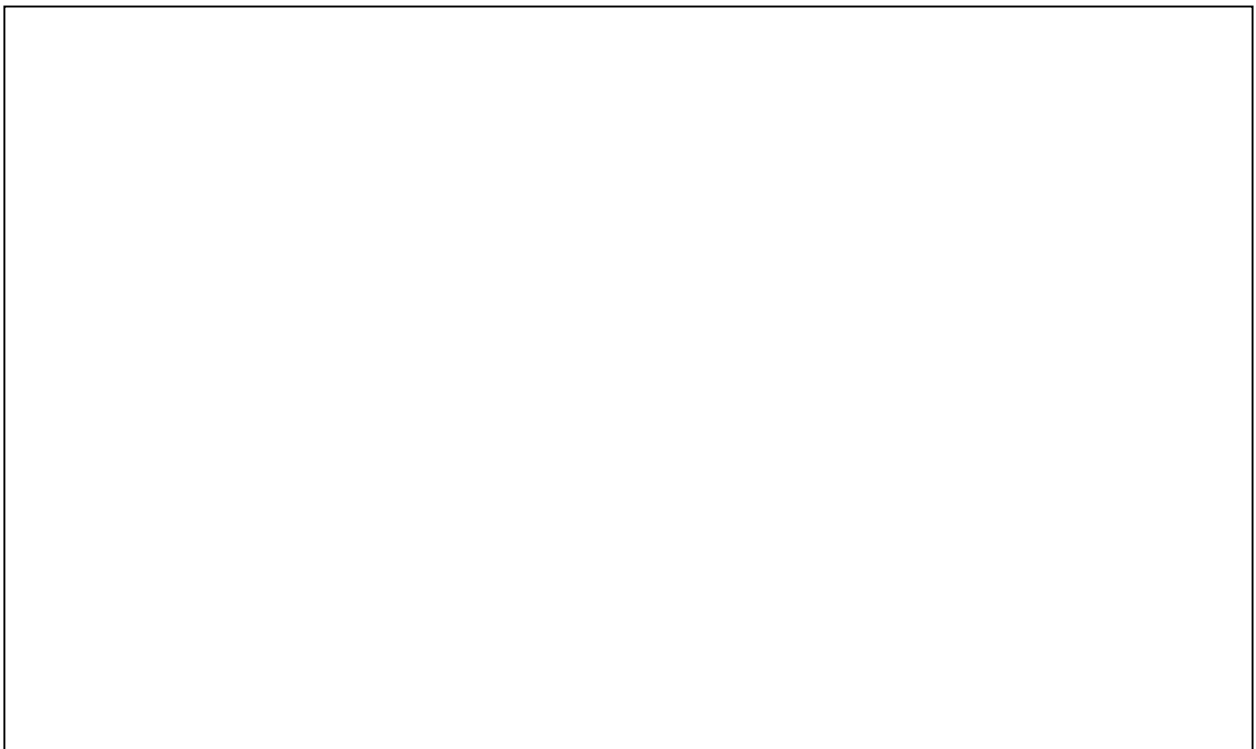
Starting torque (1.5 times)



When motor is started from rest the slip is 1 (one) at time of starting and starting torque is 1.5 times of rated torque. As the motor accelerates slip reduces and torque increases. Because the power factor of rotor is improving due to the decrease in rotor frequency and at certain slip the rotor reactance is equal to rotor resistance. At that time torque is maximum (pull out torque). When the motor accelerates to the rated speed the torque comes to the rated value, which is less than the starting torque. Torque is zero when slip is zero, because there will be no relative motion between stator magnetic field and rotor.

c) *Generator capability curve*

This curve gives the operating limits of the turbine generator at different power factor what should the power output of the generator to avoid the heating of generator stator winding, rotor parts and end parts.





14. What is the cooling medium for different parts of the turbo generator?

Stator – DM water.

Rotor – Hydrogen.

Bearing – Oil.

15. What are the effects of unbalanced voltage on induction motor?

There will be negative sequence current, which will heat up the stator winding and weakens the insulation. These currents will induce emf in rotor and heat up the rotor bars and cause breakage in them. Also due to high leakage fluxes due to negative phase sequence current the end parts heating will be more.

16. What are the types of bearings are adopted for small motors and large motors?

Small motors (LT motors)

Horizontal mounted – deep groove ball bearing at both ends.

Medium motors

Roller bearing at DE and deep groove bearing at NDE.

Large motors (HT motors above 750 kW)

Horizontal mounted – sleeve bearing (pedestal) cooled by lub oil.

Vertical mounted – face to face angular contact ball bearing at NDE and roller or ball bearing at DE.

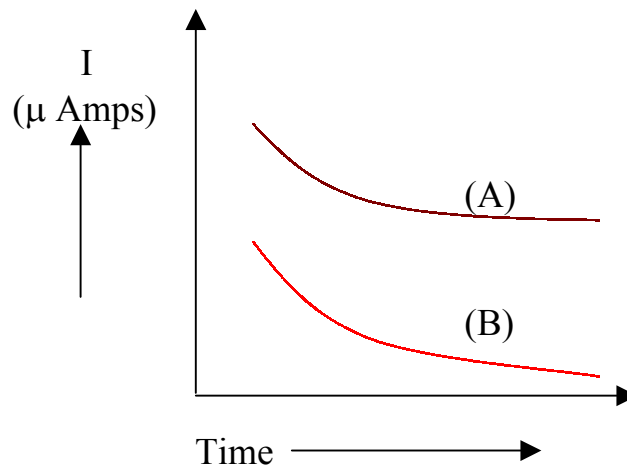


***Insulation classification and testing.***

1. What is good dielectric break down value for insulating oil?  
60 kV.
2. What is the temperature coefficient of insulating materials?  
Insulators are negative temperature coefficient materials.
3. What is gap between the electrodes in transformer oil testing kit?  
0.1 Inch.
4. What is the life insulation if temperature increased by 10°C?  
The life of the machine insulation decreases by half if the temperature of the insulation increases by 10°C.
5. What is the value of vacuum maintained by vacuum pump in oil filtration machine?  
27 Hg.
6. What is the DC HV test voltage range?  
1.7\* 1.5\* rated voltage.
7. What do you mean by term insulating resistance? How it is measured?  
*Insulating resistance:* insulating resistance is the opposition offered by an insulating material to the flow of current (electrons) through it when an high potential is applied across it.  
Insulating resistance are measured by megger.  
First the equipment whose resistance is to be measured is disconnected from supply. If the machine is a large one, there may be accumulated static charge on the machine. So we have to discharge it by connecting a wire between the terminals and ground for 15 minutes. Otherwise megger will give wrong reading.  
After this we should remove the wire and we have to connect megger terminals (live & earth) to the motor terminal and earth. The rating of the megger should be selected properly. Then rotate the megger at rated speed of 160 rpm and take the readings.

8. What you mean by dielectric absorption test?

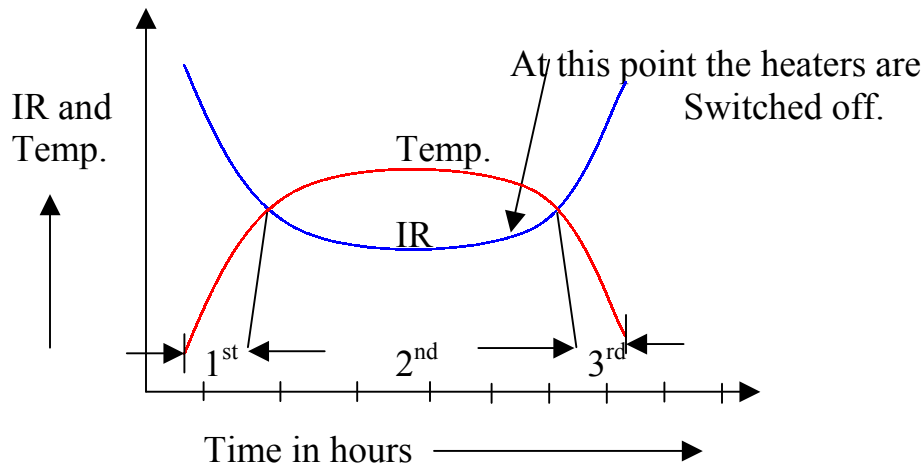
Whenever we apply a potential from the megger to test the IR value, initially the needle of the megger will go to low value of the resistance. This is due the capacitance effect of the insulation material and after some seconds the needle will start moving towards the higher value. Because in the insulating material there is strain on the molecules when the potential is applied. Polarization of the molecules occurs and they form a Di – pole. The negative charges are attracted to positive terminal and positive charges are attracted to negative terminal. So there is a strain on the insulation molecules and they align themselves parallel. This aligning may take more time. This test is done to know the condition of insulating material.



If the insulation is good the graph is as shown as B and if there is dirt, moisture the graph will flatten early as shown in A.

After the test terminals to be discharged so that molecules may return to their unstressed state.

9. Draw the transformer drying out curve and explain each stage.



When we start the filtering process initially the temperature will be low, as the insulation value is high. But on temperature increases the IR value starts to decrease because the moisture entrapped in the coils are released due to rise in temperature and this causes the IR value to go down. This is the first stage.

Then comes the point where all the moisture is released and then will be no decrease in IR value or rise in the temperature. This is the second stage.

At this point the heaters are switched off. Now the moisture is removed by the oil filters and the IR value goes up and as the heaters are off the temperature decreases. This is the third stage.

10. The insulation resistance of a DC motor is observed to be  $15 \text{ M}\Omega$  at a temp. of  $70^\circ\text{C}$ . what is its value corrected to  $40^\circ\text{C}$ . the correction factor for  $70^\circ\text{C}$  is 8.0.

Observed resistance at  $70^\circ\text{C}$  –  $15 \text{ M}\Omega$ .

Temperature correction factor – 8.

$R_m = k_t * R_t$                        $k_t$  – correction factor.

$R_m = 8 * 15$                        $R_t$  – resistance measured at  $70^\circ\text{C}$ .

$R_m = 120 \text{ M}\Omega$ .                       $R_m$  – corrected value to  $40^\circ\text{C}$

The IR of DC motor corrected to  $40^\circ\text{C}$  is  $120 \text{ M}\Omega$ .

11. The armature of a 600 kW, 0.24 kV, 1000 rpm DC generator has an indicated IR to ground of  $2\text{ M}\Omega$  at a temp. of  $30^\circ\text{C}$ . What is the recommended value of insulation? Is it advisable to put the machine in service? Give reason. Correction factor for  $30^\circ\text{C}$  is 0.5.

Data given are

kV – 0.24

Indicated IR –  $2\text{ M}\Omega$

Temp. -  $30^\circ\text{C}$

Correction factor – 0.5

Recommended value ( $R_m$ ) = kV +  $1\text{ M}\Omega$

=  $0.24 + 1$

=  $1.24\text{ M}\Omega$

Indicated IR at  $30^\circ\text{C}$  =  $2\text{ M}\Omega$

Correction factor – 0.5

So value corrected to  $40^\circ\text{C}$  =  $R_m = k_t * R_t$

=  $0.5 * 2$

=  $1\text{ M}\Omega$

The generator cannot be put in service because the corrected value is lesser than recommended value. It should be sent for IR re-conditioning.

***Motorised valve actuator***

1. What are the advantages of motorised valve actuators?

Advantages

- a. Can be used to operate in remote areas, high heat areas etc.
- b. Suitable logics can be wired up easily.
- c. Hammer blow mechanism (which will release valve in stuck open or close). The motor has high torque.

2. What are the four basic parts of any valve actuators?

- a. Valve motor.
- b. Gear mechanism.
- c. Limit switch and torque switch assembly.
- d. Terminal box.

3. Explain how the motor motion is transmitted to the valve stem?

The motor shaft is connected to a spur gear. It engages on a worm wheel. The worm wheel has dog teeth. This dog teeth engages or hits the dog teeth on moving or sliding clutch. The sliding clutch has splines and these are on the splines of valve stem. So when the sliding clutch rotates the valve also rotates simultaneously.

4. Do you require separate limit switch for closing and separate limit switch for opening? Ans. YES.

5. What does the limit switch mechanism senses to operate?

Limit switch mechanism senses whether the open and close travel of the motor has exceeded the limit setting of the motor to operate.

6. What does the torque switch mechanism senses to operate?

Torque switch senses whether the torque of motor has exceeded the set point irrespective of position of valve.

7. Explain the operational aspects of limit switch and torque switch in rotork valve actuator.

- a. When limit function is selected?
- b. When torque function is selected?

Limit function – when limit function is selected in rotork valve, the limit switches will operate when the limit set points are reached. Suppose limit switches fails to operate the torque switches will act and cuts off the supply to the motor (both torque switch and limit switches can act when selected to limit function).

Torque function – when torque function is selected the torque switches will act when set point is reached. The limit switches will not act (only torque switch will act when selected to torque function).

8. Indicate how you will select the limit switch contacts for indication and for cutting the supply to the motor?

For cutting off the supply to the motor normally closed (NC) contacts of limit switch (LS) should be wired in series with interposing relay coil of respective direction of the valve so that when valve reaches their respective direction contact will open and cut the control supply. For indication normally open contacts (NO) of opposite direction of valve should be used so that when valve fully closes open indication contact should remain NC only and vice-versa.

So for close direction

NC contact of close direction

9. What indication will you get in control room when
- a) valve is open – green
  - b) valve is closed – amber
  - c) valve is intermediate – both
  - d) valve is closing and torque switch operate – both

10. What is the function of hammer blow mechanism?

Hammer blow mechanism allows motor to rotate freely for  $\frac{1}{2}$  or  $\frac{1}{4}$  turn and the dog teeth on worm gear comes against the dog teeth on sliding clutch with a blow. This is use full when valve is stuck in fully open or closed condition.

11. How will you proceed to operate the valve manually after an electrical operation?

After electrical operation to operate manually we must tilt the lever provided on the actuator to hand (manual) position by which the sliding clutch gets engaged with hand drive.

12. Know the setting procedure for all valves.

13. Know the control and power circuit diagram of electrical motorised valve.

**Transformers**

1. What is the colour of silica gel in dry stage and when saturated with moisture in a breather?  
Dry stage – Deep blue.  
Saturated stage – Whitish pink.
2. What is the static pressure of diaphragm in the transformer explosion vent?  
5 psi.
3. In buchholz relay how the top and bottom mercury switches are connected?  
Top mercury switch is connected for alarm and bottom switch for trip.
4. What is the normal value of moisture content allowed in transformer oil?  
<10 ppm.
5. What is the vector group of distribution transformer?  
Dy11.
6. What are the losses in a power transformer and mention how these losses can be minimised?  
There are two losses in a transformer.
  - a. Iron losses.
  - b. Copper losses.

**Iron losses** – Iron losses constitutes of two losses.

- a. Eddy current losses, these are due to the induced emf in the core, which constitutes a current in the core. These will heats up the core.  
Eddy current losses can be minimised by using laminated core immersed in varnish. This provides a high resistance between the laminations and thus eddy current in reduced.
- b. Hysteresis losses, these are due to the magnetic reversal of current by which there is friction between molecules of core and heat is generated.  
Hysteresis losses can be minimised by selecting proper magnetic material, like silicon steel.

**Copper losses** – these losses are due to the resistance of the winding, which is equal to  $I^2rt$  (calories). These losses are depends on load. That is the losses are increased to the square of the load current  
I – current through winding.  
r – resistance of winding.  
t – time duration.

7. Define the percentage voltage regulation and efficiency of a power transformer.

**Voltage regulation** is the difference between no load voltage and full load voltage by no load voltage.

Voltage regulation =  $\frac{\text{No load voltage} - \text{Full load voltage}}{\text{No load voltage}}$ .

Voltage regulation is mentioned in % (percentage).

% Voltage regulation =  $\frac{\text{No load voltage} - \text{Full load voltage}}{\text{No load voltage}} \times 100$ .

**Efficiency** of a transformer is the ratio of output in watts and input in watts.

Efficiency =  $\frac{\text{Output in watts}}{\text{Input in watts}}$ .

% Efficiency =  $\frac{\text{Output in watts}}{\text{Input in watts}} \times 100$ .

% Efficiency =  $\frac{\text{Output in watts}}{\text{Output in watts} + \text{losses}} \times 100$ .

8. Mention the important parts of a power transformer and their purposes.

**Conservator:** This allows for shrinkage and swelling of transformer oil. When the oil is heated up it swells and rises to the conservator. When cools down it goes back to main tank. Conservator reduces sludge formation of oil because only the oil surface in conservator is exposed to atmosphere where oil in the main tank is not exposed to atmosphere.

**Breather:** It provides dry air to conservator when transformer breathes. That is when there is shrinkage of oil atmospheric air enters conservator through breather. The moisture is absorbed in breather by silica gel.

**Buchholz relay (gas operated):** If there is an initial fault, heating up of core, high resistance joints heating up by conduction through insulation and supports. There is heating up of oil, which breaks down and gases are released. This gas actuates the mechanics in the relay, There by closing contacts of mercury switches for alarm. Also if there is a short circuit, the buchholz relay will trip the transformer. Also if there is any leakage of oil through bushing etc and oil level comes down the relay will give alarm and also will trip the transformer if transformer oil level comes down the point. Gases can be taken from the relay to identify nature of fault.

**Explosion vent:** It provided on transformer main tank, provided with two Bakelite diaphragm which break when the pressure exceeds 5 psi in the transformer tank and relieve the pressure.

**Core:** To provide low reluctance path for the magnetic lines of force. It carries both the HV and LV windings.

**HV Winding:** High voltage is given to HV winding and low voltage is taken from the LV winding.

**LV Winding:** Low voltage is given to LV winding and high voltage is taken from the HV winding.

**Cooling tubes:** These are provided to cool the transformer oil so that the heat of oil will be given to the atmosphere.

**HT bushing:** Carries the HV terminals.

**LT bushing:** Carries the LV terminals.



***Tap changer:*** this is provided so that we can get the required voltage out put. There are two types of tap changer. Online tap changer and off line tap changer.

9. Mention the properties of transformer oil.

Properties of transformer oil are,

- a) Colour – pale yellow.
- b) Moisture content - <10 ppm.
- c) Acidity (KOH/gramme of oil) – <0.1.
- d) Dielectric strength – limit value is 45 kV and preferable value is 60 kV.
- e) Flash point - 141° C.
- f) Inter surface tension – 30 to 40 dynes / cm or 0.3 to 0.4 Newton.
- g) Resistivity –

10. How explosion vent works?

Explosion vent is provided on the transformer tank to relieve pressure if the pressure in the transformer exceeds 5 psi. It is swan neck shaped having two Bakelite diaphragms. One at top and another at bottom. These break if the static pressure increases to 5 psi. Wire meshes are provided below the bottom diaphragm and above the top diaphragm. When there is any breakage due to excess pressure the bottom wire mesh prevents broken pieces from entering transformer tank and the wire mesh provided above the top diaphragm protects the diaphragm from any external damage. There is an oil level indicator provided above the bottom diaphragm. It indicates the level of oil in the vent if the bottom diaphragm ruptures.

A ruptured diaphragm must be immediately replaced. Also we should check the top diaphragm for any external damage.

11. Explain the operation of silica gel breather.

Silica gel breather is used in a transformer to provide dry atmospheric air to the conservator when transformer breathes. The breather consists of an inner container and outer container. The inner container contains silica gel, which absorbs moisture. An oil bath is provided at the bottom of breather so that the silica gel will not be in direct contact with the atmosphere. Also it will trap dust and dirt entering the breather. Dry silica gel will be deep blue in colour. After it gets saturated with moisture it will turn into white pink. The change of colour silica gel can be viewed externally through transparent viewer provided on the breather. When the silica gel is saturated with moisture it must be replaced or regenerated or recharged. Silica gel is recharged by heating it to a temperature of 250° F to 300° F till the deep blue colour of silica gel is got back.

12. Explain with diagram the operation of on load tap changer.

Tap changer (ON LOAD type) can be used to increase or decrease transformer output voltage without break in the voltage to the load.

The tap changer consists of a diverter switch. The odd taps are taken on one side and even on another side as shown in figure.



The diverter switch is provided so that there will be no break in the supply to the load and also no cut of transition resistance when the tap changing is achieved. Transition resistors are provided to limit the current when the windings are short-circuited by the diverter switch.

*Operation:* In the above figure, the voltage at tap 2 is 406 V. the position of diverter switch is shown. It short-circuited with transition resistance.

We want to increase voltage to 420 V at tap 5. When we begin to change the tap the diverter switch connects 2 transition resistance and when the tap changeover is achieved that is when the tap changer reaches tap 5, the diverter switch short circuits transition resistance and thus the resistance is eliminated. The diverter switch switching time is very high. This is to reduce arcing, which can decompose the oil.

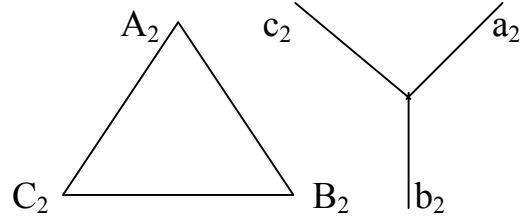
The whole assembly is immersed in oil. OLTC is connected to HV side, because in LV side current handled will be more. But in HT side current to be handled is lesser than LV side.

13. Explain the procedure for finding out the vector group of a transformer.

*Procedure:* Take the nameplate details. See from nameplate what group the transformer belongs. Suppose nameplate says that transformer belongs to Dy11.

Take the IR value between

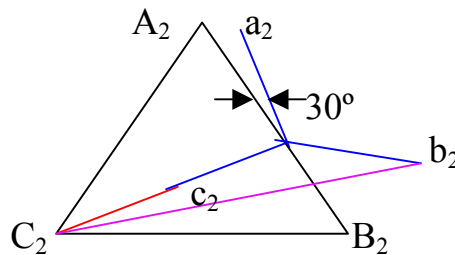
- HV and LV with body grounded. That is between  $A_2 - a_2$ ,  $B_2 - b_2$ ,  $C_2 - c_2$ .
- HV and body with LV grounded and
- LV and body with HV grounded.



Connect  $A_2$  to  $a_2$  and give low voltage (415 V) to HV side. Measure voltage between

- $C_2 - b_2 \rightarrow 410 \text{ V (example)}$ .
- $C_2 - c_2 \rightarrow 395 \text{ V (example)}$ .
- $B_2 - b_2 \rightarrow 395 \text{ V (example)}$ .
- $B_2 - c_2 \rightarrow 395 \text{ V (example)}$ .

Draw the diagram of Dy11 and check that the readings got are correct.



According to the fig.

$$C_2 c_2 = B_2 b_2 = B_2 c_2.$$

And  $C_2 b_2$  will be greater than  $C_2 c_2$ ,  $B_2 b_2$ ,  $B_2 c_2$ .

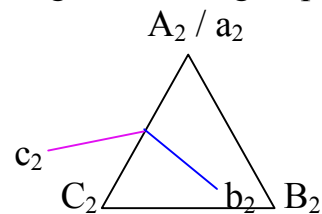
That is  $C_2 b_2 \gg C_2 c_2$ .

If these conditions are satisfied then that transformer belongs to vector group Dy11.

For Dy1 transformer

$B_2 c_2$  will be greater than  $B_2 b_2$ ,  $C_2 c_2$ ,  $C_2 b_2$ .

That is  $B_2 b_2 \gg B_2 c_2$ .

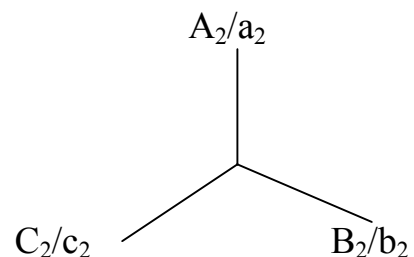


For Yy0 transformer

$$B_2 c_2 = C_2 b_2$$

$$B_2 b_2 = C_2 c_2$$

$B_2 b_2$  and  $C_2 c_2$  will be lesser than  $B_2 b_2$  and  $C_2 b_2$ .

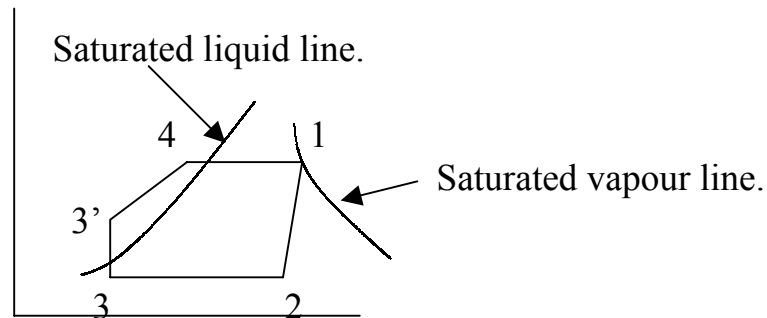


### ***Turbine Generator Basics***

1. Explain the principle of working of impulse steam turbine.

When steam enters the turbine it suffers a change in direction and momentum, which gives rise to the rotation of the turbine. There will be no drop in pressure in impulse steam turbine.

2. Mention the four processes involved in Renkine cycle.



1 – 2 → Expansion process.

2 – 3 → Constant pressure heat rejection.

3 – 3' → Reverse adiabatic expansion.

3 – 4 and 4 – 1 → Constant pressure heating.

3. What are the methods of removing moisture from turbine?

- External method by moisture separator and reheater, which separates the moisture and reheats the steam.
- Internally by stainless steel mesh, which reduces moisture (water particles) to 1%.
- By main steam reheat.

4. Define capacity factor.

Capacity factor can be defined as net power produced by the plant divided by perfect net power that can be produced in the plant.

Capacity factor = Net power produced / Perfect net power produced.

5. What is the purpose of turbine governing system?

Turbine governing system governs the speed of the turbine with the help of centrifugal governor. It reduces the steam inlet when turbine over speeds.

6. What are the benefits of feed water heating?

- It improves the plant efficiency.
- Feed water is heated nearer to saturation point thus thermal shock to boiler is avoided.

7. Mention parameters monitored by turbovisory instruments.

- a. Speed governing.
- b. Eccentricity monitoring.
- c. Vibration monitoring.
- d. Valve position monitoring.
- e. Temperature monitoring.
- f. Pressure monitoring.
- g. Level monitoring.
- h. Gas leak monitoring.
- i. Conductivity monitoring.
- j. Flow monitoring.

8. What are the purposes of turning gear?

Turning gear is used to run the turbine from rest to low speed and from normal running speed to low speed with the help of barring motor to eliminate the hogging and sagging of turbine because of the high temperature.

9. Explain the differences between the two types of feed water heaters.

- a. *Open type*: In which bleed steam and condensed water are mixed directly and there is also deaeration of steam.
- b. *Closed type (shell type)*: It has tubes and shell. The water passes through the tubes and steam passes through shell. The heat exchange takes place through the metal tubes.

10. Why condenser back-pressure must be low? How it is achieved?

Condenser back-pressure must be low, because steam should be dumped into the condenser so as to recycle it to boiler through the recycle process. It improves efficiency of the turbine, as the heat rejection is less. It is achieved by the help of ejectors and also passing cold water in the condenser through the tubes of the condenser so that maximum vacuum can be obtained.

11. What are the materials used for TG rotor and blades?

TG rotor is made up of alloy steel and blades are made up of stainless steel.

12. Define the term *heat rate*?

*Heat rate* is defined as the heat supplied in to the plant in Btu by power generated or output by the plant in kWh.

Heat rate = Heat supplied in Btu / Power output in kWh.

13. What is the purpose of gland steam system?

Gland steam system is provided to arrest the steam leak from the turbine and to protect the air ingress into the turbine.

14. Explain the main difference between impulse and reaction turbine.

When the inlet pressure of steam to the turbine is equal to outlet pressure of steam from the turbine the turbine is called the impulse turbine. In this type the heat is added is very less.

In reaction turbine the outlet pressure of steam is less than the inlet pressure of the steam. There is reduction in pressure with the increase in kinetic energy.

15. What is meant by hydrodynamic film lubrication?

In high-speed turbines the lubricating oil will be at the sides and there is metal to metal contact when turbine at rest. When the turbine speeds up there is pressure pushing the oil through the metal to metal contact. When turbine finally achieves its speed the oil film breaks the barrier and it takes the load on itself. This is hydrodynamic lubrication.

16. How does the hydrostatic lubrication differ from hydrodynamic type?

In hydrostatic lubrication which is used in slow speed turbines the lubricating oil is pressurised externally where as in hydrodynamic system it forms oil film by its speed which pushes the lubrication oil to form film.

17. What are the functions of dearator?

Dearator removes non-condensable gases ( $O_2$ ), which gets added in the steam and it, mixes steam with the condensed water for feed water heating. This is a contact type feed water heater.

18. Why non-return valves are provided in the steam extraction lines?

Non-return valves are provided because when the turbine trips there will be an instant drop in pressure inside the turbine. But there will be steam in feed water heaters, which is at high pressure. These will rush in to the turbine and overspeed will be there in turbine. So non-return valves are provided in steam extraction lines to prevent over speeding of turbine.

19. What is the function of the steam traps?

During startup the steam traps will bypass turbine drains.

20. What do the term sensible heat and latent heat mean?

*Sensible heat:* We can measure the rise in temperature. When we add more heat to a substance. Example – heat that added to water from  $0^\circ\text{C}$  to  $100^\circ\text{C}$ . This added heat is measured as sensible heat.

*Latent heat:* Though there is addition of heat there will be no rise in temperature. This is latent heat. Example – when water boils at  $100^\circ\text{C}$  though we added more heat the temperature remains at  $100^\circ\text{C}$  till all water becomes steam.

21. How are the generator rotor and stator cooled?

Passing highly DM water through the hollow conductor of the generator cools generator stator and rotor is cooled by hydrogen.



22. What is function of seal oil system?

Seal oil prevents the leakage of hydrogen from the generator casing to the atmosphere, where it can form explosive mixture. Seal oil is at higher pressure than hydrogen.

23. What are the base load and peak load power stations?

During certain periods the load demands are very high. Example the morning when all factories operate. During these time certain power plants like thermal plants gives this extra power required. These are the *Peak load* stations, which operates at certain periods.

But during the rest of period that is when there is no peak power demand there are some power stations, which cater to the *base load* always runs giving power to the grid. These stations are producing power at constant rate. These stations can not be easily stopped or restated. Nuclear power station comes under Base load power station category.

24. What are two types of governing system.

*Throttle governing system:* In this a valve (just like tap water controlling) which reduces the steam pressure controls the steam flow. This has very less efficiency.

*Nozzle governing:* In this the steam flow is reduced but the pressure remains the same. This is achieved by four valves in which when one is closed to 25% of steam is reduced. This is efficient way of governing.

***Conventional system***

1. How turbine oil purification is achieved?  
Oil purification is achieved by centrifugal operation.
2. Why morpholine is used?  
Morpholine is used for pH control.
3. By which material condenser tubes are made?  
Condenser tubes are made up of aluminium brass.
4. How boiler level is controlled?  
Feed water control valves controls boiler level.
5. Where magnetic filter is used?  
Magnetic filter is used in stator water lines to remove magnetic particles from the DM water.
6. What is the purpose of accelerator governor?  
The purpose of accelerator governor is to cut of steam momentarily when large electrical loads are taken to prevent turbine speeding up.
7. What is the use of jacking oil pump?  
Jacking oil pump is used to initial lifting of turbine rotor by hydrostatic lubrication.
8. What is the use of supplementary oil tank?  
Supplementary oil tank is used to collect the oil drains from the CIES valves.
9. How dearator pressure is maintained?  
Dearator pressure is normally maintained by extraction steam.
10. How dearator pressure is maintained after turbine trip?  
Pegging steam is used to maintain dearator pressure after turbine trip.
11. Where trust bearing is provided?  
Trust bearing is provided between HP turbine and LP turbine rotor.
12. How dissolved oxygen control is achieved in feed water system?  
Hydrazine is added to feed water system to control dissolved oxygen.
13. How seal oil pressure is maintained?  
Differential pressure regulator maintains the seal oil pressure at  $0.7 \text{ kg / cm}^2$  higher than  $H_2$  pressure.

14. What is used to purge hydrogen from the generator casing?

During generator purging  $\text{CO}_2$  is used to purge out  $\text{H}_2$  from the casing.

15. Why class B trip is provided?

Class B trip is provided to prevent damage and over speeding of the turbine.

16. How lub oil supply is maintained?

Lubrication oil supply is maintained by outlet oil from turbine oil pumps during normal operation and jacking oil pump during startup.

17. What is the function of speeder gear?

Speed raising beyond governor takeover speed upto full speed is achieved by raising and lowering the speeder gear.

18. How gland-sealing steam is supplied?

Gland sealing steam is supplied from main steam line.

19. Why exhaust sprays are provided?

Over heating of last stage LP blades is avoided by exhaust sprays by CEP.

20. What is the use of vacuum breaker?

In case of loss of seal oil to generator seals vacuum breaker is used to bring TG to rest very quickly.

21. How relay oil is supplied?

Relay oil is supplied from the main oil pump for the operation of governing system.

***Electrical system***

1. What are the main two divisions of MAPS electrical system and what do you understand by it?

The two main divisions of MAPS electrical system are

- a. Main output system. Output system supplies power to the grid. Generated voltage is stepped up to 220 kV from 16.5 kV and supplied to grid.
- b. Station service system. This system supplies the load inside the power station. The generated voltage is stepped down to 6.6 kV and 415 V from 16.5 kV and supplies to auxiliary loads.

2. List out the components of station output system.

Main generator, Generator transformer, PT, CT, CVT, lightning arrestor, wave trap, main 220 kV bus, transfer bus, SF6 circuit breakers and isolators, line protection scheme, GT and Generator protection scheme, bus bar protection scheme etc.

3. Why earth switches are provided in 220 kV bays?

When bay CB trips, both end (station and grid) CB will trip. The earth switches are provided because the grid will always be alive so to prevent any shocks to the operator or maintenance personnel who is working on the line or bay due to accidental energizing of the bus.

4. What is the purpose of CVT (capacitance voltage transformer)?

Purposes of CVT are

- a. To indicate if line is charged or not.
- b. To synchronize grid with generator.
- c. For power line communication and carrier tripping.

5. What are the protections provided for 220 kV lines and bus bars?

- a. Bus bar differential protection.
- b. Distance protection.
- c. Over current protection.
- d. Earth fault protection.

6. What are the main sources of power supply to 6.6 kV buses?

- a. Unit transformer which steps down the generated voltage to 6.6 kV from the generator.
- b. Start up transformer, which steps down the grid voltage to 6.6 kV.

7. List some important loads to 6.6 kV buses.

- a. Auxiliary transformers.
- b. PHT motors.
- c. BFP motors.

- d. CEP motors.
- e. CCW motors.
- f. Chiller motors.
- g. Pressuring pump motors.

8. What type breakers are provided in 6.6 kV buses?  
ABB. Make, SF6 gas, 1250A and 2000A capacity circuit breakers are provided in 6.6 kV buses.
9. What is the difference in action of lock out pressure signal on 6.6 kV and 220 kV breakers?  
When lock out signal comes to 6.6 kV breakers the breaker will trip. Where as in case of 220 kV breakers the breaker will not trip. If the breaker is open it will be open only and can not be closed. If it is in closed condition it will be closed.
10. For how long 220 V DC batteries can supply power UPS?  
220 V DC batteries can supply Power UPS for 30 minutes. Within this time class III power supply should be restored by DG's.
11. What do you understand by station black out?  
When class IV and class III power supply fails and DG's cannot be started and also this condition prevails for 5 minutes then it is called station black out condition.
12. What are the sources of power supply to class I bus?  
a. Through control UPS 240 V AC.  
b. Through control UPS 220 V DC backed by 220 V batteries.  
c. Through control UPS 48 V DC backed by 48 V batteries.
13. What are the lighting systems adopted in KGS?  
There are two systems.  
a. Normal lighting with class IV power supply.  
b. Emergency lighting with class II power supplies and in control room with class I power supplies.

***Measuring instruments***

1. What are the two main classifications of analog instruments?

The two main classifications of instruments are,

- a. *Absolute instruments*. Example tangent galvanometer.
- b. *Secondary instruments*. Example ammeter, voltmeter. Analog instruments are classified according to their electrical quantity they measure. Example frequency meter, voltmeter, etc. Principles they work are moving coil, induction.

2. What are three types of secondary instruments?

The three types of secondary instruments are,

- a. *Indicating type*: It only indicates the electrical quantity measured. Example: Ammeter, Voltmeter, Frequency meter etc.
- b. *Integrating type*: It integrates (sums up) the quantity being measured. Example: Energy meter.
- c. *Recording meter*: It records as well as indicates the electrical quantity being measured. Example: 3 pen graphical recorder.

3. Give three operating forces acting on indicating instruments.

- a. Deflecting force.
- b. Controlling force.
- c. Damping force.

4. What are the advantages of digital instruments over analog instruments?

- a. Human errors are avoided (comparative error) because the output is displayed in form of numbers.
- b. Power consumption of digital meters are low as compared to analog meters.

5. What is the range of resistances that can be measured using following.

- a. Wheatstone bridge – 1 milli  $\Omega$  to 11 M $\Omega$ .
- b. Kelvins double bridge – 0.2 micro  $\Omega$  to 11  $\Omega$ .
- c. Megger – Insulation resistances more than 100 k $\Omega$

6. What do you understand by tan delta for a insulating material?

Tan delta measurement is done to find the qualities of insulating material. Tan delta is angle between current due to surface leakage or current due to capacitance and the capacitive current. That is  $\tan \delta = I_r / I_c$ .

7. For what purposes transformer ratio meter can be used?

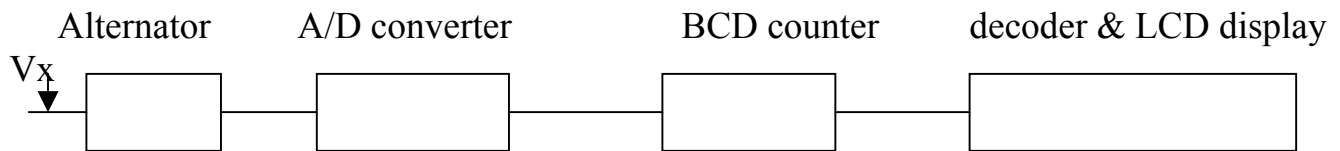
Transformer ratio meter can be used for,

- a. To find the ratio of a transformer.
- b. To find the phase angle deviation of primary and secondary voltage of transformer.



- c. To find the magnitude of magnetizing currents.

8. Draw connection diagram of ammeter, voltmeter, energy meter, and wattmeter.
9. Illustrate how can you use a single-phase wattmeter to measure 3 phase reactive power in a circuit?  
 We can measure reactive power of 3 phase circuit by single phase wattmeter by connecting the current coil in series with a line or load and connecting the pressure coil across the other two lines.  
 $\text{Reactive power} = 3\sqrt{3} V * I * \sin\phi \text{ Watts.}$
10. Draw the basic block diagram of digital meter and explain the function of each block.



*Alternator:* It reduces the unknown voltage to a small value. Because the reference voltage is very less and the unknown voltage is maximum.

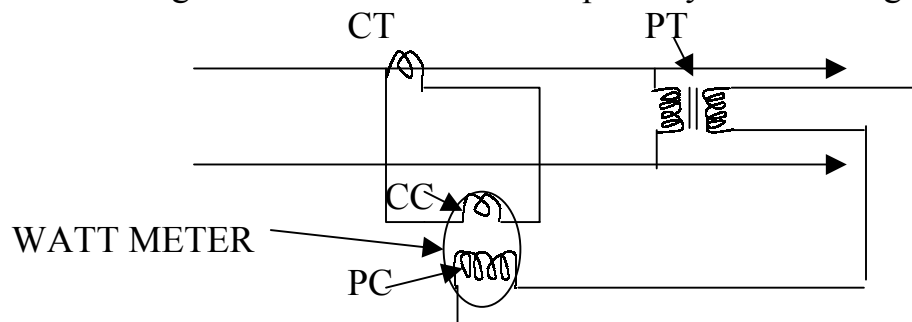
*A/D converter:* It converts the analog signal from alternator to digital signals.

*BCD counter:* It counts the number of pulses (binary counter).

*Decoder and display:* It decodes the binary code to decimal form and gives a visual display of it.

11. Draw a neat sketch and explain the use of CT and PT for measurement of power in a single-phase circuit?

If wattmeter of proper range is not available or if voltage and current ranges are high we can use CT and PT of suitable ratio. Connect the CT and PT as shown in figure. The reading of wattmeter can be multiplied by the ratio to get the actual power.



## 12. Explain the construction and working of moving coil instrument.

**Construction:** The moving part is a coil wound on a light aluminium frame, mounted on a shaft made of stainless steel which is pivoted at either ends on jewel bearing made of sapphire. The coil is placed between poles of a permanent magnet. Moving system is made light as far as possible to have high torque and weight ratio. There are two phosphor bronze springs of very less resistance. This is used as terminals for the current to pass through the coil and out of coil. It also serves the purpose of control force.

Aluminium coil former acts as a damping device by eddy current damping. There is a knife edge pointer and a counter weight to avoid its sagging.

**Working:** When ever a current carrying conductor is placed in a magnetic field a force is experienced by the conductor. Moving coil meters work on this principle.

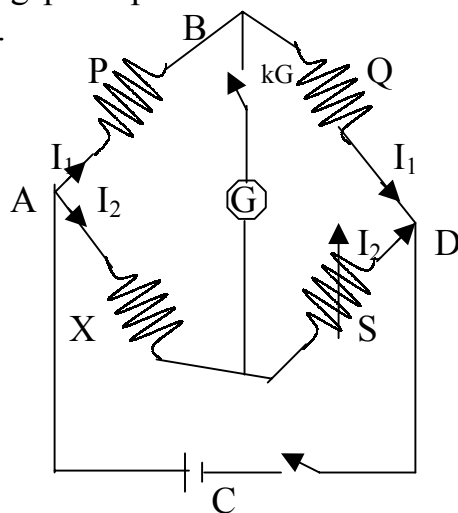
$$\text{Force} = BILN$$

As the BNL is constant, force (F) is directly proportional to current (I).

That is  $F \propto I$ . Where B is magnetic flux, N is number of turns and L is length of coil.

## 13. Explain the procedure for measurement of earth resistance.

## 14. Explain the working principle of wheat stone's bridge along with equations under balanced condition.



Wheat stone's bridge works on kirchoff's law. It is used to measure medium range resistances. P and Q are fixed standard resistances. S is standard variable resistances. X is the unknown resistance. G is galvanometer, kG is galvanometer switch and kC is battery switch. No current will flow through galvanometer if the potentials across its terminals are equal. So there will be no deflection of galvanometer. This condition is called the balanced condition.

This is achieved by varying S and also by varying P/Q ratio.

At balanced condition  $V_{AB} = V_{AC}$  And  $V_{BD} = V_{CD}$

$$I_1^* P = I_2^* X \quad \& \quad I_1^* Q = I_2^* S$$

Dividing both  $\frac{I_1^* P}{I_1^* Q} = \frac{I_2^* X}{I_2^* S}$

$$I_1^* Q = I_2^* S$$

$$= P/Q = X/S$$

$$\text{Unknown resistance (X)} = P/Q * S \Omega$$

15. Explain the working principle of Kelvins double bridge and procedure for the measurement of terminal resistance.

***Protective relays and application***

1. What you mean by accuracy limit factor?  
The ratio between the accuracy limited primary current to rated primary current is called the accuracy limit factor.
2. What is the characteristic of inverse time over current relay?  
If the fault current increases the time of the operation of the relay will be decreases.
3. What are the two errors in instrument transformer?
  - a. Ratio error.
  - b. Phase angle error.
4. Where core balance CT is used?  
Core balance CT is used in earth fault protection.
5. Define knee point voltage of a CT.  
When the primary of a CT is open circuited and supply (variable) of system frequency is given to secondary, then a 10% increase in voltage constitutes 50% increase in current. That voltage is the knee point voltage.  
At this point the core is saturated and a little increase in voltage constitutes a great increase in current. kpv decides the opening range of the CT. Above kpv the ratio of transformer will not be applicable.  
 $kpv = R_{CT} + R_{LEADS} + R_{RELAY}$
6. What do you mean by the term 5P10?  
This indicates the type of relay, Its % error and accuracy limit factor.  
5 – composite error (Phase angle error + ratio error) 5%.  
P – Protection CT.  
10 – Accuracy limit factor.
7. Mention the important properties of relay contacts.
  - a. Should be robust in construction.
  - b. Self-cleaning (oxides easily breakdown).
  - c. Corrosion resistant.
  - d. Bounces free and striction free (low contact resistance).
  - e. Able to carry rated continuous current and short time rated current.
8. What is a composite error and write down the formula for composite error?  
Basically composite error = Ratio error + Phase angle error. It is the ratio error integrated over one cycle at steady state of operation.

$$\text{Composite error} = 100 * \sqrt{\frac{1}{\omega} \int_0^T \frac{(k_n * I_s - I_p)^2}{-108} dt}$$

T

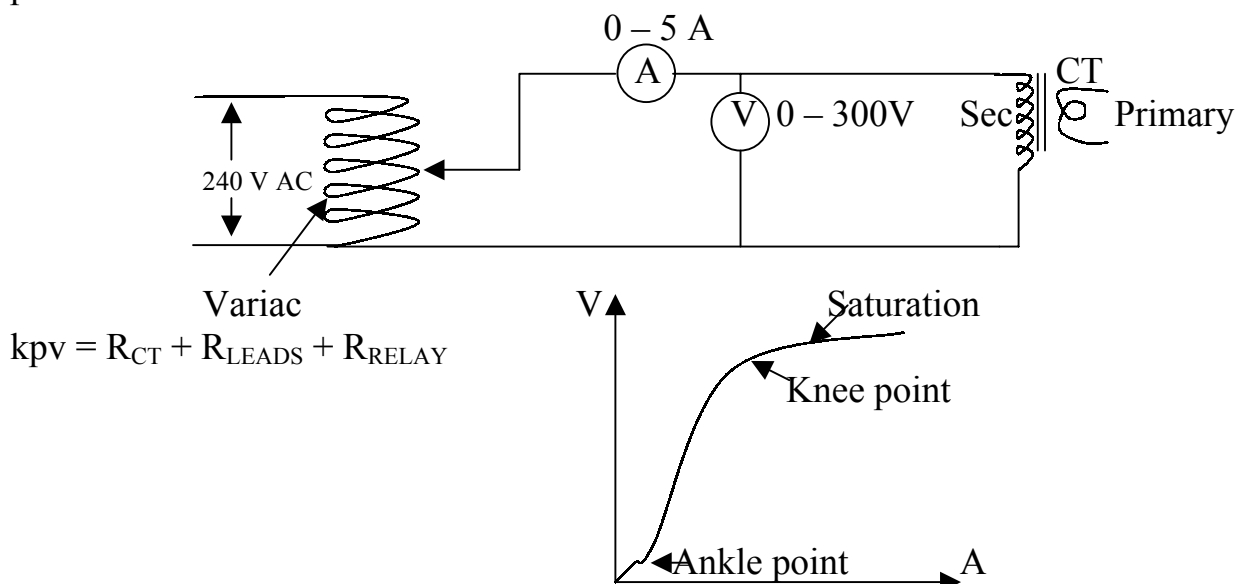
$I_p$

## 9. Define pickup value and reset value.

*Pickup value:* It is the smallest value of actuating quantity when its value is increased from zero to pickup value, the relay will energise.

*Drop out value:* It is the largest value of the actuating quantity when its value is decreased from pickup value, the relay will reset or de-energize.

## 10. Draw the circuit diagram for finding out the knee point voltage and explain the procedure.



Connect the circuit as shown. O/P of variac should be zero. Increase it to 5 Volts and take down the value of current from the ammeter. Now increase the voltage by 10% ( $5 + 10\% = 5.5 \text{ V}$ ) and take the current reading. Now increase the voltage by 10% ( $5.5 \text{ V} + 0.55 \text{ V} = 6.05 \text{ V}$ ) and note down the current. Now keep on increasing voltage by 10% and note down current reading. At some value there will be 50% increase in current for 10% increase in voltage.

Example  $40 \text{ V} \rightarrow 0.2 \text{ A}$

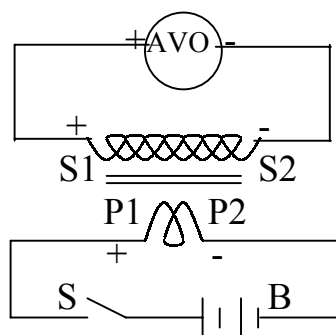
$40.4 \text{ V} \rightarrow 0.3 \text{ A}$  ( $0.2 + 50\% = 0.3 \text{ A}$ ).

That point is the knee point voltage of that particular CT. From this point onwards a little increase in voltage will lead to a large increase in current, because the core is saturated fully. When we plot all the values on a graph taking current as X-axis and voltage as Y-axis, we will get the above graph. Protective relays operate between ankle point and knee point. Above this they cannot detect the fault correctly. Measuring CT operate in the ankle region.

11. Explain the procedure for finding out the polarity and ratio test in a CT with circuit diagram.

**Polarity test:** Connect the circuit as shown in figure with a battery, switch and AVOMeter. Now momentarily close the switch S and see the deflection in the AVOMeter. If it is in the direction as shown in the figure, then the polarity of the CT is correct. If it is in opposite direction the polarity of CT is not correct. Polarity test is very important because if polarity is not correct in differential protection the relay will fail to act when fault occurs.

**Ratio test:** Connect circuit as shown in figure (2). Slowly increase the current. Take down the readings of A1 and A2. Then see whether it confirms to reading of nameplate. Ratio =  $A1/A2$ .



POLARITY TEST (FIG 1)

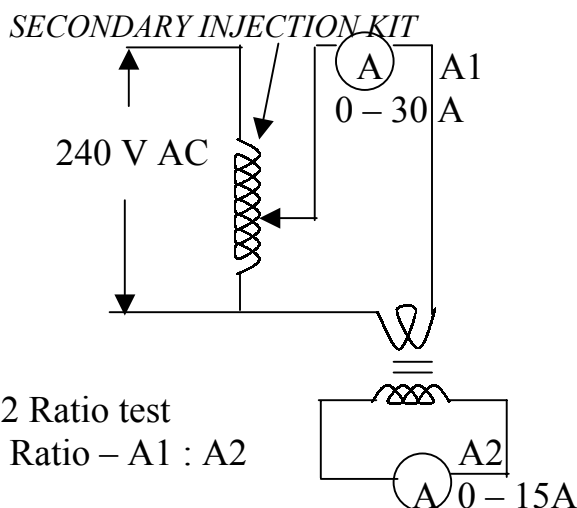


Fig – 2 Ratio test  
Ratio –  $A1 : A2$

12. Explain the principle of operation of attracted armature relay with equation and characteristics curve.

**Principle:** It works on the principle that when a current is passed through a coil magnetic lines of force develop and the coil behaves like a magnet. When we place a magnetic material inside the coil it is attracted.

In attracted armature type of relays there is a spring that keeps the contact open, a plunger that tends to close the contact and a coil through which current is passed. The spring force and magnetic force oppose each other. When these both are equal the relay will pickups.

At verge (time) of pickup

$$k_1 I^2 = k_2$$

$$f = k_1 I^2 = k_2$$

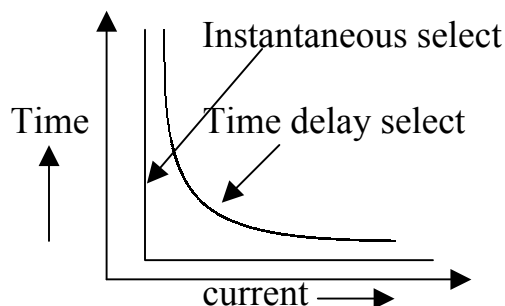
$$I = \sqrt{k_2 / k_1}$$

Where  $f$  – force.

$k_1$  – magnetic force constant.

$k_2$  – spring tension constant.

$I$  – current in the coil.





We can see the inverse characteristics from the above formulae. Usually attracted armature relays are instantaneous. That is there is no intentional (fixed) time delay. If we want a time delay we can add a slug in the armature core.

### 13. Mention the initial commissioning checks on CT's, PT's and relays.

Commissioning checks on

*CT*

- a) Terminal marking correctness.
- b) Polarity of terminals.
- c) Insulation resistance between primary and secondary.
- d) Insulation resistance between primary to earth and secondary to earth.
- e) Magnetization characteristic and knee point voltage test.
- f) Ratio test.

*PT*

- a) Terminal markings.
- b) Polarity checks of terminals.
- c) Insulation resistance between primary and secondary.
- d) Insulation resistance between primary to earth and secondary to earth.
- e) Ratio test.
- f) Whether PT can supply as per the burden of load check.

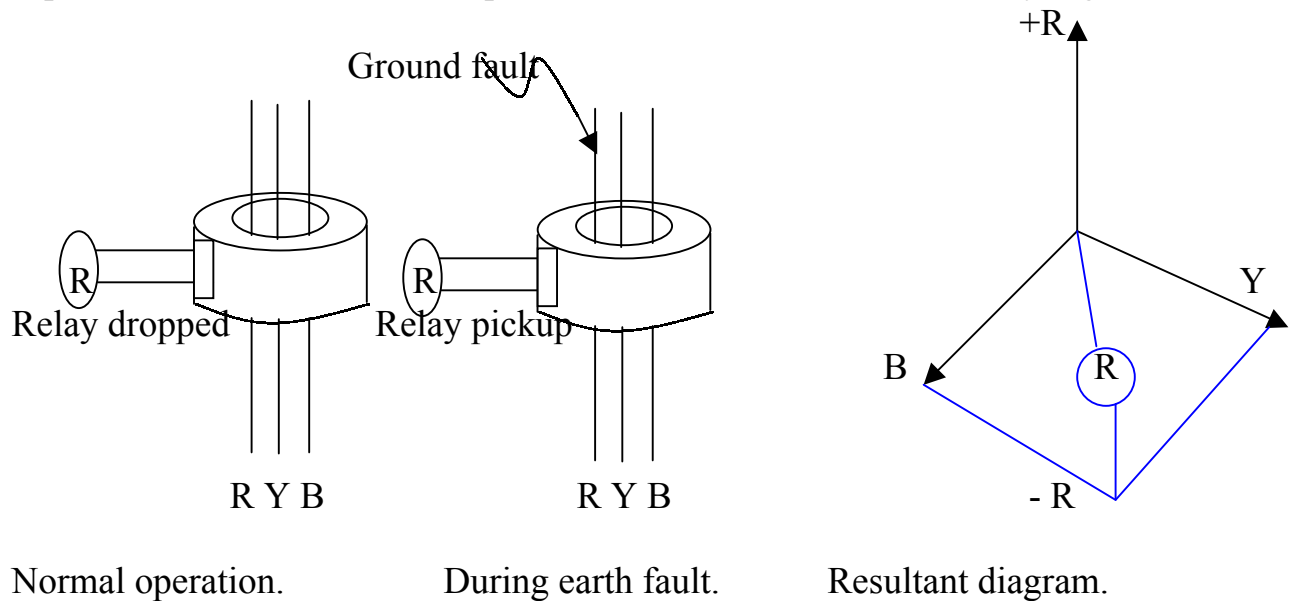
*RELAYS*

- a) Pickup and dropout value check.
- b) Insulation resistance of contacts and relay coil.
- c) Time delay (if relay is not instantaneous), operating time value check of relay.
- d) See that the correct circuit breaker trips on energisation of the particular relay.
- e) Continuity checks of contacts after energisation of relay.
- f) See if plug-shorting contacts are correct.
- g) See if CT's and PT's are corrected in correct polarity.
- h) Burden check of relay.
- i) Primary injection test.
- j) Secondary injection test.

#### 14. Explain with simple diagram the core balance CT.

In core balance CT all the three phases go through the core and the resultant magnetic flux is zero. Because the flux of three phases cancel each other. So the secondary output of CT is zero and the relay will not energise.

When there is a earth fault in one of the phase the fluxes cannot balance each other and there is a voltage induced in secondary of the CT and the relay is energised to trip the circuit. Saturation is no problem because the core size is very big.



***Logics and circuits***

1. Give the definition of following.

|      |                                         |
|------|-----------------------------------------|
| 27C  | Closing circuit supervisory relay       |
| 27T  | Tripping circuit supervisory relay      |
| 3C   | Interposing relay (closing coil)        |
| 3T   | Tripping coil                           |
| 52   | AC circuit breaker                      |
| 88   | Auxillary motor (spring charging motor) |
| 52Y  | Anti-pumping relay                      |
| 86.1 | Lockout relay                           |
| 42   | Main contactor                          |
| 50   | Instantaneous over current relay        |
| 50N  | Earth fault relay                       |
| 94   | Trip or Trip free relay                 |
| 49   | Thermal overload relay                  |
| 49S  | Stalling protection relay               |
| 27   | Supervisory relay                       |
| 64   | Ground protection relay                 |

2. What is the operating voltage of 3C?  
48V DC.
3. DC relay coil or contactor coils must be connected to which side?  
Negative side of the DC supply to avoid galvanic effect on the coil, which will corrode the coil.
4. How special current limiting resistance is connected with the seal in contact?  
Special current limiting resistance is connected in series with the seal in contact.
5. How you will connect start and stop push button to control the motor from two different places?  
Start push button should be connected in parallel and stop push button in series in the circuit.
6. What are the basic principles of ED?  
Basic principles of ED are,  
 a) All the contacts of corresponding relays and contactors are shown in de-energised condition.  
 b) Control circuit gives us idea about ON / OFF selection of motor, fuse rating, forward reverse control, seal in protections etc.  
 c) Power circuits are drawn in thick lines and control circuits are drawn in thin lines.  
 d) When relay or contactor energises normally open contact closes and normally closed contact opens.  
 e) Auxillary contacts acts with main device such as contactors and relay.
7. What is anti pumping?  
When a breaker is closed on fault condition there will be continuous tripping and closing of the breaker because 3C is energized. Anti pumping in circuit avoids frequent tripping and closing of circuit breaker when the breaker is closed in fault condition.

***Switchgear***

1. Mention the commissioning tests on breaker and bus bars.

***Breaker***

- a. Milli volt drops test between the interrupting contacts and between the isolator contacts.
- b. Closing and opening timing of the breaker for 5 times.
- c. Checking whether the breaker trips or closes when the logics are fulfilled.

***Bus bars***

- a. Milli volts drop test for the contact resistance value.
- b. Tightness of the joints.
- c. IR values between phase to phase and phase to ground.

2. Explain clearly the three positions in 415 V breaker.
  - a. Service position: Power connections and control connections are available to the breaker.
  - b. Test position: Power connections are cut off but control connections are available to the breaker and it can be tested.
  - c. Disconnect position or rack out position: This is for maintenance of the breaker and in this positions both the control and power connections are not available.

3. What do mean by trip free system in breaker?

In trip free the breaker is free to trip at any time. If both close and trip signal is present at same time (instant) the breaker will attempt to close and positively trip. When the breaker trips it will not close again even if closing signal exists because of anti pumping feature.

4. What is the purpose of spring charging in 415 V breaker?

If the breaker is to be closed and tripped manually the closing time and tripping time would vary from person to person. Also it would not be very fast. So spring charging is provided. It gives uniform timings irrespective of the operator and its action is fast and closing and tripping time is very less.

5. What are the built in protections provided in 415 V breaker?

a. DINF (making current magnetic release)

This consists of a laminated magnetic circuit. This is placed under the lower current terminal pole. This is provided for all the three poles. It has a core that rotates in the air gap. It is held by spring. During protection the magnetic forces developed overcome the spring tension and the core is attracted. The mechanical force developed is used to trip the breaker. This protection acts during the closing of breaker if any fault exists. The current is set to 5 times the rated current.

b. DIRS (short time magnetic release)

The construction is same as DINF, but it has a mechanical timer, which can be set accordingly. This protection acts when any fault comes during breaker in service. The current rating is set to 3 to 8 times the rated current.

c. DIT – S (thermal over load protection)

This consists of a three bimetallic strip, which gets heated up when over loaded and trips the breaker by a lever. It is placed in front of the breaker. Setting range is 60% to 100%.

***MCC***

1. What are the advantages of MCC?
  - a. Starters and contactors all will be a standard size.
  - b. Spares inventory will be less.
  - c. Cost of cables will be less because same size of cable is used for all capacity and gland holes can be provided before hand.
  - d. Maintenance and trouble shooting is easier in MCC.
2. What type of motor starting adopted in MCC?  
DOL (direct on line) starter.
3. What is the purpose of grounding secondary of the control transformer?  
To protect the operating personnel from high induced voltage.
4. Based on what factors will you select rating of components for a starter cell?  
Factors for selecting rating of components are,
  - a. Capacity of load.
  - b. Type of starting.
  - c. Duty (continuous or intermittent).
  - d. Type of protection.
  - e. Nature of starting (acceleration time is slow or fast).
5. What maintenance checks you will do for an MCC cells and MCC panel?  
*Maintenance checks on MCC cells*
  - a. Ensure that the load is tripped from control room and switch is in off position.  
Switch off the isolator at MCC cell.
  - b. Open the door and rack out the cell into isolation position.
  - c. Check the tightness of terminal of contactor, 3C, control transformer, control fuses, wipe in contacts, power cables, etc.
  - d. Check the tightness of component mounted.
  - e. Look for any charred components or terminals.
  - f. Check the IR value of 3C, contactor, control transformer, isolator etc.
  - g. Check the isolator double switch feature.
  - h. Check the OLR and calibrate the OLR.
  - i. Check the pick and drop out value of contactor, 3C.
  - j. Check the fuses for healthiness and fuse carriers for proper contacts.
  - k. Clean the arc-chutes of the contactor and clean all the components of the MCC cell properly.
  - l. Check the resistances of control transformer, contactor, 3C etc.
  - m. Check the tightness of control cable at main TB compartment.

*Maintenance on MCC panel.*

- a. Ensure the permit and all isolations.
  - b. Open the bus bar chamber and discharge the bus bar.
  - c. Disconnect the cables connected to bus bar and take the IR value of bus bar and cable individually. Connect it properly and tight it to proper torque.
  - d. Check the tightness of nut and bolts and cables connected to buses.
  - e. Open the main TB compartment and check the tightness of all cables and clean it.
  - f. See the tightness of power terminal compartment and clean it.
  - g. Check that cables are supported properly.
  - h. Do checks on CT, PT used for indication purposes.
  - i. Clean the entire MCC panel properly and take the IR value.
  - j. Carry the checks on relays, which are used in the MCC panel.
  - k. See for proper earthing connection and tightness of the earthing connections.
  - l. See for proper house keeping.
6. What is the difference between an auto reset and manual reset overload relay?
- a. *Auto reset relay* closes its contacts when the bimetallic strip gets cooled. In *manual reset relay* we have to manually reset the relay because even though bimetallic strip cools its contacts are not closing without manual reset. L & T type OLR have only manual reset and siemens type has both manual and auto facility.
  - b. *Auto reset over load relay* is reset by switching OFF the respective had switch and again switching it ON.
  - c. *Manual over load relay* is reseted by pushing the reset button provided on the MCC cell.



**Batteries and charger**

1. How you will prepare electrolyte for a lead acid battery?

While preparing electrolyte for lead acid battery sulphuric acid is added to distilled water.

2. How battery capacity is expressed?

Always battery capacity is expressed in *Ampere – hour*.

3. What is the instrument used to measure the specific gravity?

The instrument used to measure the specific gravity is called *Hydrometer*.

4. What you mean by SCR?

SCR is meant for silicon controlled rectifier.

5. Define specific gravity and mention the specific gravity of a fully charged lead acid battery?

Specific gravity of a substance is the comparison of density of the substance with the density of pure water.

Specific gravity = Density of the substance / density of pure water.

$$= \frac{\text{kg} / \text{cm}^3}{\text{kg} / \text{cm}^3}$$

$$= (\text{No unit})$$

Specific gravity is only number. It has no unit.

Specific gravity of pure water is one.

Specific gravity of fully charged lead acid battery is 1.215. Specific gravity should always be corrected to 27°C.

Corrected specific gravity is equal to indicated specific gravity  $\pm (t - 27^\circ\text{C}) \times 0.0007$ .

Indicated specific gravity = 1.205 and 't' means electrolyte temperature.

6. What are the parts of the battery?

Parts of the battery are

- a. Battery container.
- b. Battery cover.
- c. Positive plate ( $\text{PbO}_2$ ).
- d. Negative plate (Pb).
- e. Cell connector.
- f. Grid.
- g. Cell separator (porous material).
- h. Sediment chamber.
- i. Positive and negative terminals.
- j. Vent plugs.

k. Dilutes sulphuric acid (electrolyte).

7. What are the indications of a fully charged cell?

- The colour of the + ve plates will be dark brown. This can be seen only if the battery has transparent cover.
- Voltage per cell will be a 2.15 volts.
- Gassing in the will electrolyte will indicate. But the current is splitting up water to  $H_2$  and  $O_2$ . Because the positive and negative plates are fully converted to their original constituents.

8. What are the difference between primary cell and secondary cell?

*Primary cell:* The electrolyte in primary cell is chemically irreversible. That is once the cell is discharged it cannot be recharged. It should be replaced with a new cell. The cells can supply only low currents and have low efficiency. They supply intermittent current. Their internal resistance is more. These cells are comparatively cheap.

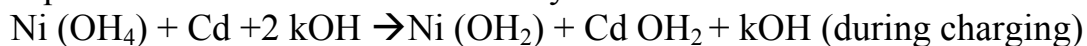
*Secondary cell:* These cells are chemically reversible. They can be discharged and charged. They can supply large currents because their internal resistance is less. These have high efficiency compare to primary cells. These can supply constant current. These are comparatively costly.

9. What do you mean by sulphation? And what are the effects of sulphation?

*Sulphation:* During normal discharge of battery  $Pb\ so_4$  is formed. This  $Pb\ so_4$  is chemically reversible by passing current. These split up to their original constituents. But under certain condition crystalline lead sulphate is formed (Example: under charging after some time without trickle charging). This  $Pb\ so_4$  is chemically irreversible. So if the sulphation occurs the battery life decreases. Efficiency decreases and the active material starts falling of the grid.

10. Write down the equation for Nickel cadmium battery.

Equation for Nickel cadmium battery.



(Nickel hydrate + cadmium + potassium hydroxide  $\rightarrow$  Nickel hydroxide + cadmium hydroxide + potassium hydroxide.)

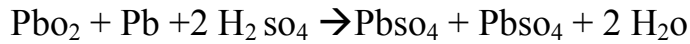


We see that there is no change in electrolyte. It just acts as a catalyst. So there is no need to change the electrolyte.

## 11. Write down the theory of lead acid battery.

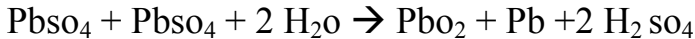
A simple lead acid battery consists of positive and negative electrodes Immersed in an electrolyte. The positive electrodes are  $PbO_2$  (lead oxide) and the negative electrodes are Pb (spongy lead). The electrolyte is dilute sulphuric acid.

On discharging the battery



Lead acid is converted into lead sulphate. Spongy lead is also converted into lead sulphate and  $H_2 SO_4$  used up in the process. Only water is remain. So the specific gravity of the cell comes down.

On charging the battery



Here the products are converted to their original constituents and the acid is released. So the specific gravity rises as the cell is charged. How much ever larger be the cell the voltage of each cell will be approx. 2.15 V when fully charged.

The positive plate is made of a paste lead oxide, lead sulphate that is fitted in a mesh like material and is connected to grid. All positive plates are made common and connected to a grid.

The negative plate is made of spongy lead also it is in mesh and connected to grid. These are also grouped together.

These plates are separated by a micro porous separator for the diffusion of electrolyte.

The electrolyte is prepared by adding sulphuric acid to distilled water drops by drop and stirring it until the reasoned specific gravity is attained.

Every thing is placed in a container of hard rubber. The cells of a battery are connected by a cell connector. The container is leak proof.

## 12. What are the parts of a 48V DC charger?

*Main transformer:* This steps down the  $3\Phi$  415V supply to the require value of voltage.

*Synchronizing transformer for phase sequence:* This gives the synchronizing signal to the firing card. That is, the pulses from this card if fed to the firing card. The firing card gives pulses to the SCR of R or Y or B depending upon which phase is positive maximum.

*Half control module:* This has a diode and a SCR for each phase. The firing card controls the firing angle of SCR.

*Firing card:* This gives the firing pulses to SCR depending on phase sequence and the feed back from output.

*Controller card:* This card monitors the output and gives signal to firing card to conduct at certain angle to maintain constant output voltage.

*Power supply card:* This gives power supply for the controller card, firing card and protection.

13. Explain the operation of 48 V battery charger.

The supply for the charger is from MCC. The supply is tapped for power supply to control card, PF correction capacitor. LC filter is used for suppressing surge voltage. The main supply is stepped down and given to the half control rectifier module. The SCR conducts only when gate gets positive pulse. This pulse is given by pulse transformer, which gets pulses from firing card. Firing card gives pulse to the respective RYB SCR only when their phases are positive maximum. The freewheel diode is incorporated to protect the SCR and diodes from back emf when supply to coils is cut off due to collapsing magnetic field.

The filter is provided to smoothen the ripple output and the bleeder is used for voltage regulation. It gives improved voltage regulation and acts as a minimum load. Also it keeps the SCR in conducting state by drawing the minimum current which is higher than the SCR holding current. Thus there is always output voltage irrespective of load.

DC CT is used for limiting output current. It works on principle of magnetic amplifier. There is also provision for smooth rising of output voltage.

14. What is purpose of freewheeling diode and DC filter circuit in the charger?

*Freewheeling diode* is used to protect the semiconductor components used in the charger from the back emf, which is induced in the inductive coils of relays when the supply to the relays is cut off. The magnetic field in the relays collapses and induces high voltage in reverse direction. This emf is shunted by the freewheeling diode, which is connected in reverse bias with the output.

*DC filter* is used to smoothen the output, which has ripple. Ripple frequency is same as system frequency for half wave rectifier and 2 times of system frequency for full wave rectifier. The filter, which is a capacitor, will oppose any change in voltage. Thus the ripple will not be allowed to come to zero.

***Electrical equipment fundamental***

1. Why indoor switchyard is provided in MAPS?

The salt contamination in the switchyard is avoided by providing indoor switchyard in MAPS. Because the plant is just 300 metres away from the seashore and the atmosphere is saline. This salt will get deposited on the insulators and on the conductors used in the switchyard. Due to this deposition insulators may fail to unnecessary trip the system and conductor used must be copper for better performance instead of low cost aluminum. So to avoid unnecessary trip and to have low cost of installation and spare parts of aluminium indoor switchyard is used.

2. What do ABCB and ACB mean?

ABCB – Air blast circuit breaker.

ACB – Air circuit breaker.

3. What do you mean by frequency?

The number of cycles per second is called the frequency.

4. State the voltage and current relation in star and delta connection.

In star connection line current is equal to the phase current and line voltage is  $\sqrt{3}$  times that of phase voltage.

In delta connection line voltage is equal to the phase voltage and line current is  $\sqrt{3}$  times that of phase current.

5. In DC motor what is the relation between speed and field flux?

Speed of a DC motor is inversely proportional to the field flux.

6. What is the difference between self-excited and separately excited DC generator?

*Self-excited generator:* In a self-excited generator the field winding is excited by an external DC source like a battery etc.

*Separately excited generator:* In a separately excited generator the field poles have some residual magnetism. When the armature is rotated a small emf is induced in it. This is fed to the field winding and if the current direction is such that it adds the residual magnetic flux to the field winding and the field strength is increased. The more emf in the armature, which is again fed to the field winding and goes on till the generator builds up voltage.

***Power and control cables.***

1. Define conductor.

*Conductor:* A material of low resistance used to transmit electrical energy. Example wires, cables, bus bars etc.

2. Define unprotected insulated wire.

*Unprotected insulated wire:* Unprotected insulated wire is which the insulation of the wire is not covered by a protective sheathing to prevent it from mechanical damage.

3. Define cable.

*Cable:* One or more insulated conductor enclosed in a protective mechanical sheathing of either GI wire or GI strip or aluminium to protect the insulation from mechanical damage.

4. Define insulated wire.

*Insulated wire:* A conductor or multi-stranded conductor which has a insulating material on it is called a insulated wire.

5. Explain briefly about armouring for an under grounded cable.

Armouring is required to protect the cores from mechanical damage.

6. Explain briefly about grounding of cable trays.

Cable trays are grounded because to avoid any shocks to personnel incase of leakage. A grounding wire runs at the side of tray through a parallel groove clamp through out the length of the cable tray. If trays are one above another we can loop up the grounding wire to the tray below. This saves extra ground wire.

7. What are the differences between the power and control cable?

*Power cable:* It is used for supplying current to load. It is of larger current carrying capacity available in single core, 2 cores, 3 cores, 3 | cores, and 4 cores. Single core is available upto 1000 mm<sup>2</sup>. Usually power cables are of aluminium. These cables are graded for higher voltages and possess more cross section area.

*Control cable:* Control cables are used for control purposes for logics, indication or annunciation etc. These are of lower current carrying capacity and voltage grading is also less. These are of less cross sectional area are available in pairs of 2,5,10,25,50 etc.

8. What is the purpose of using corrosion inhibiting compound?

It is used for aluminium conductors while crimping to a lug or ferrule. It prevents corrosion of aluminium conductor due to oxidation and due to saline atmosphere.

9. Why aluminium armouring for single core 1000 mm<sup>2</sup> is used?

Aluminium armouring for single core 1000 mm<sup>2</sup> is used so that heating will not take place due to the flux around the conductor, as the aluminium is a non-magnetic material.



10. What is resistance of copper compare to the aluminium?

Copper is less resistive than aluminium.

11. What is applied over the steel tape armour of PILC cable as serving?

Bituminous covered jute.

12. What is used as insulation for PILC cable?

Impregnated paper.

13. A small quantity of impurity reduces how much of conductivity of copper?

35% of conductivity will be reduced due a small impurity in the conductor.

14. Why cast aluminium tri-foil clamp is used in single core cables laying?

When three conductors are clamped together the fluxes around the conductors are get cancelled

15. What are the parts of a cable gland?

- a. Check nut.
- b. Nipple.
- c. Metal washer.
- d. Neoprene rubber.
- e. Metal washer.
- f. Compression nut.

16. What are the advantages of PVC insulated cable?

- a. Plumbing is not required. Joints can be made easily.
- b. As PVC is light the injury caused to it while laying is less.
- c. It is corrosion resistant.
- d. It has high fire retarding property.
- e. It does not break down even if moisture enters.

***Basic electronics***

1. How many types of logic gates are there?
  - a. OR gate.
  - b. AND gate.
  - c. NAND gate.
  - d. NOR gate.
  - e. Inverter gate.
  - f. Exclusive OR gate.
  - g. Equivalent gate.

***Mechanical equipment fundamentals*****1. Why feed valves are used?**

Feed valves are used to prevent back flow.

**2. What are the functions of a heat exchanger?**

The function of heat exchanger is to transfer heat efficiently and economically between two fluids. Heat is transferred from the fluid, which has higher temperature to the fluid, which has lower temperature. The modes of heat transfer are,

- a. Conduction – Heat transfer in solids by momentum of molecules.
- b. Convection – Heat transfer in liquids by movement of molecules.
- c. Radiation – Heat transfer by energy waves.

There are three types of flow in heat exchangers

- a. Parallel flow.
- b. Counter flow.
- c. Transverse flow.

**3. Why baffle plates are used in heat exchanger?**

Baffle plates are used in heat exchanger so that the maximum heat can be transferred and to avoid tube sagging.

**4. How pumps are classified?**

- A. Centrifugal pumps –
  - a. Single volute
  - b. Double volute
  - c. Diffuser type
  - d. Mixed flow
  - e. Axial flow
  - f. Turbine or regenerative type
- B. Rotating pumps
  - a. Screw type
  - b. Gear type
  - c. Vane type
- C. Reciprocating pumps
  - a. Piston
  - b. Plunger
  - c. Bucket

**5. What you mean by cavitation and NPSH?**

**Cavitation:** Bubbles form in the liquids whenever there is pressure reduction inside the pump. These bubbles collapse when they approach high-pressure areas damaging pump internals. This is called the cavitation.

**NPSH:** Net Positive Suction Head. It is the head available at the eye of the impeller corrected to vapour pressure.

6. Name the functions of the valve?
  - a. ON and OFF service.
  - b. Throttling or regulating liquid flow.
  - c. Avoid back flow.
  - d. Regulating pressure.
  - e. Relieving pressure.
  
7. What are the advantages of butterfly valve?
  - a. Less holdup.
  - b. No support needed.
  - c. Any actuator can be used.
  - d. Quick opening and closing.
  - e. Less space required.
  - f. Used for low-pressure low temperature and large pipelines.

***Instrumentation fundamentals***

1. What are the classifications of industrial instrumentation?
  - a. Information gathering instrumentation.
  - b. Regulating instrumentation.
  - c. Protective instrumentation.
2. What are the units of pressure?  
Pounds / inch<sup>2</sup> and kg / cm<sup>2</sup>.
3. What is the use of BAROMETER?  
*Barometer* is used to measure atmospheric pressure.
4. What are the methods used to measure the flow?  
Mechanical (float) type and ultrasonic type methods are used to measure the flow.
5. What is the equivalent of atmospheric pressure?  
One atmospheric pressure is equal to 10 meters of water column or 760 mm of mercury.
6. What method is used to measure the level?  
Bubbler method is used to measure the level.
7. State some elements of pressure measurement.  
Manometer, Diaphragm gauges, Bellows, Strain gauges etc.
8. State some elements of flow measurement.  
Orifice, Venturi tubes, flowrator (rotameter) etc.
9. State some thermocouple.  
Copper – constantan, Iron – constantan.
10. What is the purpose of instruments?  
The purpose of instruments is to measure, safeguard the process for efficient plant operation.  
Instruments are very accurate and fast acting. This accuracy and speed is not possible by human. Also in some places there may be too much heat for man to work or some where there may high radiation field. In such cases instruments provide remote operation.
11. What is primary element and what should be its response?  
Primary element is one, which senses the condition of process, and converts it to some other form, which can be measured accurately. Example in a bourden gauge the pressure if changed to the uncoiling (displacement), which can be measured.

The response of primary element is that it should convert the condition in to some other form, which can be interpreted and measured easily.

12. Name some process variables, which are appropriate for our plant with examples.

Process variables with examples, which are appropriate to our plant, are

- a. Flow – flow of D<sub>2</sub>O in PHT system.
- b. Temperature – temperature of coolant in PHT system.
- c. Level – moderator level.
- d. Speed – speed of turbine.
- e. Voltage – voltage generated by main generator.
- f. Neutron flux – number of neutrons produced in reactor during operation.
- g. pH – pH of moderator.

13. What is use of 2/3 logic in our plant?

All our protection instruments (system) are triplicated to have following uses.

- a. To increase system integrity.
- b. To decrease faulty trips.
- c. Maintenance can be done on one protective instrument without shutting down the whole system.

We don't want our plant (reactor) to trip just because one instrument failed. So we have triplication (2/3 logics) in protection instruments. The trip signal will pass if only two out of three switches operate. Of only one operates there will be no trip. This logic is used to trip the reactor in our plant.

14. What is resistance temperature detector (RTD) and mention some examples?

Resistance temperature detector is an instrument, which is used to measure temperature. This uses the property that the resistance of a metal changes (increases or decreases) with temperature. This is very accurate. These will be a wire, which will sense the temperature and changes its resistance as the temperature changes. This varying in resistances is measured by an external electronic or electrical circuit calibrated to measure temperature.

Different types of RTD's are Platinum, copper, nickel.

15. What is recorder and how it is useful to our plant?

Recorder is an instrument, which gives instantaneous values as well as records the values.

Recorder can show us where a fault has occurred if reactor trips. It also gives us past information recorded in it. It saves human effort because an operator cannot sit and record the information required and it is a very difficult task to an operator.

***Fire fighting***

1. How combustion takes place?  
For combustion to take place three elements are needed. They are *fuel*, *heat* and *oxygen*. This is called the triangle fire. Combustion can not survive without these three. Remove any one of them, combustion ceases to take place. So wherever fuel, oxygen and heat is there together combustion takes place.
2. How many types of extinction media's are used in fire fighting?
  - a. Sand.
  - b. Water.
  - c. Foam.
  - d. Carbon – di – oxide.
  - e. Dry chemical powder.
  - f. Halons.
3. What are the classifications in fire?
  - a. Class A – Ordinary fire like burning of paper, wood etc.
  - b. Class B – Oil fire like burning of petrol, diesel, LPG etc.
  - c. Class C – Gas and dust fire like burning of butane, acetone, natural gas etc. and burning of dust like uranium dust, sodium dust etc.
  - d. Class D – Metal fire like burning of uranium, thorium, sodium etc.
  - e. Class E – electric fire example transformer or switchgear fire etc.
4. How many types of fire extinguishers are there and state their suitability?
  - a. Soda acid type – suitable for Class A type of fires.
  - b. Foam type – suitable for Class A and Class B type of fires.
  - c. Carbon-di-oxide type – suitable for Class B, Class C and for Class E type of fires.
  - d. Dry chemical powder – suitable for Class B, Class C, Class D and Class E fires.
  - e. Halons BCF (bromo chloro difluoro methane) – suitable for Class A, Class B, Class C and Class E types of fires.
5. At what areas of risk the CO<sub>2</sub> flooding system, mulsifyre systems are provided?  
CO<sub>2</sub> flooding system is provided in diesel generator and turbine oil tank area.  
Mulsifyre system is provided in generator transformer, start up transformer and unit transformer areas.
6. What are the equipments kept inside the hose boxes?
  - a. Double female adapter (1 No).
  - b. Delivery hose pipe (50 feet – 2 Nos).
  - c. Branch pipe (1 No).
  - d. Valve wheel (1 No).
  - e. A hose box key (situated in a cabinet at side of hose box).



7. How water is used in a fire?

Water is used as a cooling effect in a fire.

8. How foam is used in a fire?

Foam is used as a blanketing effect in a fire.

9. Which extinguisher you use for electronic equipment fire?

Co<sub>2</sub> or DCP type fire extinguisher can be used on fire involving electronic equipments.

10. What you mean by starvation method?

Starvation method means elimination of fuel from the fire.

11. What is the name of powder used in Dry Chemical Powder extinguisher?

Sodium-bi-carbonate.

12. What you mean by cooling method?

Cooling method means elimination of heat from the fire.

13. What you mean by blanketing method?

Blanketing method means elimination of oxygen from the fire.

14. Why Co<sub>2</sub> is used on Class E fire?

Co<sub>2</sub> is a non-conductor of electricity.

***First aid***

1. What is the golden rule of first aid?  
Do first thing first, artificial respiration, stop bleeding and treat shock. Do not attempt too much, reassurance, avoid crowing and transfer.
2. What do you mean by diagnosis?  
Determining the nature and course of a disease.
3. For a bleeding what is the first aid?  
Take care to stop the bleeding by giving pressure.
4. What is the first aid for bone injury?  
Support the injured part and painkillers.
5. What is the first aid for burn cases?  
Water, warm fluids should be given when the victim is conscious.
6. How we can differentiate the bleeding from artery and vein?  
By the colour of the blood which is bleeding.
7. What is the first aid for chlorine inhaled victims?  
Remove the victim from the source, fresh air and artificial respiration if necessary.
8. What is the first aid for dog bite?  
Suck the wound and spit out.
9. What is the first aid for snakebite?  
Bath the wound and constrictive bandage. Give warm drinks and rest to the patient and artificial breathing if necessary.

***D<sub>2</sub>O handling***

1. What is the instrument name used for accurate measurement of IP?  
Infra red spectro photometer.
2. How D<sub>2</sub>O vapour is recovered?  
Dryer recovers D<sub>2</sub>O vapour.
3. What is the amount of D<sub>2</sub>O used in moderator?  
140 tonnes.
4. Name the heavy water plants in India.
  - a. Nangal.
  - b. Kota.
  - c. Baroda.
  - d. Tuticorn.
  - e. Talcher.
  - f. Thal (under construction).
  - g. Hazira (under construction).
  - h. Malugum (under construction).
5. Define reactor grade and down graded D<sub>2</sub>O.  
*Reactor grade D<sub>2</sub>O*: If the isotopic purity of a given D<sub>2</sub>O is more than or equal to 99.7% then the D<sub>2</sub>O is reactor grade D<sub>2</sub>O.  
*Down grade D<sub>2</sub>O*: If the isotopic purity of a given D<sub>2</sub>O is less than 99.7% then the D<sub>2</sub>O is downgraded.
6. What precautions should be taken while working in high tritium areas?  
Use respirators, plastic suits, VP suits if concentration of tritium is very high. Avoid getting hurt while working because tritium may go through the skin by sweat to the blood. If by chance there is tritium intake in the body drink lots of fluids.
7. Why spillage of D<sub>2</sub>O is to be avoided?  
*Cost consideration*: D<sub>2</sub>O very costly and very valuable. Cleaning of spillage also cost and extra manpower to be deployed.  
*Tritium hazard*: D<sub>2</sub>O contains tritium, which when spilled becomes tritiated vapour and finds access through human body. Tritium is a radioactive material. It is a beta emitter.
8. What is ice plugging?  
If there is a need to repair a valve of D<sub>2</sub>O PHT system, there are no other valves to shut of D<sub>2</sub>O. So we use plastic bags on pipes and it has dry ice. Then liquid nitrogen is poured inside the bag. Due to the low temperature the D<sub>2</sub>O inside pipeline solidifies preventing any flow of D<sub>2</sub>O when valve is removed. This is called the ice plugging.



9. Name the methods by which  $D_2O$  leak can be detected.
- By beetles.
  - $D_2O$  losses through stack monitoring.
  - Tritium monitoring.
  - In heat exchangers the leakage can be found by taking samples of process water from all heat exchanges and counting the tritium activity.
10. Name the  $D_2O$  recovery methods.
- Manual mopping and vacuum cleaning.
  - Active drainage recovery.
  - Vacuum mopping recovery.
  - Dryers recovery.
  - Vapour recovery.
11. Name the features for reducing  $D_2O$  leaks.
- Reduce valves and fittings in the pipelines.
  - Use welded joints instead of flanged joint.

***Nuclear reactor theory***

1. State the law of conservation of mass and energy.

Mass and energy are interchangeable. When mass is lost there is a substantial gain in energy and when energy is lost there is a increase in mass.

$$\text{Energy} = \text{mass} * C^2$$

$$E = MC^2$$

Where C is the conversion factor =  $3 * 10^{10}$  (velocity of light)

$$C^2 = 9 * 10^{20}$$

2. Which of the following material is good moderator? Why?

a.  $H_2$     b.  $D_2$     c.  $H_2O$     d.  $D_2O$     e. Beryllium    f. Graphite.

The functions of a good moderator are

- It has to thermalise neutrons effectively.
- There should be only a minimum absorption of neutrons.
- It should not be toxic.
- It should not be inflammable.

In case of Hydrogen ( $H_2$ ) though it is a effective sheatherer it cannot be used as a moderator because it is a gas and there is a lot of distance between atoms. A neutron cannot meet the nucleus in a definite manner.

For  $D_2$  also the same problem as this is also gas and it cannot be used as a moderator.

In case of  $H_2O$  it is a good scatterer but is absorbs neutrons. Its moderation ratio is 72. So it cannot be used as a moderator.

In case of  $D_2O$  though it is not as effective scatterer as that of  $H_2O$  it has minimum absorption of neutrons. It has a moderating ratio of 21000. This is an ideal moderator.

In case of Beryllium it is a toxic material. Therefore cannot be used.

Graphite absorbs neutrons and is inflammable and therefore cannot be used.

So from the above statements the  $D_2O$  is the good moderator material.

3. The activity of an Iodine – 131 is 10 curies. After how many half-lives will it come down to 625 millicuries?

Activity of an Iodine – 131 = 10 curies

To find number of half-lives for coming it to 625 millicuries,

$$10 * \frac{1}{2} = 5 \quad (1^{st} \text{ half-life})$$

$$5 * \frac{1}{2} = 2.5 \quad (2^{nd} \text{ half-life})$$

$$2.5 * \frac{1}{2} = 1.25 \quad (3^{rd} \text{ half-life})$$

$$1.25 * \frac{1}{2} = 0.625 \quad (4^{th} \text{ half-life})$$

So during 4<sup>th</sup> half-life the Iodine – 131 reduces to 625 millicuries.





4. What do Atomic number and mixture mean?

*Atomic number:* The atomic number of an atom is the number of protons in that atom.

Example – Hydrogen has one proton and its atomic number is one (1).

– Uranium has 92 protons and its atomic number is 92.

*Mixture:* It is a substance formed by different elements and these elements can be separated by physical methods.

Example – Air is a mixture of oxygen and nitrogen and these can be separated by physical methods.

5. What is the weight of a proton?

1.00759 amu (atomic mass unit)

6. What is the energy of a thermal neutron?

0.025 eV (energy volt)

7. What is the charge of an alpha particle?

2+.

***Nuclear system***

1. What is the purpose of moderator D<sub>2</sub>O?  
The purposes of moderator D<sub>2</sub>O are,
  - a. To thermalise neutrons to maintain criticality.
  - b. Emergency core cooling when PHT fails.
  - c. Structural cooling.
2. What is the cooling water used in moderator heat exchanger during normal operation? And during class IV failure?  
During normal operation process LP water is used in moderator heat exchangers, which transfers heat to seawater. During class IV failure firewater is used for the moderator heat exchanger.
3. During loca how the cooling of fuel bundle is achieved?  
During loca there is provision for taking D<sub>2</sub>O from the moderator system, which is connected to PHT system for fuel cooling and there is one more option for the cooling of the fuel from the fire water system.
4. How coolant flow is maintained in the event of loss of power to the PHT system?  
When the PHT power fails, it takes two minutes for DG to come to full power. The circulation is maintained by flywheel, which increases the de-acceleration and maintains the flow for two minutes.  
If there is a station blackout the flow is maintained by thermo-symphoning by which more denser cold water comes down and less denser hot water goes up by convection method.
5. What are the materials in contact with PHT system?  
Piping – carbon steel.  
Pressure tubes – zircalloy-2  
Fuel cladding – zircalloy-2  
End shield – stainless steel. Etc.
6. What are the main features of PHT system?
  - a. Impeller – To reduce the water flow.
  - b. Self-injection Hx – Cools the water in case of leakage.
  - c. Gland supply – Cools the seals.
  - d. Primary and secondary seals – sealing the pump.
  - e. Thrust bearing – To take the axial thrust.
7. What are the purposes of bleed condenser?  
The purposes of bleed condenser are,
  - a. To cool the bleed water, which goes to bleed cooler.

- b. To provide cool hot water to the PHT purification system.

8. What is header level control?

For the purpose of maintenance of PHT pipe valves, boiler inlet valve the level of the coolant should be below the valve to prevent the coolant coming out of the system. This is called the header level control and achieved by means of manual operation of valves and shutdown cooling pump.

9. In MAPS Unit # 1 end-shield cooling system has got heaters. Why?

Unit # 1 end-shield is made of nickel steel, which had a nil ductility temperature of  $-100^{\circ}\text{C}$  while commissioning. After 30 years of operation this will rise to  $+32^{\circ}\text{C}$ , because of radiation exposure. To avoid the failure of end shield of MAPS Unit # 1 the temperature of the end-shield should be maintained at  $68^{\circ}\text{C}$  always. MAPS 1 end-shield cooling system is operating at elevated temperature. But in MAPS Unit #2 this problem is not existed because in this unit end-shields are made up of stainless steel.

***Reactor general***

1. What are V1 and V2? How they are connected? What is the harm in opening F/M vault door during reactor operation?

The reactor building is divided into two areas. They are V1 and V2.

V1 – Dry volume area.

V2 – Wet volume area.

V1 area includes F/M vault, boiler room, and entire dome area. Rest of the areas in the reactor building is V2 area. V1 and V2 are connected by vent shaft through suppression pool.

F/M vault is a V1 area and F/M maintenance bay is a V2 area. Usually when there is an accident in F/M vault the pressure is relieved through boiler room through suppression pool and the uncondensed gases to V2 area. When the reactor is in operation and if we open the F/M vault door, suppose of there is an accident in F/M vault the pressure released directly goes to F/M maintenance area, which is a V2 area. Thus pressurizing the entire building.

2. What is the purpose of inlet manifold inside calandria? What is the material used for that?

The purpose of inlet manifold is to introduce heavy water to the calandria with low velocity to avoid mixing. That is stratified flow of D<sub>2</sub>O is obtained b inlet manifold. Thus the temperature is kept minimum. It is made of zircalloy.

3. Why bi-directional flow is chosen for PHT system?

Bi-directional flow is chosen for PHT system because,

- Uniform temperature gradient is facilitated so there will be no differential thermal expansion.
- It facilitates fuelling even when the reactor is working, which facilitates uniform neutron flux and this intern gives rise to maximum fuel burns up.

4. What is the purpose of end-shield?

The purposes of end-shield are,

- To permit access to F/M vault during shut down.
- To provide tight clamping for fuelling machines.
- To support the calandria tubes and also system.

***Station grounding***

1. What is grounding?  
It is an electrical connection with the general mass of earth through an earth electrode.
2. What is difference between earthing and grounding?  
Both have same meaning. The term earthing is used in U.K. and grounding in U.S.A. ground means earth.
3. What are types of grounding?  
There are two types
  - a. System grounding.
  - b. Equipment grounding.
4. What does mean by system?  
Grounding of neutral point of equipment is called system grounding. For instance grounding of generator neutral, transformer neutral etc.
5. What does mean by equipment grounding?  
Grounding of non-current carrying metallic parts is called equipment grounding. For instance no-current carrying parts include the following:
  - a. Motor body, switchgear metal enclosure, transformer tank, conduits of wiring etc.
  - b. Support structures, tower, poles etc. in the neighborhood of electrical circuits.
  - c. Sheath of cables.
  - d. Body of portable equipment such as iron, oven, etc.
6. What is the important of system grounding?  
It is important because:
  - a. Earth fault protection is based on the method of neutral earthing.
  - b. System voltage during earth fault depends on neutral earthing.
  - c. It is a protection against arcing grounds, unbalanced voltages with respect to earth and lighting.
7. What is the important of equipment grounding?  
Equipment earthing ensures safety.
8. How safety could be ensured by equipment grounding?  
In order to enumerate this, let us first find out the effects of current and voltage developed during fault condition.

9. What is the permissible body current limit?

The magnitude and duration of current conducted through a human body at 50 Hz should be less than those that cause ventricular fibrillation.

(Ventricular fibrillation is considered to be the main cause of death due to electrical shock). These below given data are also applicable for current limits to human body.

| Current magnitude | Physiological effect               | Description                                                                                                                                       |
|-------------------|------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 mA              | Threshold of perception            | A current at which a person is just able to detect a slight tingling in his hand or finger                                                        |
| 1 – 6 mA          | Unpleasant to sustain              | This is often termed as let go currents. Do not impair the ability of a person holding an energised object to control his muscles and release it. |
| 6 – 9 mA          | Threshold of muscular contraction. | These are threshold values, since 10.5 mA current and 16 mA current are the let go values for women and man respectively.                         |
| 9 – 25 mA         | Muscular contraction               | May be painful and can make it hard or impossible to release energised objects grasped by the hand.                                               |
| 25 – 60 mA        | Muscular contraction               | Make breathing difficult.                                                                                                                         |
| 60 – 100 mA       | Ventricular fibrillation           | Ventricular fibrillation, stoppage of heart or inhibition of respiration might occur and cause injury or death if time is more than 1 sec.        |

Hence the grounding equipment shock current can be kept below the value sufficient to cause injury or death by lowering the step and touch potential.

## 10. How fibrillation current functions?

Fibrillation current is actually function of individual body weight.

For 50 kgs body weight: fibrillation current (IB) =  $0.116/\sqrt{ts}$  (Limited to 0.03 – 3 sec. Range)

Where ts = duration of current exposure in sec.

Note = Above equation results = 116 mA for 1 sec. and 367 mA for 100 sec.

For 70 kgs body weight: fibrillation current (IB) =  $0.157/\sqrt{ts}$

Note = Above equation results = 157 mA for 1 sec. and 496 mA for 100 sec.

Above times are very - very important from the point view of clearing the fault. Above limit dictates that grounding should be such that current magnitude through human body should not increase the specified values.

In order to ensure above following have been done.

1. Current conductor have been buried in ground
  - a. At the depth of 600 mm in switchyard. Depth 600 mm is normally selected because of freezing or drying out, the Resistivity of upper layers could vary with seasons, while the Resistivity of lower soil layers remains nearly constant.
  - b. Horizontal grid conductors are more effective in reducing the danger of high step and touch voltages on the earth surface by creating equipotential surface during fault conditions.
  - c. At the depth of 800 mm else where. Here depth is kept more because to care for under grounding services. Example laying of power cables, drainage etc.
2. 25-mm dia copper rod electrodes have been driven in soil.
  - a. Upto 5 meters depth in 220 kV switchyard.
  - b. Upto 3 meters elsewhere.

Why only 5 meters and 3 meters depths have been selected is that the resistance is diminishes rapidly with the first few feet of driving, but less so at depths greater than 2 to 3 meters in soil of uniform resistivity.

These lengths are adopted in selecting the ground electrodes.
3. 4-inch layer of gravel in 220 kV switchyard has been used. Purpose of using gravel is by doing steps 1,2 above touch and step potential are computed and compared with tolerable potential and found as given below.

| Potential                                     | Computed value | Tolerable value |
|-----------------------------------------------|----------------|-----------------|
| Tough                                         | 550 V          | 665V            |
| Step 2.a switchyard with crushed rock surface | 230V           | 2165 V          |
| Step 2.b elsewhere with natural soil          | 166V           | 168.5 V         |



### 11. Why grounding is necessary?

The purpose of grounding is to maintain the surface under and around a station at as nearly zero potential as possible with reference to absolute earth so that operating staff who walk in the station yard and touch equipments are at earth potential and when faults occur there is safety to staff and equipments.

### 12. What are the harms of under grounded system?

- a. Step and touch potential will increase more than maximum tolerable value.
- b. Under single line to ground fault the voltage to earth of the two healthy phases rises from their normal phase to neutral voltage to full line voltage, which may result in insulation break down.
- c. The capacitive current in two healthy phases increases  $\sqrt{3}$  times the normal value.
- d. The capacitive current in the faulty phase is 3 times its normal value.
- e. Experience shows that capacitive current in excess of 4 amps may be sufficient to maintain an arc in the ionized path of the fault and this persistent arc phenomenon is called ARCING GROUND, which ultimately causes high voltage build up. Some time this voltage builds up to 5 to 6 times its normal value, which results in break down of insulation.
- f. Being fault current low, it is difficult to isolate fault.

### 13. How system grounding and equipment grounding achieved?

System grounding is obtained by grounding the neutral through resistance, through transformer and through effective or solidly grounding.

Equipment grounding is obtained by Grounding of non-current carrying metallic parts equipment. For instance non-current carrying parts include the following:

- a. Motor body, switchgear metal enclosure, transformer tank, conduits of wiring etc.
- b. Support structures, tower, poles etc. in the neighborhood of electrical circuits.
- c. Sheath of cables.
- d. Body of portable equipment such as iron, oven, etc.

### 14. What does mean by grounding electrode, grounding system, and grounding resistance?

*Grounding electrode:* A conductor driven in the earth and used for collecting ground current from or dissipating ground current into the earth.

*Grounding system:* Comprises all interconnected grounding facilities in a specific area.

*Grounding resistance:* The resistance offered by the ground when power frequency current is discharged to the ground through a particular grounding electrode or grounding system.

15. How grounding resistance could be measured?

There are few methods, which can give approximately true value. These are described below.

- a. *Fall of potential method*: This method is applicable for small grid or sub station where induction effect of voltage is less.
- b. *Measurement of earth resistance by 61.8% distance rule*:
- c. *Alternate – 1 of fall of potential method*: This method is influenced by induction effect.
- d. *Alternate – 2 of fall of potential method*:

16. How value of grounding resistance could be kept constant?

While measuring of grounding resistance is more than computed design value  $0.11\Omega$ , then following are recommended to reduce it. Add in water the following highly conductive substances and pour into treated pit.

- a. Sodium chloride (NaCl), known as common salt.
- b. Calcium chloride ( $\text{Ca Cl}_2$ )
- c. Sodium carbonate ( $\text{Na}_2 \text{CO}_3$ )
- d. Copper sulphate ( $\text{Cu SO}_4$ )
- e. Soft choke and
- f. Salt and charcoal in suitable proportions.

17. What is the effect of moisture content on earth resistivity?

The moisture content is expressed in percent by weight of dry soil. Dry earth weights about 1440 kg per cubic meter and thus 10% moisture content is equivalent to 144 kg of water per cubic meter of dry soil. So about 20% moisture, the resistivity is very little affected. Below 20%, the resistivity increases very abruptly with the decrease in moisture.

18. What is the effect of salt content in moisture on resistivity?

The resistivity decreases and the salt content is expressed in percent by weight of the contained moisture. It will be noted that the curve flattens off at about 5% salt content and a further increase in salt content gives little decrease in the soil resistivity.

19. What is the effect of temperature on earth resistivity?

The temperature co-efficient of resistivity for soil is negative, but it is negligible for temperature above freezing point. Below  $0^\circ\text{C}$  the water in the soil begins to freeze and introduces a tremendous increase in the temperature co-efficient, so that as the temperature becomes lower the resistivity rises enormously.

20. What does mean by neutral floating or neutral displacement?

When a ground fault occurs, there is a tendency of neutral shift with consequent change in voltage on the un-faulted phases. This phenomenon is called neutral floating or neutral displacement.

21. Why grounding of power cable is needed? How it should be done?

- a. The magnetic fluxes produced by the three phases in a multi core power cable almost cancel out each other, since the vector sum of these currents at any instant is zero and practically there is no residual magnetic flux around the cable. In case of single core cable, the magnetic flux induces the voltage in the metallic sheath.
- b. When the cable conductor is carrying alternating current, for safe and reliable operation, the metallic sheath must be grounded. If the metallic sheath is at one end the potential of the unearthed end could be much above the earth potential. If both ends are grounded, a circulating current is induced in the metallic sheath.
- c. The maximum acceptable induced voltage under normal load current operation is limited by *corrosion* and *safety considerations*.
- d. Code of practice of earthing (IS 3043) as well as electricity council London recommended permissible induced voltage level of *65 Volts*.

Hence keeping above all points in mind metallic sheath and armour of all multi core power cables shall be earthed at both end equipment and switchgear end. Sheath and armour of single core power cable shall be earthed at switchgear end only. The sheaths of shielded control cables should be grounded at both ends to eliminate induced potentials.

22. In 220 kV switchyard why lightning arrestor should be properly grounded?

- a. During lightning, surges should be discharged to ground, otherwise it will puncture the equipment insulation and it is possible only when lightning arrestor is grounded properly.
- b. In order to make it effective, the ground terminal of lightning arrestor should be connected direct to the tank of transformer. This will eliminate voltage build up due to earth resistance. For example for each ohm of earth resistance the voltage build up for 5000 Amps discharge current is 5 kV. Soil resistivity should be minimum and may be it is 3.5 ohm per meter.

23. Why grounding mat is important near ground switch operating handle and disconnecting switch operating handle?

Equipment operating handles deserve special attention because of the higher probability for co-incidence of adverse factors. For example,

- a. Hand operation equipment such as grounding switches and disconnecting switches requires the presence of operator near a grounded structure at a point where opening of an energised circuit can some times result in an arc to the structure or perhaps mechanical failure and electrical break down of a switch insulator. A large percentage of fatal accidents from voltage gradients are in fact associated with operating handles. Hence in order to avoid above problems following should be an additional safety factors:

1. Use closer mesh in the vicinity of operating handle area (150-mm approx.) and operating handle shall be directly connected to the earthing mat.
2. Use higher resistance surfacing such as crushed rock or both in order to bring down the values of touch potential and step potential.

**24. Why fences grounding are important?**

Because the most dangerous touch contacts involves and outside the fence are usually accessible to the general public. In order to minimise the effect of step potential and touch potential following two philosophies could be adopted.

- a. Inclusion of the fence within the ground grid area and
- b. Placement of fence outside the ground grid area – not safe to use.

With this effective area is increased and reduces ground grid resistance substantially and maximum ground – grid voltage rise as well. In this case the perimeter conductor of grid normally either follow the fence line, or parallel to it at a short distance about 0.5 m – 1.5 m outside. In either case, the perimeter ground conductor and fence are bonded electrically at frequent intervals.

**25. What are the specifications for procurement of grounding conductor and grounding rods?**

Grounding conductor, pad, rods etc. should have following specifications:

- a. Copper : 91.8 to 94.9%
- b. Zinc : 2.0 to 3.0%
- c. Tin : 0.8 to 1.5%
- d. Lead : 2.0 to 2.5%
- e. Iron : 0.5 to 1.0%

Impurities must be limited to the percentage specified below:

- a. Nickel : 0.3% maximum.
- b. Antimony : 0.3% maximum.
- c. Manganese : 0.04% maximum.
- d. Phosphorous : 0.04% maximum.

**26. Why copper is only preferred as material for grounding?**

An advantage of use of copper is in addition to their high conductivity, has the advantage of being resistant to underground corrosion. Copper is cathodic with respect to other metals that are likely to be buried in the vicinity.

Disadvantages of use of copper are,

- a. Grid of copper forms a galvanic cell with buried steel structures, pipes and any of the lead based alloys that might be present in cable sheaths, it is likely to hasten the corrosion of the latter.
- b. Use of tinned copper conductor accelerates and concentrates the natural corrosion of metal in small area however cell potential with respect to steel and zinc reduces by about 50% and practically eliminates this potential with respect to lead.

**27. What should be the frequency of measurement of earth resistivity?**

As per IS: 3043, 1987, measurement of earth resistivity should be carried out annually or biannually and value should be recorded.

**28. What should the statutory provision of earthing?**

- a. Earthing shall generally be carried out in accordance with the requirement of India electricity rule 1956, as amended from time to time and the relevant regulations of the electricity supply authority concerned.
- b. All medium voltage equipment shall be earthed by two separate and distinct connections with earth. In the case of high and extra high voltages, the neutral points shall be earthed by not less than two separate and distinct connections with earth, each having its own electrodes at the generating station or substation and may be earthed at any other point provided no interference is caused by such earthing. If necessary, the neutral may be earthed through suitable impedance.
- c. As far as possible all earth connections shall be visible for inspection.
- d. All connections shall be carefully made. If they are poorly made or inadequate for the purpose for which they are intended, loss of life or serious personal injury may result.
- e. Each earth system shall be so devised that the testing of individual earth electrode is possible. It is recommended that the value of any earth system resistance shall be such as to confirm with the degree of shock protection desired.
- f. It is recommended that a drawing showing the main earth connection and earth electrodes be prepared for each installation.
- g. No addition to the current carrying system, either temporary or permanent shall be made which will increase the maximum available earth fault or its duration until it has been ascertained that the existing arrangement of earth electrodes, earth bus-bar etc. are capable of carrying the new value of earth fault current which may be obtained by this addition.
- h. No cut-out link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and the live conductors, shall be inserted on any supply system. This however, does not include the case of a switch for use in controlling a generator or a transformer or a link for test purposes.
- i. All materials fittings, etc. used in earthing shall conform to Indian standard specifications, wherever these exist.

**29. What maintenance of earth electrodes should be done?**

The neighbouring soil to the earth electrode shall be kept moist where necessary, by periodically pouring water through a pipe where fitted along with it or by pouring water in the immediate vicinity of the earth electrode.

Periodical visual inspection of all earth electrodes connection wherever available, shall be carried out to ensure their rigidity and other signs of deterioration.

30. In case new installation is to be done, what basic guidelines should be followed for grounding?

- a. Earthing conductors in outdoor areas shall be buried 500 mm below finished grade level unless stated otherwise.
- b. Minimum 6000 mm spacing between rod pipe electrode shall be provided unless stipulated otherwise.
- c. Earthing conductor around the building shall be buried in earth at a minimum distance of 1500 mm from the outer boundary of building.
- d. Earthing conductors embedded in the concrete floor of the building shall have approximately 100-mm concrete cover.
- e. Earthing conductors along their run on columns, beams, walls etc. shall be supported by suitable cleats at intervals of 750 mm.
- f. Earthing conductors crossing the road shall be either installed in hume pipes or laid at greater depth to suit the site conditions.
- g. Whenever earthing conductors cross underground service ducts, pipes, trenches, under ground service ducts, pipes, trenches, tunnels, railway track etc. it shall be laid 800 mm below them.
- h. Earthing conductor shall be buried 1000 mm outside the switchyard fence. Every alternate post of the fence and gates shall be connected to earthing loop by one lead.
- i. Each earthing lead from the neutral of the power transformer shall be directly connected to a rod or pipe or plate electrode treated earth pit, which in turn shall be connected to station earthing.

31. How much resistance human body has?

- |                                                          |                          |
|----------------------------------------------------------|--------------------------|
| Resistance of internal body tissues (Not including skin) | : 300 $\Omega$ .         |
| Resistance of body including skin                        | : 500 to 3000 $\Omega$ . |

32. What is the effect of voltage frequency and current on resistance of the human body?

- a. For touch voltages upto approximately 50V the value of impedance of the skin varies widely with surface area of contact, temperature, respiration etc. even for one person.
- b. For higher touch voltages in order of approximately 50V to 100V the skin impedance decreases considerably and becomes negligible when the skin breaks down.
- c. Wet hand contact resistance becomes very low at any voltage.
- d. With increase in frequency, impedance of skin decreases.



**33. What are the paths of current through the body?**

A value of  $1000\ \Omega$  is selected for the calculations that follows as representing the resistance of a human body from hand to both feet and also from hand to hand or from one foot to other foot.

Above paths includes vital organs such as heart.

- a. Path from hand to foot is much more dangerous than foot to foot, since current flow through heart during foot to foot current flow will be much less than the current flow from hand to foot approximate ratio is 25:1
- b. However deaths have occurred during foot to foot current flow. Hence can not be ignored.

**34. What are the effects of re-closure shock?**

During re-closure, when fault is persisting a person might be subjected to the first shock which would not permanently injure him, but would upset and disturb him temporarily.

Next, a single fast automatic re-closure could in a second shock initiated within less than 500 ms from the start of first. It is this second shock, occurring after a relatively short interval of time before the person has recovered, that might cause a serious accident. With manual re-closure the possibility of exposure to a second shock is reduced since the time interval may be substantially greater.

**35. State DC/AC equivalent factor (K).**

Ratio of direct current (DC) to its equivalent rms value of alternating current (AC) having the same probability of inducing ventricular fibrillation.

$K = I_{\text{DC fibrillation}} / I_{\text{AC fibrillation (rms)}}$

$K = 3000\ \text{mA} / 100\ \text{mA}$

$K = 30$

Threshold of let-go is unlike AC there is no definable threshold of let-go for DC for current magnitude below approximately 300 mA. Only the making and breaking of current leads to painful and cramp like contractions of muscles.

Above approximately 300 mA, let-go may be impossible or only possible after several seconds or minutes of shock duration. Below approximately 300 mA a sensation of warmth is felt in the extremities during the flow of current. Above 300 mA unconsciousness frequently occurs.

**36. Why AC is more dangerous than DC?**

Because the excitatory action of current (stimulation of nerves and muscle, induction of cardiac atrial or ventricular fibrillation) are linked to the changes of current magnitude especially when making and breaking of the current. To produce the same excitatory effects the magnitude of direct current flow of constant strength is 2 to 4 times greater than that of alternating current.

***Transformer oil tests***

## 1. What are the characteristics of transformer oil?

| Characteristics                                                                                        | Requirement                                                                            | Method of testing                                                                     | Remarks                                                                                               |
|--------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|
| Appearance                                                                                             | The oil shall be clear and transparent and free from suspended matter of sediments     | A representative sample of the oil shall be examined in a 100-mm thick layer at 27°C. |                                                                                                       |
| Density at 29.5°C max.                                                                                 | 0.89 gm / cm <sup>3</sup>                                                              | IS-1448(P:16):1977                                                                    | See note 1                                                                                            |
| Kinematic viscosity max. at<br>a. 27°C<br>b. 40°C                                                      | 27 cSt<br>under consideration                                                          | IS-1448(P:25):1976                                                                    |                                                                                                       |
| Interfacial tension at 27°C minimum                                                                    | 0.04 N/m                                                                               | IS- 6104:1971                                                                         |                                                                                                       |
| Flash point pensky-marten (closed) minimum                                                             | 140°C                                                                                  | IS-1448(P:21):1970                                                                    |                                                                                                       |
| Pour point max.                                                                                        | -6°C                                                                                   | IS-1448(P:10):1970                                                                    |                                                                                                       |
| Neutralization value<br>a. Total acidity max<br>b. Inorganic acidity/alkalinity                        | 0.03 mg KOH/g<br>nil                                                                   | IS-1448(P:2):1967<br>IS-1448(P:2):1967                                                | Alcoholic potassium hydroxide solution of 0.02 N should be in place of 0.1 N indicated in test method |
| Corrosive sulphur                                                                                      | Non-corrosive                                                                          |                                                                                       |                                                                                                       |
| Electric strength (Breakdown voltage)<br>a. New unfiltered oil minimum.<br>b. After filtration minimum | 30 kV (rms)<br><br>If the above value is not attained the oil shall be filtered 60 kV. | IS-6792:1972                                                                          | See note 2                                                                                            |
| Dielectric dissipation factor (tan $\delta$ ) at 90°C max.                                             | 0.002                                                                                  | IS-6262:1971                                                                          | See note 2                                                                                            |

|                                                                                                                                                                                                                                 |                                                                                                         |                                                                                            |            |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|------------|
| Specific resistance (resistivity)<br>a. At 90°C min.<br>b. At 27°C min.                                                                                                                                                         | 35 * 10 <sup>12</sup> Ω-cm<br>1500* 10 <sup>12</sup> Ω-cm                                               | IS-6103:1971                                                                               | See note 2 |
| Oxidation stability<br>a. Neutralization value after oxidation max.<br>b. Total sludge, after oxidation max.                                                                                                                    | 0.4 mg KOH/g<br>0.1% by weight.                                                                         |                                                                                            |            |
| Ageing characteristics after accelerated ageing (open beaker method with copper catalyst)<br>a. Specific resistance at 27°C minimum & at 90°C minimum.<br>b. Tan δ at 90°C max.<br>c. Total acidity max<br>d. Total sludge max. | 2.5 * 10 <sup>12</sup> Ω-cm<br>0.2 * 10 <sup>12</sup> Ω-cm<br>0.20<br>0.05 mg KOH/g<br>0.05% by weight. | IS-12177:1987<br><br>IS-6103:1971<br><br>IS-6262:1971<br><br>IS-1448(P:2):1967<br>IS-12177 |            |
| Presence oxidation inhibitor                                                                                                                                                                                                    | The oil shall contain antioxidant additives                                                             | IS-13631:1992                                                                              | See note 3 |
| Water content max.                                                                                                                                                                                                              | 50 ppm                                                                                                  | IS-13567:1992                                                                              |            |
| SK value                                                                                                                                                                                                                        | Under consideration                                                                                     |                                                                                            |            |

*Notes:*

- Density of the oil may be measured at ambient temperature and converted to 29.5°C using the following equation.  

$$29.5\rho = \rho_t \{1 + X(t - 29.5)\}$$
Where t = Ambient temperature (in °C)  
 $\rho_t$  = Density measured at temperature t  
X = Correction factor (Equal to  $65 * 10^{-5}$ ).
- As a consequence of the tendency for water absorption to occur due to breathing on storage even when drums are sealed the oil shall be filtered to remove moisture and particulate contaminants present in the original sample before the test as follows.
  - A sufficient quantity of oil is heated to  $90 \pm 2^\circ\text{C}$ , then filtered hot under vacuum corresponding to an absolute pressure of about 2.5 kPa through a sintered glass filter of porosity grade 4'.

- b. A portion of filtered is cooled in a desiccator and used immediately to measure electric strength, if required, and specific resistance at 27°C. The remaining hot filtrate is immediately used for measuring dielectric dissipation factor at 90°C and specific resistance at 90°C.
3. For both phenol and amine types of indicators, qualitative methods shall be adopted. In case of ambiguity (marginal cases) in finding the intensity of colour, a quantitative method shall be adopted. Value of 0.5 (max.) shall be treated as absence of DBPC-Phenolic type inhibitor (quantitative method for amine is under consideration).

## 2. What are the permissible limits for the transformer oil?

| Test required                                                   | Equipment voltage             | Permissible limits                | Importance                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-----------------------------------------------------------------|-------------------------------|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Electric strength (breakdown voltage) min.                      | Above 145 kV<br>145 – 72.5 kV | 50 kV<br>40 kV<br>30 kV           | The electric strength does not give a true indication of the deteriorated condition of the oil. An oil which is significantly oxidised under high temperature may show a high dielectric strength in the absence of moisture. The presence of oil deterioration particles, water and foreign contaminants results in general overall reduction in the efficiency of the equipment. A normal method of oil filtration and dehydration only maintain the electric strength but does not improve the deteriorated oil. It is therefore not advisable to rely solely on the electric strength of the oil by periodic tests without verifying its other characteristics. |
| Water content (max.)                                            | Above 145 kV<br>Below 145 kV  | 25 PPM<br>35 PPM                  | The presence of water in oils is harmful as it lowers the electric strength and resistivity. And it reacts with solid insulating materials particularly paper.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Dielectric dissipation factor (Tan $\delta$ delta) at 90°C max. | Above 145 kV<br>Below 145 kV  | 0.2 max.<br>1.0 max.              | This characteristic is very sensitive to the presence in the oil of soluble contaminants and ageing products. This test is therefore of special interest. If tan delta increases resistivity decreases. This is highly influenced by temperature, voltage, and frequency of the equipment.                                                                                                                                                                                                                                                                                                                                                                          |
| Resistivity (min) 90°C                                          | All voltages                  | $0.1 * 10^{12}$<br>$\Omega$ - cm. | The specific resistance is another important test for the quality of oil. High resistivity reflect low contents of free ions and ion forming particles and normally indicates low concentration of conducting contaminants. Water contents and cold precipitable materials can reduce the resistivity.                                                                                                                                                                                                                                                                                                                                                              |
| Neutralizati                                                    | All voltages                  | 0.5 mg                            | The acid products formed by the                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

|                                    |              |                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|------------------------------------|--------------|---------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| -on value<br>(max.)                |              | KOH/g                                       | oxidation of the oil activity encourage deterioration of insulating paper and pressboard. It is therefore essential to detect and monitor this process. The test is required to be performed more frequently if value exceeds 0.3 mg KOH/g.                                                                                                                                                                                                                                                                                                                                                     |
| Sediment and precipitable sludge   | All voltages | No sediments of sludge should be detectable | The presence of those particle normally reduces the electric strength of the oil and in addition deposits hinder heat exchange, thus encouraging from the deterioration of the insulating material.                                                                                                                                                                                                                                                                                                                                                                                             |
| Flash point                        | All voltages | 125°C                                       | The test is for finding lower hydrocarbons which formed due to some incipient fault in the equipment such as electrical discharge, excessively high internal temperature core fault etc. this test should be made more frequently if the oil has been subjected to high temperature or shows any sign of unusual odour.                                                                                                                                                                                                                                                                         |
| Interfacial tension at 27°C (min.) | All voltages | 0.018 N/m                                   | The interfacial value of oil against water provided a very sensitive means of determining the degree of oil contamination. We can measure the concentration. A low interfacial value indicates that the oil is damaged.                                                                                                                                                                                                                                                                                                                                                                         |
| Dissolved gases (max.) PPM         | All voltages | IS :10593 1983                              | Under normal service conditions only small amount of CO, CO <sub>2</sub> and very small quantity of H <sub>2</sub> and hydrocarbons are found. Large amount of these gases is an indication of an incipient due to overheating, sparking, hotspot, arcing, selector breaking current, solid insulation deterioration etc.<br>Knowledge of the effect of such faults in operation and safety of the power apparatus is of great importance, as transformers are required to operate over a long period of time.<br>To obtain such information and rectify the faults at regular intervals (using |

|  |  |  |                                                                                        |
|--|--|--|----------------------------------------------------------------------------------------|
|  |  |  | dissolved gas analysis method) ensures trouble free operation and safety of equipment. |
|--|--|--|----------------------------------------------------------------------------------------|

***Recommended or permissible values for 220 kV switchyard.***

1. Rated voltage of equipment = 220 (Nominal system voltage) \* 1.1  
= 245 kV
2. Permissible duration of short circuit in network 220 kV nominal voltage = 180 ms.
3. Permissible over voltage factors for 220 kV nominal voltage system
  - a. 
$$= \frac{220 * 6.5}{3}$$
  
= 825 kV (Approx.)
  - b. Power frequency flash over (wet) voltage  
$$= \frac{220 * 3.0}{3}$$
  
= 380 kV (Approx.)
4. Cable charging breaking current requirement:-  
The CB for opening high voltage cable or cable networks should be capable of interrupting the charging currents of cables successfully with the over voltage within specified limits. The recommended value of rated cable charging breaking current for 220 kV (Nominal voltage) is 250 A.
5. Impulse and power frequency with stand levels for various system voltages (Applicable at 20°C 760 mm of Hg pressure and 11-g/m<sup>3</sup> humidity).

| Nominal system voltage (L-L) kV (rms) | Highest Rated voltage (L-L) kV (rms) | Impulse withstand kV crest |                         | One minute power frequency test voltage kV (rms) |                         |
|---------------------------------------|--------------------------------------|----------------------------|-------------------------|--------------------------------------------------|-------------------------|
|                                       |                                      | Full insulation (kV)       | Reduced insulation (kV) | Full insulation (kV)                             | Reduced insulation (kV) |
| 220                                   | 245                                  | 1050                       | 900                     | 460                                              | 395                     |

Note: *Reduced insulation value* – applies where internal insulation is more important.  
*Full insulation value* – applies where external insulation is more important.

6. Standard clearances:-  
For rated nominal system voltages of the order of 220 kV  
Minimum clearance to earth = 117.8 cms.  
Minimum clearance between phase in air = 205.8 cms.  
Note: clearances indicated above are applicable for effectively earthed system.
7. Duty cycle for 220 kV ABCB:



0 – 3” – CO – 3” – CO.

## 8. Operating time for 220 kV breaker:

Opening time - 19 to 23 m sec.

Closing time - 45 to 54 m sec.

Blast time - 26 to 40 m sec.

## 9. mV drop across the arc chambers:

Acceptance limit – 35 mV.

## 10. 220 kV isolators:

a. mV drop test for the main contact – 11 mV for 1250 A isolators.

7.5 mV for 2000 A isolators.

b. Interrupting capacity of magnetising current – 0.8 A at 0.15 PF (lag)

c. Interrupting capacity for line charging current – can interrupt charging currents of bus bars and cables of upto 20 – 220 kV bays.

## 11. 220 kV transformers:

Arcing horns settings for 220 kV transformer having BIL = 900 kV should be 1200 mm.

## ***Electrical or electronic equipment design factors***

### **1. Explosion protection**

A source of energy along with the concentration of the following factors in the atmosphere is all that required to trigger off an *Explosion* in hazardous locations.

- Flammable substances such as gas, vapour, mist and dust.
- Air / Oxygen present in the atmosphere.
- Ignition level.

The factors leading to explosion also depends upon the inherent properties of gas and its concentration in the atmosphere.

Developing and designing of electrical or electronic products for explosion protection is very much vital for safety purpose of human life as well as for plant sites. For design and selection of an equipment for hazardous area, it is very much essential to know the parameters or characteristics of the atmosphere. Measures have to be taken to prevent formation of explosive atmosphere and restricting the explosion to a safe level. Those hazardous locations are classified in to zones and areas as per NEC and IEC classifications.

#### *Types of protection.*

Areas where explosive atmospheres can occur despite the explosion protection measures employed, only *explosion protected* electrical equipment may be used. Explosion protected electrical equipment can be manufactured to following protection type levels.

| Protection type           | Basic principal                                                                                                                                                                                                                                             | Principal application                                                                                                                                                    |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Flame – proof enclosure d | Part which can ignite an explosive atmosphere are placed in an enclosure which, if there is an ignition of an explosive mixture internally, will withstand the pressure and prevent the explosion being transmitted to the atmosphere around the enclosure. | Switchgear and switching installations, control and display units, control boards, motors, transformers, heating devices, light fittings.                                |
| Increased safety e        | Additional measures are taken to achieve a higher level of safety and avoid the risk of impermissibly high temperature and the occurrence of electrical equipment, which in normal use produce neither sparks arcs or dangerous temperature.                | Terminal and connected boxes, control boxes for the installation of excomponents (which are protected in another protection call), squirrel cage motors, light fittings. |
| Pressurised apparatus p   | The formation of an explosive atmosphere inside an enclosure is prevented by using a protective gas to maintain an internal overpressure                                                                                                                    | Switching and control cabinets, analysis devices, large motors.                                                                                                          |

|                    |                                                                                                                                                                                                                                                                                                                               |                                                                                                |
|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|
|                    | relative to the surrounding atmosphere, and if necessary, the interior of the enclosure is permanently supplied with protective gas so that there is dilution of flammable mixtures.                                                                                                                                          |                                                                                                |
| Intrinsic safety i | The equipment placed in the hazardous are contains only intrinsically safe circuits. A circuit is intrinsically safe if no sparks or thermal effects occur under established test conditions (including the normal operating and certain fault conditions), which could lead to the ignition of a given explosive atmosphere. | Measurement and control equipment, communications equipments, sensors, actuators.              |
| Oil immersion (o)  | Electrical equipment or parts of electrical equipment are immersed in a protective liquid in such a way that an explosive atmosphere above the surface or outside the enclosure cannot be ignited.                                                                                                                            | Transformers, starting resistors.                                                              |
| Powder filling q   | Type of protection by which the equipment parts that could become and ignition source are fixed in position and completely surrounded by finely ground solids, so as to prevent ignition of an external explosive atmosphere.                                                                                                 | Electronic devices                                                                             |
| Moulding m         | Parts, which can ignite an explosive atmosphere, are embedded in a casing compound so that the explosive atmosphere cannot be ignited.                                                                                                                                                                                        | Switchgear for low powers, control gear and indicating equipment, display equipments, sensors. |

## 2. *Index of protection (IP)*

IP (index of protection) for enclosures of electrical equipment as per IS: 13947 (Part-1): 1993 are as following.

| Protection against solids |                                                                                           | Protection against liquids |                                                                         | Mechanical protection |                            |
|---------------------------|-------------------------------------------------------------------------------------------|----------------------------|-------------------------------------------------------------------------|-----------------------|----------------------------|
| IP                        | Principal                                                                                 | IP                         | Principal                                                               | IP                    | Principal                  |
| 0                         | No protection.                                                                            | 0                          | No protection.                                                          | 0                     | No protection              |
| 1                         | Protected against solid bodies larger than 50 mm (eg:- accidental contact with the hand). | 1                          | Protected against vertically falling drops of water (condensation).     | 1                     | Impact energy 0.225 joule. |
| 2                         | Protected against solid bodies larger than 12 mm (eg:- finger of the hand).               | 2                          | Protected against drops of water falling at upto 15° from the vertical. | 2                     | Impact energy 0.375 joule. |
| 3                         | Protected against solid bodies larger than 2.5 mm (eg:- tools, wires).                    | 3                          | Protected against drops of rain water at upto 60° from the vertical.    | 3                     | Impact energy 0.500 joule. |
| 4                         | Protected against solid bodies larger than 1 mm (fine tools and small wires).             | 4                          | Protected against projections of water from all directions.             | 5                     | Impact energy 2.00 joule.  |
| 5                         | Protected against dust (no harmful deposit).                                              | 5                          | Protected against jets of water from all directions.                    | 7                     | Impact energy 6.00 joule.  |
| 6                         | Completely protected against dust.                                                        | 6                          | Protected against jets of water of similar force to heavy seas.         | 9                     | Impact energy 20.00 joule. |
|                           |                                                                                           | 7                          | Protected against the effects of immersion.                             |                       |                            |
|                           |                                                                                           | 8                          | Protected against prolonged effects of immersion under pressure.        |                       |                            |



## ***Thyristor engineering***

### ***Introduction***

Thyristor is the name of a large family of semiconductor devices, which includes the following.

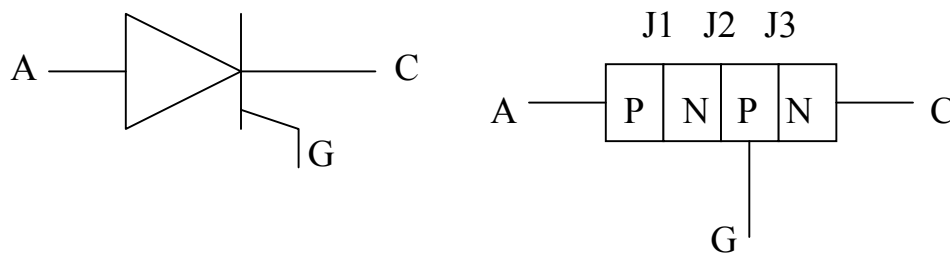
- Silicon controlled rectifier (SCR).
- Triac.
- Diac.
- Silicon controlled switch (SCS).
- Light activated switch (LAS) etc.

But in general the silicon controlled rectifier is referred to as thyristor. This device finds extensive applications in industrial equipments such as rectifiers, inverters, choppers etc. In our station thyristors are used in the following equipments.

- Main generator static excitation system.
- Power UPS.
- Control UPS.
- Diesel generator excitation system and etc.

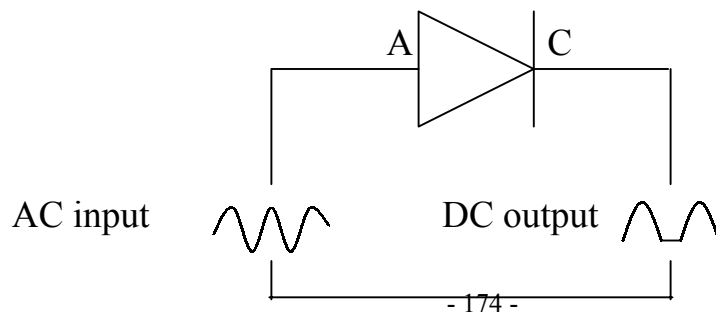
### **Construction of thyristor**

The thyristor is a four-layer P-N-P-N semiconductor device. The biasing at the three junctions J1, J2, J3 determine the state of the thyristor. Ohmic connections are made to the P, P, N regions and these terminals thus formed are called *Anode*, *Gate*, and *Cathode* respectively. This is shown in the figure below.



### **Difference between diode and thyristor**

Diode is an uncontrolled rectifier device whereas a thyristor is a controlled rectifier device. The condition for the conduction of a diode is that the anode must be positive with respect to the cathode. In case of a thyristor in addition to the above condition a positive gate pulse should also be applied to the gate terminal. By controlling the instant of the pulse release the conduction of the thyristor can be controlled.



*V – I characteristics of thyristor*

The thyristor characteristics are divided into four regions of operation. They are as follows.

- Forward blocking region.
- Forward conduction region (Useful region of operation).
- Reverse blocking region.
- Reverse conduction or breakdown region.

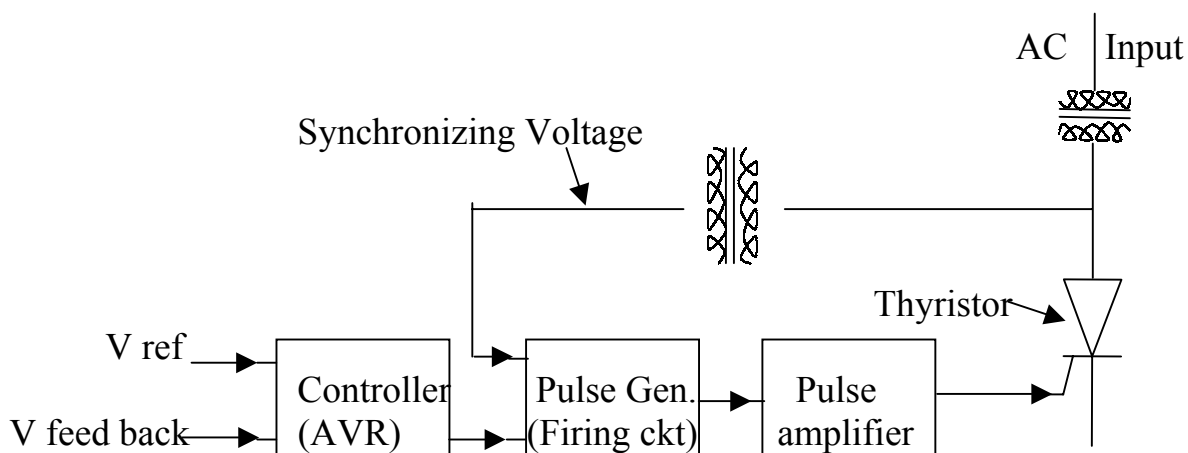
a. Forward blocking region: When an external voltage is applied to the thyristor making anode positive with respect to the cathode, the thyristor is said to be 'forward biased'. In this conditions

- Junctions J1 & J3 are forward biased.
- Junction J2 is reverse biased.
- A small forward leakage current flows which increases with the applied voltage.

The thyristor is in the 'off state' since the voltage applied is less than the break over voltage of the device. This is represented by region OA in the characteristic graph.

b. Forward conduction region: As the forward voltage is increased, a point is reached where the junction J2 gets forward biased and allows a large current to flow through the device. This voltage is known as the 'forward break over voltage'. Above this point the voltage across the device falls to a low value and the current is limited only by the external load resistance. This is represented 'purpose of gate triggering'.

As seen above thyristors can conduct even in the absence of gate pulses provided the forward voltage across them is more than the break over voltage. The application of the positive gate pulse reduces the break over voltage and the thyristor starts conducting at a much lower forward voltage. This characteristics of the thyristor makes it possible to control its conducting period in each cycle of the applied voltage by the release of gate pulses at the desired instant. The firing circuit or the pulse generator generates the firing pulses, the position (with reference to the voltage across the thyristor) of which depends on the DC voltage signal given to it by the controller (voltage, current regulator). This is shown in the diagram given below.





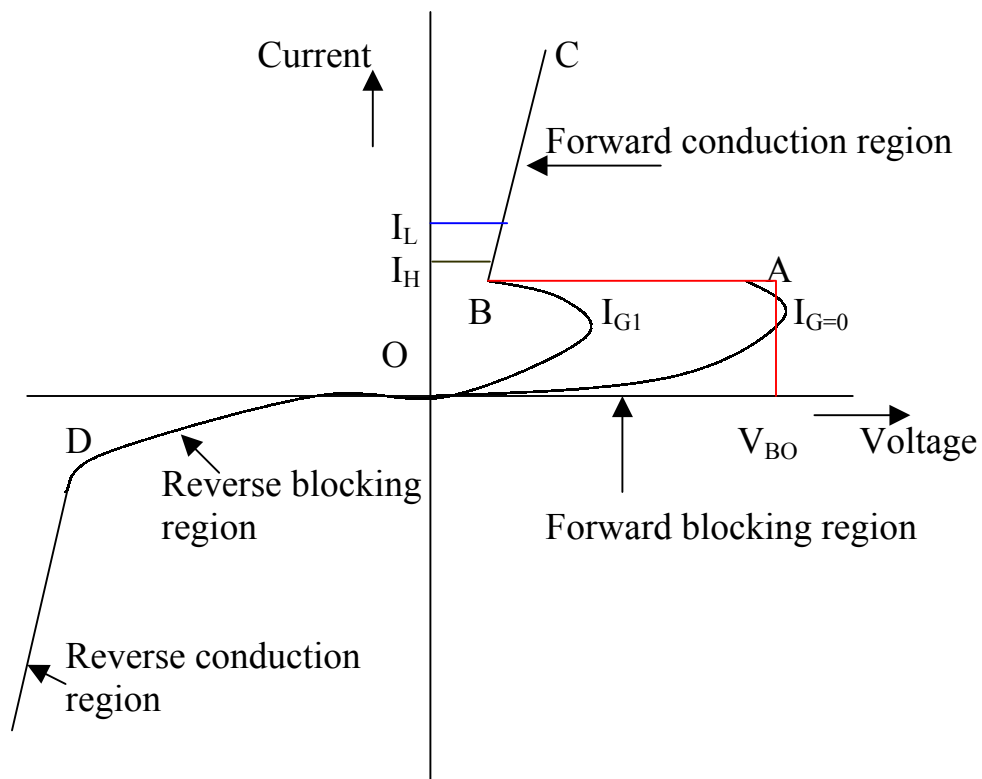


c. Reverse blocking region: When a reverse voltage is applied across the thyristor in such a way that the anode is at a negative potential with respect to the cathode the thyristor is said to be 'reversed biased'. Under this condition,

1. Junctions J1 and J3 are reversed biased.
2. Junction J2 is forward biased.

Only a small leakage current flows through the device, which increases with the applied voltage. This is indicated by region OD in the characteristics.

d. Reverse conduction region: When the reverse voltage across the thyristor is increased a point is reached when the junctions J1 and J3 breakdown causing heavy current to flow through the device. The voltage at this point is known as the 'reverse breakdown voltage'. This is indicated by region DE in the characteristics.



$I_L$  – latching current.

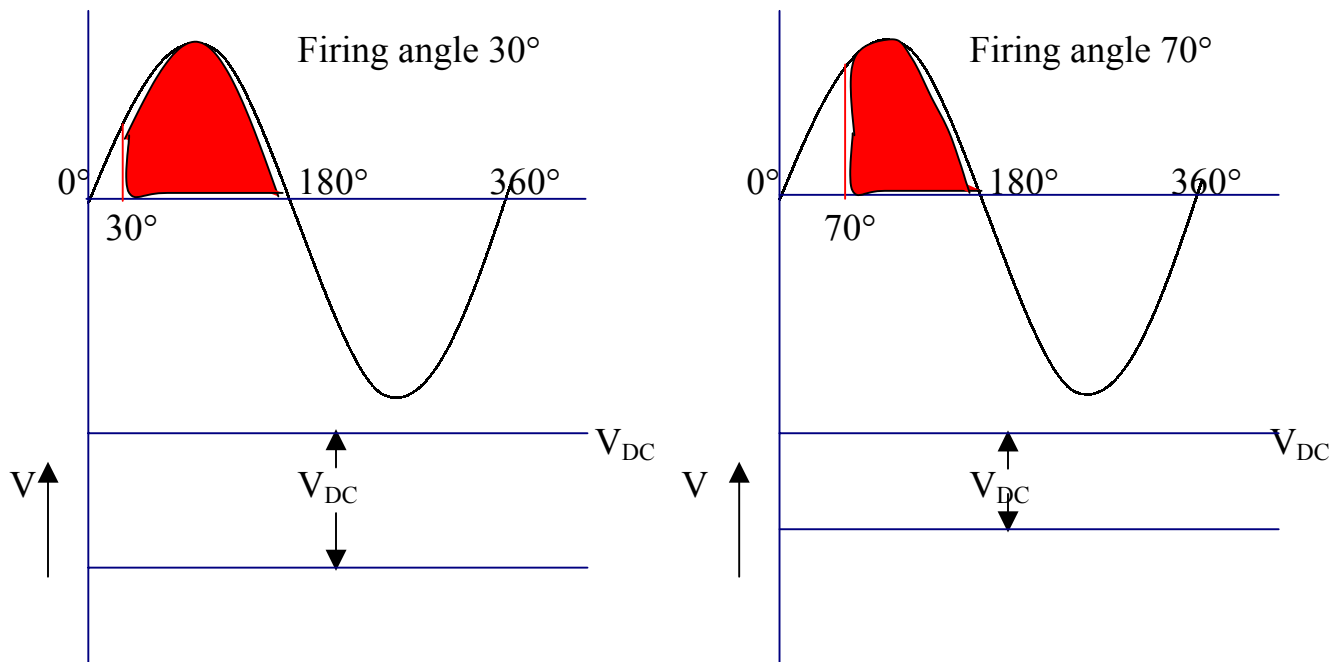
$I_H$  – holding current.

$V_{BO}$  – break over voltage.

$I_G$  – gate current.

*Some important technical terms*

- a. Latching current: It is the minimum ON state current required to keep the thyristor in the ON state after the triggering pulse has been removed. In control and power ACVR's this has been achieved by bleeder or dummy load resistances connected across the output terminals (DC side).
- b. Holding current: It is the value of anode current below, which the thyristor in conduction (ON state) turns OFF. Thus holding current is ON state to OFF state current where as latching current is OFF state to ON state current.
- c. Firing angle: The instant at which the gate pulse is released expressed in electrical degrees with reference to the applied voltage across the thyristor is known as 'firing angle'. For rectifier mode of operation the firing angle will be between  $0^\circ$  to  $90^\circ$ . Greater the firing angle lesser will be the output voltage of the rectifier. This is illustrated in the figure given below.



- d. Triggering: The process of switching the thyristor ON by the application of the gate pulse is known as triggering.
- e. Ripple: The AC components in the DC output of any rectifier are called the ripple. In control and power ACVR's on no load the ripple voltage is about 80 V AC at a DC output voltage of 260 V. This AC voltage indicates the conduction of all the thyristors in the bridge. For example the ripple voltage of ACVR's rise to about 140 V AC if one thyristor of the bridge does not conduct.
- f. Filter: Filters are used to remove the ripple components from the output of any rectifier so that it does not reach the load circuit. Inductors and capacitors are used as filters in the output of rectifiers.

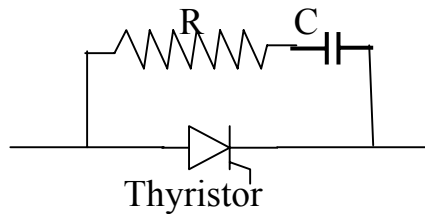


### Protection of thyristors

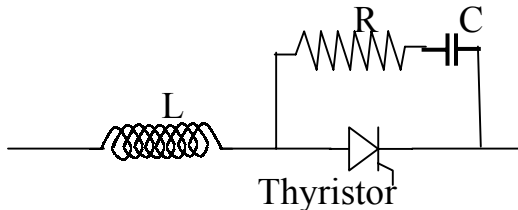
The thyristor is a very sensitive semiconductor device and it needs to be protected for the following abnormal conditions while in service.

- High  $dv/dt$ .
- High  $di/dt$
- Short circuit / over current.

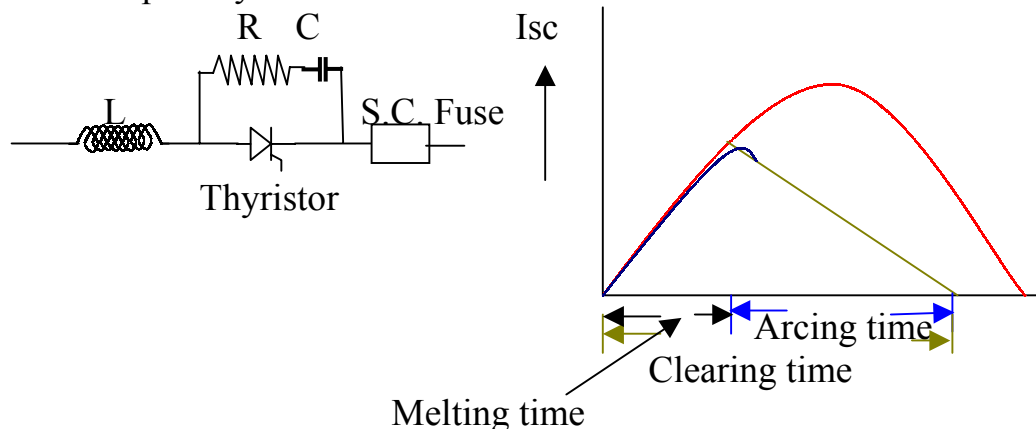
**High  $dv/dt$ :** This indicates the rate of rise of anode voltage. This rating specified for a particular thyristor should not be exceeded because it would lead to spurious triggering (switching ON) of the thyristor. The 'snubber circuit' (a resistance and a capacitance in series) connected across the thyristor as shown below provides the protection against high  $dv/dt$ .



**High  $di/dt$ :** This rating of the thyristor indicates the maximum rate of rise of ON-state current. When a thyristor is turned ON conduction starts at one or more places near the gate. Small area of conduction then spreads from these points to the whole crystal. Sudden rise of current causes 'hot spots' in the junctions and subsequent failure of the device due to melting. Connecting an inductor in series with the thyristor shown below provides protection against high  $di/dt$ .



**Short circuit protection:** A semi conductor fuse in series with the thyristor provides protection against short circuits. The semi conductor fuses operate very fast with pre-arcing time less than 0.5 m-sec and arcing time of about 3 m-sec. Hence the fault current will be interrupted by these fuses before it reaches its maximum value.



Semi conductor fuse characteristics

*Testing of thyristor*

1. Resistance checks: The anode – cathode resistance and gate – cathode resistance of the thyristor should be as follows.

Anode – cathode resistance for power thyristors

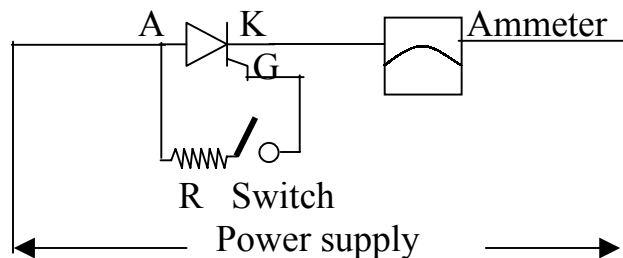
In the forward direction – about  $1\text{ M}\Omega$ .

In the reverse direction – about  $1\text{ M}\Omega$ .

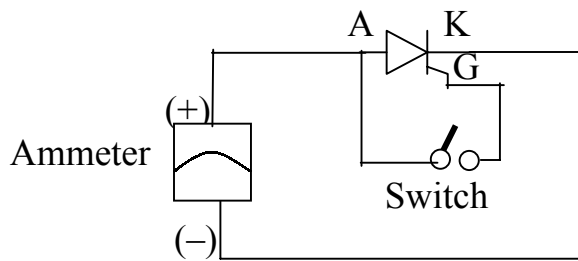
Gate – cathode resistance about  $25\Omega$  in both the directions.

In case of fused thyristor these resistances will be zero  $\Omega$ .

2. Current deflection test: The thyristor should be connected to a power supply as shown below.



The moment the switch is closed the thyristor conducts and the ammeter reads the current. If there is no deflection in the meter it shows that the thyristor is faulty. This is a foolproof method for testing any thyristor. The above testing can also be done with the help of a motwane analog multimeter. The arrangement for the same is as follows.



Motwane ammeter selected in resistance range.

Switch open high resistance.

Switch closed zero resistance.



**Miscellaneous (Tests on power cables)**

1. What are precautions to be taken while doing maintenance or repair work on power cables?

A research organised by EPRI (electric power research institute) on medium voltage XLPE cables found that DC high potential at 80% of the factory value

- a. Subsequently reduces the life of the cable and
- b. It did not identify significantly weakened cable.

Based on above research recommended maintenance proof test voltage = 60% of the factory test voltage.

**Maintenance and repair:**

Before attempting for any corrective maintenance on power cables like replacement of lugs or jointing of cables following should be taken care

- a. IR value should be good and it should be comparable to the previous values.
- b. The quality of joints should be such that it does not add any resistance to the circuit. Before jointing is commenced it is advisable that IR of both sections of cable to be jointed be checked.
- c. Before jointing a paper insulating cable (for PVC cables this step is not required), the paper insulation should be tested for the presence of moisture by immersion in hot compound for paraffin wax at a temperature between 120°C and 140°C. the presence of moisture indicated by the formation of bubbles when a piece of the paper is immersed in hot compound. Use only single strip of the paper.
- d. In case dia of die to be used for crimping is slightly more than dia of cables, then use some loose strand before doing crimping of lug. While crimping it should be ensured that homogeneity of cramped conductor strands is achieved otherwise it will add resistance and create over heating.

2. What are the tests to be carried out during DC high voltage test on power cables?

**DC high voltage testing.**

During DC high voltage testing flow of following currents will take place.

- a. Capacitance charging current.
- b. Dielectric absorption current.
- c. Surface leakage current.
- d. Partial discharge current (corona).
- e. Volumetric leakage current.

- a. Capacitance charging current.

The capacitance charging current is high as the DC high potential is applied and can be calculated by the formula

$$i_g = \frac{E - t}{rc / R}$$

where  $i_g$  – capacitance charging current.

$E$  – voltage in kilovolts.

$r$  – resistance in mega ohms.

$c$  – capacitance in micro farads.



$t$  – time in seconds.

The charging current is a function of time and will decrease as the time of the application of voltage increases. It is the initial charging current when voltage is applied and therefore not of any value for test evaluation. Test readings should be taken until this current has decreased to a sufficiently low value.

b. Dielectric absorption current.

The Dielectric absorption current is also high as the test voltage is applied and decreases as the voltage applicable time increases. This current can be calculated by the formula

$$i_a = VCDT^{-n}$$

Where  $i_a$  – dielectric absorption current.

V – test voltage in kilovolts.

C – capacitance in micro farads.

D – proportionately constant.

T – time in seconds.

n – constant.

Again time should be allowed before recording test readings so that this current has decreased sufficiently.

c. Surface leakage.

The surface leakage current is due to the conduction on the surface of the insulation and not desired in test results and should therefore be eliminated by carefully cleaning the surface.

d. Partial discharge current.

The partial discharge current, also known as corona current is caused by ionization of air due to high-test voltage. This current is not desirable and same is normally controlled by providing semi-conducting tape to separate the conductor from insulation.

Semi-conducting tape is used to separate the conductor from the insulation to prevent possible damage of the insulation from the corona and ionization. The voltage may develop between stranded conductor and insulation, thereby causing the ionization of air and breakdown of cable insulation. The application of semi-conducting smoothes the voltage stress and keeps such voltage stress constant and to a minimum.

e. Volumetric leakage current.

The volumetric leakage current flows through the insulation volume itself. This is the current that is used to evaluate the condition of the insulation under test. Sufficient time should be allowed for the volumetric current to stabilize before test readings are recorded.

***Predictive (preventive) maintenance on Induction Motor.***

1. What are the reasons for high current in motor?
  - a. High frequency – at 51 Hz current will be 105% of the normal current.
  - b. Low frequency – at 47.8 Hz current will be 102% of the normal current.
  - c. High voltage.
  - d. Under voltage.
  - e. Mechanical over loading.
  - f. Process requirement.
2. What are the reasons for unbalanced current in motor?
  - a. Loose power cable connection.
  - b. Voltage unbalance.
  - c. Short-circuited turns of coils of winding.
3. What are the reasons for vibration in the motor?

Vibration could be because of mechanical faults and electrical faults.

  1. *Mechanical faults.*
    - a. Wrong alignment of the motor on foundation.
    - b. Wrong installation.
    - c. Improper fitting of bearing and cooling fans.
    - d. Periodic impulse loads such as reciprocating compressors.
    - e. Pulley of heavy weight which cause bending of motor shaft resulting in non uniform air gap.
    - f. Damage of bearing or bad bearing.
    - g. Bad coupling.
    - h. If the axial alignment of the motor and the driven machine is incorrect and rotor is allowed to contact its axial stops, high axial vibrations may occur, together with high bearing temperature high and even bearing failure.
    - i. Machine base and foundation problem.
    - j. Under sized bearing.

## 2. *Electrical faults.*

- a. Air gas dissymetry.
- b. Broken rotor bars.
- c. Slackened stator core.
- d. Slackened rotor core.
- e. Interturn short in the rotor winding in the two-pole machine.
- f. Unbalance in rotor winding.
- g. Unbalance power supply voltages.

If the vibration is because of electrical fault, de-energise the machine and watch the vibration as it runs down.

The possible vibration frequencies observed are

- a. Twice the power supply frequency – it indicates that the vibration is developed by unbalanced power supply voltages, unbalanced air gap, unbalance in rotor winding, slackened stator core etc.
- b. Multiple of power frequency – the stator and rotor slots co-ordinate to develop radial lines of force to deform and pulsate the cores.
- c. Twice the slip frequency – magnetic unbalance due to unbalance air gaps, slackened rotor core, interturn short in the rotor-winding etc. of two-pole machine.
- d. Beat (Humming) – in case of two-pole machine the beat is developed when the vibration of twice as much as power frequency developed between the stator and rotor is superimposed on the vibration of twice the slip frequency developed due to irregular air gap.

## 4. What are the reasons for winding temperature high in the motor?

For motors having class – B insulation the temperature should not be more than 110°C and for motors having class – F insulation the temperature should not be more than 130°C. In case temperature is more, then the following could be the possible reasons.

### 1. *Electrical overloads.*

- a. Over and under voltage.
- b. Over and under frequency.
- c. Voltage unbalance. Voltage unbalance create unbalance of currents and increase in temperature which will be  $2 * (\% \text{ voltage unbalance}) * (\% \text{ voltage unbalance})$ .

$$(\% \text{ Voltage unbalance}) = 100 * \frac{\text{maximum deviation from average voltage}}{\text{average voltage}}.$$

For instance if voltages are 390V, 410V & 440V,

$$\% \text{ Voltage variation} = 100 * \frac{(440-390+410+440)}{3} / \frac{(440-390+410+440)}{3} = 6.45\%.$$

Therefore increase in temperature rise =  $2 * (6.45) * (6.45) = 83^\circ\text{C}$  (approximately).

- d. Voltage transients and interruptions.

- e. Loose connection at motor terminals.
- f. Unbalance current.
- g. Single phasing (if OLR protection is not working).
- h. Long acceleration cycle.
- i. Unusual system grounding conditions.

2. *Mechanical overloads.*

- a. Locked rotor.
- b. Heavy starting.
- c. Bearing problem.
- d. Overload in continuous duty and intermittent duty.

3. *Environmental overloads.*

- a. Excessive temperature of cooling medium or ambient temperature.
- b. Restricted flow of cooling.
- c. Reduction in the density of cooling medium.
- d. Heat transfer from machine parts connected to the motor.

4. *Others.*

- a. Excessive number of switching operations.

5. What are the reasons for bearing temperature high?

Temperature of bearing should not be more than 90°C. In case temperature is higher than the 90°C the following could be the possible reasons.

- a. Inadequate lubricants inside the bearing.
- b. Faulty bearing.
- c. Bearing is jammed.
- d. Over greasing.
- e. Improper grade of lubricant.

6. What are the reasons for abnormal sound or noise?

Motors in general should run very quietly and no abnormal noise is desired. However if noise is there, it could be because of following reasons.

- a. Windage noise – the noise due to ventilating system, (whistling noise).
- b. Bearing noise – the noise due to its rolling contact.
- c. Unusual noise – some defects inside the motor (example – motor bar failure).
- d. Deep heavy growling noises – some electrical fault.

For permissible limits of noise levels for rotating electrical machines IS: 12065:1987 is being referred.

7. What are the reasons for harmonics in the motor?

Generally even harmonics are not expected to be present in three phase motors. Triple-n harmonics like 3<sup>rd</sup>, 9<sup>th</sup>, 15<sup>th</sup> etc. are also not expected. The dominant odd harmonics expected are 5<sup>th</sup>, 7<sup>th</sup>, 11<sup>th</sup> and 13<sup>th</sup> etc.

Presence of strong 2<sup>nd</sup> harmonics indicates unbalance voltage, unbalance winding impedance, rotor defects, magnetic imbalance, faulty rotor skewing etc.

Very strong 3<sup>rd</sup> harmonics indicates magnetic saturation, ground leak currents, overloads etc. Overloading causes overheating, resulting in non-linear magnetization

which gives high 3<sup>rd</sup> harmonic winding faults, short circuits. Hot spots in rotor or stator also may indicate higher harmonics.

8. What are the possible reasons for not coming of rated speed during start?

In case motor does not come to its rated speed then following could be the probable causes.

- a. Starting load is too high.
- b. Broken rotor bars (look for cracks near rings).
- c. Open primary circuit.
- d. Voltage is too low.

9. What are the possible reasons for motor to take long acceleration time?

Following may be the possible reasons for motor to take long acceleration time.

- a. Excess loading.
- b. May be rewound motor with poor quality of winding conductor having high resistance.
- c. Defective squirrel cage rotor.
- d. Applied voltage is too low.

10. What are the points contribute in insulation resistance of the motor?

If the measured insulation resistance of the motor is less than  $1 \text{ M}\Omega / \text{kV}$  with a minimum of  $1 \text{ M}\Omega$ , when the machine is cold it is to be dried out before full voltage is applied to the terminals of the motors and the drying out is to be continued as long as the insulation resistance rises or until a sufficiently high value that is not less than  $1 \text{ M}\Omega / \text{kV}$  with minimum of  $1 \text{ M}\Omega$  at  $75^\circ\text{C}$  is reached.

While proceeding for point as above said, following factors are to be kept in mind which affect the insulation resistance measurement. They are,

- a. Surface condition.
- b. Moisture.
- c. Temperature.
- d. Magnitude of test voltage.
- e. Duration of application of test voltage.
- f. Residual charge in the winding.
- g. Ageing of the insulation.
- h. Mechanical stresses.

11. What are the minimum recommended PI values for AC and DC rotating machines?

Following minimum recommended PI values criteria is to be followed.

- a. 1.5 for class – A insulation.
- b. 2.0 for class – B insulation.
- c. 2.5 for class – F insulation.



12. What is the minimum recommended absorption coefficient value for AC and DC rotating machines?

$$\text{Absorption coefficient} = \frac{\text{IR value for 60 seconds}}{\text{IR value for 15 seconds}} = 1.3 \text{ (minimum recommended value)}$$

Tips:

- IR value decreases somewhat with an increase in applied voltage. However for machines in good condition substantially the same IR is obtained for any test voltage up to the peak value of the rated operating voltage.
- If the IR value decreases significantly with an increase in applied voltage it is an indication of imperfections or fractures of the insulation aggravated by the presence of dirt or moisture or may be due to the effects of dirt or moisture alone, or may result from numerous other phenomena not necessarily associated with any defect or weakness.
- IR value for good dry winding continues to increase for hours with constant test voltage continuously applied, however a fairly steady value is usually reached in 10 to 15 minutes. If the winding is wet or dry or dirty the steady value is usually reached in 1 or 2 minutes after the test voltage is applied.
- The recommended minimum IR value for AC and DC machines is determined by the following empirical relationship.

$$\text{IR} = kV + 1$$

Where IR = recommended minimum IR in mega ohms at 40°C of the entire machine winding and kV = rated machine voltage in kilo volts.

Temperature correction is to be applied, if winding is not at a temperature of 40°C.

- IR of the one phase of three phases winding with other two phases earthed, is approximately twice that of the entire winding. Therefore when the three phases are tested separately, the observed insulation resistance of each phase should be divided by two to obtain a value which after correction for temperature, may be compared with the recommended minimum value of IR.

13. What is use of Tan – Delta test? And what are the recommended values?

The very purpose of this test is to detect moisture content, voids, cracks and deterioration in the insulation and same is to be conducted on HT motors.

Based on the guidelines given in the article 'Diagnostic testing on the winding insulation' by J. S. Simon (IEE vol. 127 may 1980) the contamination level of motor winding is to be assessed from the given Tan – Delta value.

| Starting Tan – Delta values | Degree of contamination |
|-----------------------------|-------------------------|
| 0 – 4%.                     | Low void content.       |
| 4 – 6%.                     | Clean.                  |
| 6 – 10%.                    | Some dirt.              |
| 10 – 14%.                   | Dirt and moisture.      |
| 14 – 16%.                   | Gross contamination.    |

|            |                                      |
|------------|--------------------------------------|
| 16 – 20%.  | Heavy deposit of oil dirt.           |
| Above 20%. | Severe oil and carbon contamination. |

**14. What are important guidelines for conducting HV test?**

Based on the recommendations given in IS: 4029:1977 decided DC test voltage  
 $= (2E+1kV) 1.6 * M$

Where E = rated voltage.

2.6 = AC to DC conversion factor.

M = derator factor which is a function to be decided on the basis of the age and condition of equipment.

The DC voltage applied in steps and the leakage current recorded at each step. A plot leakage current Vs test voltage is to be plotted as the test progress.

Some recommendations of IS : 4029 : 1977.

- a. The HV test made on the windings on acceptance shall as far as possible not be repeated. If however a second test to be made at 80% of the voltage given by the empirical formula given above.
- b. Test voltage for completely rewound motor = full test voltage for new motor.
- c. Partially rewound or overhauled motor = 75% \* full test voltage for a new motor.
- d. Before the test for the old parts of the winding shall be carefully cleaned and dried.
- e. Before attempting of HV DC test a minimum PI value of motor should be obtained.

**15. What are the uses of high voltage surge test?**

This test gives distinct wave forms giving indications of various defects such as,

- a. Turn to turn short in same phases.
- b. Coil to coil short in same phases.
- c. Partial phase to phase short.
- d. Complete phase to phase short.
- e. Improper coil connections.
- f. Reverse coil connections.
- g. Open coil connections.
- h. Short to ground partial.
- i. Short to ground complete.

## 16. What is the thumb rule for motor current?

Thumb rule for NO LOAD current of motors.

| Type of enclosure | No. of poles | % No Load current of rated current |
|-------------------|--------------|------------------------------------|
| TEFC              | 2            | 15 – 20                            |
| TEFC              | 4            | 30 – 35                            |
| SPDP              | 2            | 25 – 30                            |
| SPDP              | 4            | 35 – 40                            |
| SPDP              | 6 to 8       | 50 – 55                            |
| SPDP              | 10           | 80                                 |

Note: TEFC (Totally enclosed fan cooled) motors are low inductive having low active material in comparison to SPDP (Screen protected drip proof) motors.

Thumb rule for calculating positive sequence and negative sequence current in motors.

- Positive sequence current: Average of all three phases currents.
- Negative sequence current: Maximum deviation of any of the phase currents from the average.

## 17. How you evaluate the insulation condition based on PI value?

Evaluation of insulation condition based on PI value

| PI value  | Insulation condition | Recommendation        |
|-----------|----------------------|-----------------------|
| 1.0 – 1.5 | Bad                  | Drying is mandatory   |
| 1.5 – 2.0 | Doubtful             | Drying is recommended |
| 2.0 – 3.0 | Adequate             | No drying is needed   |
| 3.0 – 4.0 | Good                 | No drying is needed   |
| > 4.0     | Excellent            | No drying is needed   |

## 18. What are the conditions monitoring for the motor bearings?

Bearing oil analysis is a useful tool in determining bearing performance and possible deterioration. Periodic checks for oil colour, viscosity and acidity can aid in preventing or anticipating bearing failure.

Oil analysis tests

| Symptoms                          | Possible cause                          | Test                            | Cost     |
|-----------------------------------|-----------------------------------------|---------------------------------|----------|
| Viscosity                         | Water or high temperature               | Water content                   | Low      |
|                                   |                                         | ASTM 445 viscosity              | Low      |
| Viscosity change<br>colour change | Oxidation                               | ASTM 974 neutralization number  | Low      |
|                                   |                                         | ASTM 664 neutralization number  | Moderate |
|                                   |                                         | ASTM 2296 neutralization number | Moderate |
| Particles                         | Bearing deterioration or foreign matter | Spectroscopy                    | Low      |
|                                   |                                         | Particle count                  | Moderate |
|                                   |                                         | Direct reading ferrography      | Moderate |
|                                   |                                         | Analytical ferrography          | High     |



***Important test on electrical equipments******1. Tests on transformer.***

| Test                                                     | Purpose                                                                                                      | Item                       | Required condition of machine                               |
|----------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|----------------------------|-------------------------------------------------------------|
| IR value<br>And<br>PI value.                             | Detects serious flaws, moisture absorption and cleanliness of winding.                                       | Winding.                   | Winding has to be isolated.                                 |
| Tan delta or dielectric loss or power factor or HV test. | Indicates insulation deterioration, contamination and physical damage.                                       | Winding, oil and bushings. | Winding has to be isolated, oil sample should be collected. |
| Excitation current at high voltage.                      | Indicates defects in the magnetic core structure, shifting or windings, failures in turn to turn insulation. | Winding                    | Winding has to be isolated.                                 |
| Turns ratio                                              | Indicates short circuited turns and internal connections                                                     | Winding                    | Winding has to be isolated                                  |
| Winding resistance                                       | Detects poor connections and conductor shorts                                                                | Winding                    | Winding has to be isolated                                  |
| Core IR and inadvertent grounds                          | Indicates deterioration of core insulation system                                                            | Core                       | Winding has to be isolated                                  |
| Water contents                                           | Indicates moisture level in oil                                                                              | Oil                        | Oil sample has to be collected                              |
| Total acidity, neutralization number                     | Measures organic and inorganic acids                                                                         | Oil                        | Oil sample has to be collected                              |
| Dissolved gas analysis                                   | Indicates specific gases generated                                                                           | Oil and winding            | Oil sample has to be collected                              |
| Furanite compounds                                       | Indicates cellulose degradation                                                                              | Winding                    | Oil sample has to be collected                              |



## 2. *Test on Circuit breakers*

| Test                             | Purpose                                                                                                                                            | Item                      | Required condition of machine |
|----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-------------------------------|
| IR value                         | Detects serious flaws, moisture absorption and cleanliness.                                                                                        | Overall insulation system | CB has to be isolated         |
| Dielectric loss or $\tan \delta$ | Indicates insulation deterioration, contamination and physical damage                                                                              | Overall insulation system | CB has to be isolated         |
| DC HV test (optional)            | Determines condition of insulation                                                                                                                 | Overall insulation system | CB has to be isolated         |
| Contact resistance measurement   | Detects poor contacts                                                                                                                              | Contacts                  | CB has to be isolated         |
| Timings                          | Detects faulty dashpots, faulty adjustments, weak accelerating springs, defective shock absorbers, buffers and closing mechanisms, or broken parts | Overall breaker           | CB has to be isolated         |

## 3. *Tests on power cables*

| Test                             | Purpose                                                           | Component                 | Required condition of machine |
|----------------------------------|-------------------------------------------------------------------|---------------------------|-------------------------------|
| IR value                         | Detects serious flaws, moisture absorption and cleanliness        | Overall insulation system | Cable has to be isolated      |
| Dielectric loss or $\tan \delta$ | Shows insulation deterioration, contamination and physical damage | Overall insulation system | Cable has to be isolated      |
| DC step voltage test             | Determines condition of insulation                                | Overall insulation system | Cable has to be isolated      |
| Resistance of bolted connection  | Detects poor connections                                          | Bolted connection         | Cable has to be isolated      |





4. *Tests on surge arrestor*

| Test                            | Purpose                                                           | Component                 | Required condition of machine |
|---------------------------------|-------------------------------------------------------------------|---------------------------|-------------------------------|
| IR value                        | Detects serious flaws, moisture absorption and cleanliness        | Overall insulation system | Arrestor has to be isolated   |
| Watts loss test                 | Shows insulation deterioration, contamination and physical damage | Overall condition         | Arrestor has to be isolated   |
| Resistance of bolted connection | Detects poor connections                                          | Bolted connection         | Arrestor has to be isolated   |

5. *Tests on HV motors*

| Test                                       | Purpose                                                                                                                                    | Item                     | Required condition of machine                               |
|--------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-------------------------------------------------------------|
| IR and PI value                            | Detects serious flaws, moisture absorption and cleanliness of winding                                                                      | Stator and field         | Winding has to be isolated                                  |
| Tan delta or power factor test             | Evaluation of stress grading, dielectric losses and homogeneity of the winding insulation                                                  | Stator winding           | Winding has to be isolated                                  |
| DC Winding resistance                      | Detects poor connections and conductor shorts                                                                                              | Stator and field winding | Winding has to be isolated                                  |
| AC Impedance on poles test                 | Detects the presence of short circuit turns                                                                                                | Field winding            | Winding has to be isolated                                  |
| DC HV step voltage or leakage current test | Detects insulation weakness and possibility of warning of breakdown of incipient fault                                                     | Stator winding           | Winding has to be isolated                                  |
| Surge voltage                              | Determines healthiness of turn insulation                                                                                                  | Stator winding           | Winding has to be isolate                                   |
| Partial discharge or corona or TVA probe.  | Evaluation of stress grading system and location of partial discharge sites                                                                | Stator winding           | Winding has to be isolated and rotor has to be threaded out |
| ELCID test (optional)                      | Determines healthiness of stator core inter lamination insulation                                                                          | Stator core              | Rotor has to be threaded out                                |
| Online motor current signature analysis    | To determine the healthiness of the motor by giving all the electrical parameters, harmonic analysis, rotor bar heath and bearing problems | Motor                    | Online condition                                            |
| Wear debris                                | Bearing condition                                                                                                                          | Bearing                  | Bearing oil or grease sample has to                         |

|                               |            |  |              |
|-------------------------------|------------|--|--------------|
| analysis for oil<br>or grease | assessment |  | be collected |
|-------------------------------|------------|--|--------------|

### 6. Tests on HV generator

| Test                                     | Purpose                                                                                   | Item                     | Required condition of machine                                                                                                        |
|------------------------------------------|-------------------------------------------------------------------------------------------|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| IR and PI                                | Detects serious flaws, moisture absorption and cleanliness of winding                     | Stator and field winding | Bus bar and neutral connection has to be isolated                                                                                    |
| Tan delta or power factor test           | Evaluation of stress grading, dielectric losses and homogeneity of the winding insulation | Stator winding           | Bus bar and neutral connection has to be isolated                                                                                    |
| DC winding resistance                    | Detects poor connections and conductor shorts                                             | Stator and field winding | Bus bar and neutral connection has to be isolated                                                                                    |
| DC step voltage or leakage current test  | Detects insulation weakness and possibility of warning of breakdown of incipient fault    | Stator winding           | Bus bar and neutral connection has to be isolated                                                                                    |
| Partial discharge or corona or TVA probe | Evaluation of stress grading system and location of Partial Discharge sites               | Stator winding           | Bus bar and neutral connection has to be isolated. Stator slot exits are be accessible and if necessary rotor has to be threaded out |
| ELCID test                               | Determines healthiness of stator core inter laminar insulation                            | Stator core insulation   | Rotor has to be threaded out in TG's, where as rotor poles has to be removed minimum in case of HG's.                                |
| Wedge tightness check                    | Determines wedge tightness                                                                | Stator wedge             | Rotor has to be threaded out                                                                                                         |
| AC impedance test                        | Detects the presence of short circuit turns                                               | Field winding            | Rotor winding should be isolated from the excitation system                                                                          |
| Recurrent surge oscillograph             | Detects interturn and earth faults in winding                                             | Field winding            | Rotor winding should be isolated from excitation system. Test can be carried out without threading out the rotor also                |
| O.C.C                                    | Detects shorted turns                                                                     | Field winding            | Online test                                                                                                                          |
| Thermal sensitivity test                 | Detects vibration cause                                                                   | Rotor                    | Online test                                                                                                                          |
| Partial discharge                        | To assess de-lamination, stress control and slot                                          | Stator winding           | PDA coupling coils has to be fixed to the machine                                                                                    |

|          |                   |  |  |
|----------|-------------------|--|--|
| analysis | support tightness |  |  |
|----------|-------------------|--|--|

## **ELECTRICAL SYSTEM**

- What are the design objectives of Electrical System?
  - a. To evacuate generated electrical power.
  - b. To provide required power to SUT, UT, DG, UPS, and CUPS.
  - c. To provide required emergency power from onsite DG, UPS & CUPS.
  - d. To provide Fast transfer in event of Class IV failure. Emergency transfer in events of Class III and Class II failure.
  - e. Load shedding in event of one DG available.
  - f. To provide un-interruptible or few milli seconds interrupted power supply by UPS and un-interruptible power supply by CUPS.
  - g. To provide operational flexibility by providing required qualities of requirement.
  - h. To provide isolation, Alarms, indication, protection of the system.
  - i. To provide fire protection.
  - j. To provide surge and lightning protection.
  - k. To provide adequate lighting.
  - l. To provide equipment earthing, system earthing, and personnel protection.
  - m. To provide necessary electrical and physical isolation of electrical equipments.
  
- What are the design guidelines for electrical system?
  - a. All safety related equipments are in control building, SRPH and are designed for SSE conditions. As per studies seismic condition is not there within 5 kms and nearest zone is away from 20 kms.
  - b. Safety related equipments are separated from suitable fire barriers of 3 hrs rating by horizontal and vertical clearances and from turbine building which are houses high energy rotating equipments and where potential for fire is exist.
  - c. Separate switchyard control is provided in case of non-availability of main control room with line and bus coupler protection and bus bar protections. Control room posses SUT, UT, GT, Generator and all classes of power supply control and protections.
  - d. Protection panels of Generator, GT, and UT are separated from SUT in physical to have system flexibility.
  - e. SCADA is provided in CER, TB and in switchyard separately.
  - f. EMTR for each A and B groups are separated.
  - g. Control supply for switchyard is separated from operating island.
  - h. To reduce fault level in lighting circuits separate 280-kVA transformer is provided.

## **MAIN GENERATOR AND IPBD**

- How output of the generator is depends?  
Output of the generator is the function of volume, length, dia, airgap, and speed.
- What you mean by Gas pickup method?  
Sucking cooled hydrogen gas from the air gap, circulating in canals and removing the heat from the rotor. While sucking the gas, gas comes through the stator parts also and removes the heat from the stator parts. The heated gas circulated to the hydrogen for cooling purpose by the fans installed at rotor shaft. Thus the stator and rotor of the generator is cooled. This method is called Gas pickup method.
- When the hydrogen explosion will take place in main generator?  
When hydrogen concentration in air is more than 4% and less than 74% causes the explosion.
- Can we excite generator without hydrogen? No
- What are the advantages of stator water?
  - a. High thermal capacity
  - b. Low electrical conductivity (Good insulator)
  - c. Low viscosity
  - d. Free of fire risk and non-toxic
  - e. Simple heat exchanger i.e. it can be circulate easily and cooled by heat exchanger
- How rotor windings are held in position against centrifugal force?  
Rotor windings are held by duraluminium wedges and by non-magnetic steel retaining rings in the overhang portion.
- What is the purpose of current carrying bolts in rotor?  
Feeding DC current from slip ring to rotor winding.
- How rotor cooled?  
Hydrogen picked up from stator core backspace, passes through ventilation canals on rotor and comes out through adjacent canals. Shaft fans aid the hydrogen flow. Heat from the hydrogen removed by 4 nos. of hydrogen coolers. (NAPW)
- What is rotor E/F relay setting?  
1.0 mA
- Are we using DCCB in the plant?

Yes, generator field breaker

- How arc is quenched in Generator Field Breaker?  
By magnetic blow out coils, arc is elongated very fastly, so resistance of arc increases, soon becoming unstable and quenched by arc chutes.



- How generator is protected from switching surges and lightning surges?  
Surge capacitor and lightning arrestor.
- What is the use of generator PT's?  
AVR, Protection & Metering.
- What is the difference between PT and normal transformer?  
Burden of PT is less and burden of normal transformer is high.
- What is the % overload allowed for TG and DG?  
For TG nil  
For DG 110% for 2 hours.
- When TG works as induction generator?  
When excitation alone lost.
- Why motoring should be prevented in TG and DG?  
In TG motoring prevented due to the turbine limitation otherwise last stage blade will fail.  
In DG motoring prevented, because of unburned fuel catches fire in DG.
- Why GFB closed only after reaching rated speed?  
To prevent over fluxing of transformers or generator.  
 $E_{mf} = 4.44 f \phi Z A$   
If  $f$  frequency is reduced due to less speed,  
 $\phi = V / f Z A$   
And flux will be more to saturate the core of transformers or generator.
- What are the protective parameters to changeover AVR auto to manual?
  - a. PT supply fail.
  - b. Auto pulse fail.
  - c. Supply of limiter fail.
  - d. Supply of auto channel fail.
  - e. Regulated supply fail.
  - f. High auto reference.
- Why AVR changes over to manual on AVR PT fuse failure?  
Because loss of feedback to voltage corrector.
- Will main generator differential relay pick up for generator earth faults?  
No earth fault current limited to 5A, while differential setting is 10%.

- Why generator differential provided?  
For generator phase to phase faults and 3 phase faults.

- What is the effect of loss of excitation on generator?  
Large induced currents in rotor leads to rotor end part over heating.  
Leading VAR taken from grid leads to severe voltage dips in grid, if grid is weak.  
Stability of machine lost.  
Stator overheating.  
Machine speed rises slightly.
- What are the limiters provided in excitation system?
  - a. Rotor current limiter (3000 A)
  - b. Rotor angle limiter ( $75^\circ$  lag)
  - c. Under excitation limiter.
  - d. Stator current limiter (lead 10000 A)
  - e. Stator current limiter (lag 10000 A)
  - f. N – 2 limiter.
- What is the effect of unbalance currents in generator?  
Double frequency currents are induced in metal parts of rotor and overheating of retaining rings and non-magnetic wedges.
- Why low forward power relay used in parallel to reverse power relay?  
A small steam leak through CIES valves will keep the machine floating on to grid at low power. So even if turbine trip, relay picks up, there is no trip actually. So low forward power relay (0.54%) used to detect the condition.
- Why earth fault current of generator should not be reduced below 5A?  
To limit over voltage due to neutral shift.
- Why not high resistance for earth fault than using grounding transformer & resistor 0.45 ohms?  
It is mechanically unwieldy. Difficult to manufacture.
- Why starting resistor is provided in barring gear motor?  
Starting resistance at stator reduces voltage at stator terminals and accelerates the motor very slowly so as to allow smooth gear engagement.  
Other methods are
  - a) Auto transformer.
  - b) Star-delta starter.
- Will rotor earth fault relay operate for earth fault in main exciter winding or RCU Diode Bridge also?  
Yes.

- Why neoprene rubber bellows in generator IPBD?  
Prevent vibrations transmitted from generator to IPBD.
- How moisture entry is prevented into bus duct?  
Silicagel breathers at either end.

- Why aluminium bus duct is used?  
Aluminium is nonmagnetic material.  
Short circuit forces are less.
- Where fault level is more, whether in generator bus duct or UT bus duct? Why?  
Fault level is more in UT bus duct. Because the fault currents fed by the both generator and GT adds up within UT bus duct in case there is a fault in UT bus duct.
- Which is better, whether  
a) Phase segregated bus duct or  
b) Common bus duct?  
Phase segregated bus duct is better, since phase to phase faults are avoided.
- Why cannot we have cables instead of bus duct in main generator?  
Very large number of cables in parallel required problems of sealing the terminations.
- What is the material of slip ring?  
Alloy steel
- Why rotor impedance testing done during static and running condition?  
To detect rotor earth fault.
- Which parameter indicates the rotor short-circuited turns (Not involving earthfault)?  
Vibration increases.
- How stator water purity is held?  
Filters, Vacuum pumps, Expansion tank, and magnetic filter.
- What are the routines checks on slip rings?
  - a. Correct mV drops brush to be used.
  - b. Brush tension adjustment.
  - c. Air cleaning to reduce leakage current.
  - d. Brush bedding before use.
  - e. Field polarity change every 6 months.
- Can we trip GFB from control room during unit operation?  
No only if generator breaker is off.
- What is the voltage and frequency limit of generator?  
 $\pm 5\%$ ,  $\pm 5\%$

- What is the negative sequence capability?  
 $I_2 = 5\% \text{ max,}$   
 $I_2^2 t = 7$

- Why should we keep the brushes released during long shutdown?  
Brushes wear out unevenly, when run on barring gear speed.
- How hydrogen purity reduces?  
Due to seal oil vapour mixing.
- What is the purpose of back up impedance protection in main generator?  
Covers inter-phase faults both externals to the GT and in GT. This also covers partially faults inside generator, time delayed to coordinate with 230 kV-distance protection.
- Why alternator rotor is made of solid iron?  
Because, rotor flux = DC continuous  
No iron loss problems.
- Why 50 Hz chosen?  
Earlier 25 Hz generally used.  
After developing of the high-speed turbine, 50/60 Hz standardized.
- Why oil cannot be used instead of water in generator stator?  
Oil has high thermal capacity than gas, but low thermal capacity than water. Ability to absorb heat is also less than waters.  
High viscosity of oil causes linear flow and poor surface heat transfer in small ducts.  
Large pumping power required.
- What is the purpose of JOP?  
Lifts the rotor by injection of oil at high pressure, when BGM is in service. Outlet pressure of JOP is  $140 \text{ kg/cm}^2$ .
- What is the purpose of lubrication oil?  
Keep oil film in bearings, avoid metal to metal contact between bottom of journal and bearings avoid damage to bearings by lubricating the bearings. This also removes heat from that part.
- What are the purposes of barring gear?  
Start rotor from rest.  
Eliminates sag in rotor - straighten and avoid rubbing at glands.  
Avoid direct contact journals and bearings.  
Avoid differential temp between top and bottom of cylinder due to convection of Steam or hot air inside turbine cylinders.

- How shaft voltage produced by turbine?  
Due to un-symmetry in the flux path of core, non-uniform air gap, un-symmetry in the rotor magnetic field during short circuit in the rotor winding, causes voltage to develop across the ends of rotor shaft.



- Why shaft-earthing brush is different from normal brush?  
The contact resistance should be very low for shaft earthing brush, to prevent even small current through the oil film, so used copper magnite brush or silver carbon brush.
- What is the necessity of shaft voltage measurement?  
It is to observe insulation of bearing 6 & 7 and hydrogen seal assembly. It requires minimum leakage current ( $<100\text{mA}$ ) through bearings and shaft seals to avoid pitting of bearings.  
If the leakage current  $>100\text{mA}$ , clean the insulation provided between bearing pedestal and seal housing with earth.
- Why generator stator having alternate arrangements of hollow and solid conductor?  
It ensures an optimum solution for increasing current and to reduce losses.
- What type of insulation is done for stator bars?  
Bar insulation is done with epoxy mica thermosetting insulation. This insulation is void free and possesses better mechanical properties. This insulation is more reliable for higher voltages. Conductors are provided with glass lapped strand insulation. After curing the insulation the epoxy resin (glue) fill all voids in the insulation.
- How corona discharge is prevented in generator insulation?  
To prevent corona discharges between insulation and the wall of the slot, the insulation in slot portion is coated with semi conducting varnish. This eliminates the formation of creepage sparks during operation and during HV test.
- Why Generator should run within capability region?  
Operating the Generator in excess of the capability curves will causes increase in copper temperature, thermal expansion and higher insulation stresses.
- How cooling is done for slip ring and brush gear?  
A centrifuge fan is mounted on the shaft in between two slip rings for ventilation of the slip rings and brush gear.
- What is the type of brush used in brush gear?  
Low co-efficient of friction and self-lubricating morganite grade carbon HM100. Now a day we are using LFC554 for economical reasons.
- What is the name of instrument used to measure conductivity?  
Gas chromatograph.

- What is the need of staggering of brushes and helical grooves?  
The need of staggering is for uniform wear of brush and slip rings. The helical grooves are provided to improve the brush performance by breaking air pockets. The forced ventilation fan removes carbon dust from the helical grooves.

- What is the purpose of shaft earthing and bearing insulation?  
The voltage generated in the shaft due to the leakage fluxes can circulate current through the shaft. If shaft earthing is not done the leakage current will flow through the bearings to ground and pitting of bearings will result. Hence bearing foundation and pipelines are insulated.
- What is the purpose of POLARIZATION INDEX (PI) value?  
It is used to assess the degree of dryness of windings. It depends on free ions in insulating material. Initially for a new insulator free ions are less and hence more resistance will be more. For old insulation initially free ions will be more depends on age and material and hence resistance will be less. So the PI value for new insulation will be more and for old insulation it will be less.
- What is the requirement of stator water electrical conductivity?  
The cooling water must have an electrical conductivity less than 2.5 micro mho/cm. One portable polishing unit consisting of mixed bed is also provided in the system to remove impurities and maintain stator water conductivity at a less value.
- What is the necessity of Seal oil system?  
The annular gap between stator and rotor of the generator are to be sealed to prevent hydrogen leak from the casing.  
Type of seal – ring type shaft seals  
Pressure of seal oil –  $4 \text{ kg/cm}^2$
- What is the pressure of rotor gas (hydrogen)?  
 $3.5 \text{ kg/cm}^2$
- What is the paint used in the surface and interior of enclosure and why it is?  
Matt black paint, for efficient heat dissipation.
- What is type of nut and bolts are used in IPBD?  
Non-magnetic stainless steel nut and bolts are used in IPBD to restrict magnetic effect at joints.
- Why flexible expansion joints are used in IPBD?  
To cater thermal expansion and contraction due to heating and to eliminate mechanical vibrations to the equipment.

- What are the salient features of IPBD?
  - a. This for a vital link between generator, GT, UAT, SPPT, SET and neutral grounding transformer.
  - b. The continuous enclosure operating at ground potential limits the leakage flux outside the enclosure to a very low value thereby eliminating the problem of inductive heating of magnetic materials in the vicinity of the busduct.
  - c. Shielding effect of the enclosure reduced the electromagnetic forces under fault conditions between bus to bus to a great.
  - d. The IPBD consists of high purity aluminium alloy bus supported by high strength porcelain insulator (24 kV class) within enclosure separates adjacent conductor by air. This eliminates phase to phase faults to a great extent.
  - e. Practically negligible inductive heating on adjacent steel structure.
  - f. High current carrying capacity. Because the conductors are of circular type having very little skin effect and has a very large cooling surface.
  - g. Conductors are painted with epoxy Matt black paint results in heat dissipation and the temperature rise is small and current carrying capacity is improved.
  - h. High dielectric strength as conductors are supported on porcelain insulators.
  - i. Air tight, watertight and dust free bus conductors. Hence maintenance is nil.
  - j. Separate parts erected IPBD. Hence changing parts makes it easy.
- Why neoprene rubber bellows are used in IPBD?

Neoprene rubber bellows are used near the terminals of the equipment and also at building wall from indoor to outdoor area to allow thermal expansion and to minimise vibrations.
- Why aluminium bus bars are silver-plated in IPBD?

Aluminium bus bars are silver-plated at flexible connection to prevent the galvanic corrosion and also for low contact resistance.
- Why seal-off bushings are used in IPBD?

To prevent interchange of air at different temperature and leakage of hydrogen or infiltration of dust into the bus duct.
- What are the precautions to be taken while working at SPPT?

PT trolley should be isolated very carefully so as to isolate secondary terminals first and primary (HT) terminals next. When primary isolated the arrangement in the trolley make ground connection and HT terminal will be discharged at the drawn-out position.

When fuse is blown the temporary earth should be done at the HT side of the fuse to replace the fuse. Because PT may be energised through secondary side.

- What is use of hot air blower in IPBD?  
To remove moisture and to prevent moisture condensation inside the duct at commissioning time or in long shutdown periods.

- What are the temperature limits for UAT and SPPT bus bar?

|                                 |                  |                 |
|---------------------------------|------------------|-----------------|
| 2 kA (UAT) & 1 kA               |                  |                 |
| Ambient temp                    | 45°C             | 45°C            |
| Maximum temp                    | 60°C             | 60°C            |
| Short circuit for 1 second temp | 200°C (max load) | 200°C(max load) |
| Bus material                    | Al alloy         | Al alloy        |
| Thickness                       | 15 mm            | 6 mm            |
| Dia                             |                  | 12.7 cm         |

- Specification of NGT & NGR.

NGT – 1 phase, natural cooled, indoor dry type, 16.5 kV / 250V, 50 kVA.

NGR – natural cooled, stainless steel grid type, 0.5Ω, 250V, 288A (continuous) and temperature rise allowed to 375 °C.

- Surge protector and potential transformer cubicle specification.

Surge protector – non-inflammable, synthetic liquid impregnated and hermetically sealed, 24KV, 0.25μ f (micro farad).

PT – 16500/√3 /110/√3 volts. Fuse – 24kv, 3.15A.

- How the power of the Generator can be varied?

Injecting inlet steam to the prime mover can vary active power. Reactive power can vary by the Generator main field voltage variation. An excitation change PF at which load is delivered.

Active power is produced by source and used effectively. VAR is the power used for magnetization of core of transformers, motors, generators, overhead transmission lines (capacitive), household appliances etc.

- What is the protection for IPBD?

Generator – GT overall differential protection.

- How the liquid in generator can be detected?

There are three liquid detection devices provided for the same purpose.

- Why and where the magnetic filter is provided in stator water circuit?

Magnetic filter is provided to catch the metal particles in stator water circuit, which are produced in the pipelines. This is mounted at the end of the circuit nearer to the inlet of the generator.

- What are the isolations required for working on IPBD/ Generator?

- a. Generator field breaker open and tagged.
- b. GT breaker open and earth switch closed.

- c. Barring gear motor stopped and tagged.
- d. Generator PT's isolated and tagged.
- e. CB 472 and CB 474 open and PT's are isolated and tagged.
- f. Before doing any work on brush gear 64F1 relay to be taken out.

- What are the futures of turbine generator?
  - a. Low heat drop
  - b. Moisture control (HP-0.26%, LP-3%.)
  - c. Turbine governing system
  - d. 70% steam dumping to the condenser to avoid reactor trip.
  - e. Gland sealing
  - f. LP exhaust hood cooling
  - g. Generator stator and rotor cooling
  - h. Hydrogen sealing
  - i. Static excitation

- What are the intervals for generator overhauling?
  - a. 1<sup>st</sup> inspection after 8000 hrs of working
  - b. 2<sup>nd</sup> inspection after 8000 hrs of 1<sup>st</sup> inspection
  - c. 3<sup>rd</sup> inspection after 24000 hrs of 1<sup>st</sup> inspection
  - d. 4<sup>th</sup> inspection after 48000 hrs of 1<sup>st</sup> inspection

- Write nameplate details of the main generator.

|                                           |          |
|-------------------------------------------|----------|
| Type                                      | THW-235  |
| kW                                        | 237700   |
| kVA                                       | 264000   |
| Voltage                                   | 16500 V  |
| Amps                                      | 9240 A   |
| Power factor                              | 0.9 lag. |
| Field voltage                             | 326 V    |
| Field current                             | 2755 A   |
| Insulation                                | Class-F  |
| Speed                                     | 3000 rpm |
| 50 Hz, 3 $\phi$ , double star connection. |          |

- What are the torque settings used in IPBD connection?

|                |       |           |           |
|----------------|-------|-----------|-----------|
| M12 (Nut bolt) | 4506  | 100 kg-cm | or 55 NM  |
| M16 (Nut bolt) | 9006  | 250 kg-cm | or 80 NM  |
| M20 (Nut bolt) | 18006 | 300 kg-cm | or 100 NM |

- Write critical speeds of turbine generator?

|                                |          |
|--------------------------------|----------|
| Generator rotor                |          |
| 1 <sup>st</sup> critical speed | 1283 rpm |
| 2 <sup>nd</sup> critical speed | 3600 rpm |
| Combined turbine generator     |          |
| 1 <sup>st</sup> critical speed | 1938 rpm |
| 2 <sup>nd</sup> critical speed | 2120 rpm |



|                                |          |
|--------------------------------|----------|
| 3 <sup>rd</sup> critical speed | 2385 rpm |
| 4 <sup>th</sup> critical speed | 2837 rpm |

- What type of governing system used in turbine and what are the purposes of the system?

Hydraulic governing system of centrifugal (speed) governor type is adopted in turbine.

Sensitive oil pressure to actuate centrifugal governor is  $6.1 \text{ kg/cm}^2$  (max). At  $6.7 \text{ kg/cm}^2$  relief valve is attached for on load testing.

Relay oil at pressure  $21 \text{ kg/cm}^2$  (max) is used to actuate HP CIES valve, governor valve, LP CIES valve and LP governor valves.

At speed of 2560-rpm governor system becomes effective and starts draining of sensitive oil to  $2.81 \text{ kg/cm}^2$  as speed is 2760 rpm and this is the governor take over speed. Once the speed takes over by governor, governor valves position comes to closing side and then CIES valves are opening fully. At this stage further opening of CIES valve does not change any speed of system and the speed depends only on governor valve opening position and speeder gear system.

HP speeder gear controls HP governor valves and LP speeder gear controls LP governor valves and closes fully when 6% over speed which starts when 3% over speeding.

The main purposes are as follows.

- a. Bring the TG to rated (synchronous speed) speed from rest.
  - b. Loading and unloading when synchronised.
  - c. Responding with grid frequency variations within design range and loading and unloading the machine so that grid frequency remains stable.
  - d. Limiting the load as per reactor load.
  - e. Protecting the machine from over speed and from sudden large load thrown off or trip.
  - f. Tripping the machine and bringing it on barring gear when event for not operation happens.
  - g. When synchronised the speed is regulated by speeder gear from BPC signal. Once synchronised the grid frequency and speeder gear controls the speed.
- Why inter-turn protection is provided along with differential protection in generator?  
Inter-turn protects two separate windings from the fault of the generator.
  - How patina formation is done.  
By injecting low excitation current of 50 Amps for half an hour interval to 250 Amps. (*Epoxy insulation in the stator winding absorbs no moisture*).

- What are the tests to be carried during PM checks of IPBD?
  - a) Physical inspection of bus for any spark or overheating or discoloration.
  - b) Physical inspection of copper braided flexibles for discoloration.
  - c) Physical inspection of inspection window gaskets, seal off bushings, supporting insulators, CT's, painting of IPBD.
  - d) Torque tightness of flexibles.
  - e) Connection tightness of CT's, SPPT cubicle, NGT cubicle, CT's master JB, and Generator terminal bushing connection.
  - f) Tightness of supporting insulator, seal off bushing, inspection windows
  - g) Inspection of rubber bellows
  - h) Electrical checks on SPPT, NGT, CT, mVDT of copper flexible connection.
  - i) Capacitance measurement of surge capacitor.
  - j) Healthiness checks of lightning arrestor.
  - k) HV test of IPBD
  - l) Tan-delta test of IPBD
  - m) IR value measurement
  - n) Cleanliness checks entire IPBD.
  
- What are the works to be done in generator in major overhauling?  
**Works on stator**
  - a) Hydro test (DM water at 5 kg/cm<sup>2</sup> pressure, leak acceptable is 5% for 24 hrs).
  - b) Hydro test of H<sub>2</sub> coolers (DM water at 4 kg/cm<sup>2</sup> for 30 seconds no leak is allowed)
  - c) Pneumatic test with mask air.
  - d) Drying out of stator conductor. Hot air blower is used.
  - e) IR value check.
  - f) Stator overhang portion inspection.
  - g) Inspection of Teflon tubes and rubber grummets.
  - h) Stator wedge tightness test with 200 grams hammer.
  - i) Inspection of RTD's.
  - j) Maintenance of end shields.
  - k) Hot air and hot water test of stator conductors to check whether flow through all stator conductors is uniform.
  - l) Measurement of IR and PI value.
  - m) Capacitance and tan-delta measurements.
  - n) Partial discharge test.
  - o) Winding resistance measurement.
  - p) DC step voltage.
  - q) ELCID (electromagnetic core imperfection detection) test.

**Works on Rotor**

- a) Nitrogen leak tightness test of CC bolts at 4 kg/cm<sup>2</sup>.
- b) Inspection of rotor slots.
- c) Purge test of rotor ventilation canals.
- d) DP test on slip-ring hub to detect micro crack.
- e) DP and Ultrasonic test on retaining rings to detect any cracks.
- f) Measurement of IR and PI value.
- g) Impedance measurement.
- h) Recurrence surge oscillograph.
- i) Winding resistance measurement.
- j) Slip-ring groove cutting and machining.
- k) Patina formation. Then OCC test.

- What is the purpose of tan-delta measurement?  
Insulation in electrical system has parameters such as Capacitance, Die-electric loss, and Power factor. By detecting the changes in these parameters failures can be revealed. In this tan-delta test measured quantities are dissipation factor, power factor, capacitance and dielectric power loss.  
The very purpose of this test is to detect moisture content in the insulation. This detects moisture and void in the insulation. This indicates amount of ionization.
- What is meant by partial discharge? How can be tested?  
Partial discharges are electrical sparks, which occur in gas voids within the insulation when the voltage is high enough. The discharges are partial since there is some insulation remaining to prevent a complete breakdown. Partial discharge can erode the insulation and therefore contribute to insulation ageing.  
This can be tested by electromagnetic probe, which is a detector that is sensitive to the radio frequency signals produced by the partial discharges within the winding. With this probe test it is possible to locate specific sites of deterioration within the winding when the winding is energized.

- What is the purpose of HV / leakage current test on stator?

This is to find out weakness in the stator winding. If the ambient conditions are right, and the insulation is weak, the leakage current will increase non-linearly.

The record of voltage versus leakage current provides the condition of the winding for present and future use and may permit prediction of breakdown voltage whether it is within or slightly above the test voltage.

HV test voltage =  $1.5 \times \text{rated voltage for AC}$

And DC voltage =  $(2E + 1 \text{ kV}) 1.6$

Where E – rated voltage.

1.6 – AC/DC conversion factor.

Application of HV voltage also depends on the age factor or condition of the machine.

Following are the findings of HV test.

- a) Capacitance charging current.
- b) Dielectric absorption current.
- c) Surface leakage current.
- d) Partial discharge current.
- e) Volumetric discharge current.

In HV test starting leakage current should be more than switching off current in  $\mu$  Amps.

- What is Recurrent Surge Oscillograph (RSO) Test?

RSO test is performed to detect faults in rotor windings. The electrical faults in generator rotors fall into two main categories. The faults from the winding to the body and the faults between the parts of the winding (inter-turn faults). The existence of the faults will frequently display excessive mechanical vibration and cause serious concern.

- What is the purpose of rotor AC Impedance measurement?

Periodic measurement of rotor impedance using an AC power supply is another means of detecting the presence of shorted turns in a rotor winding. Impedance measurement is more sensitive than the resistance measurement for the detection of shorted turns. This is because the induced backward current in a single shorted turn opposes the MMF of the entire coil, thus greatly reducing the reactance.

- What is IR and PI value? Why it is measured?

IR It is the ratio of the DC voltage applied between the terminals and ground to the resultant current. When the DC voltage applied three components flow,

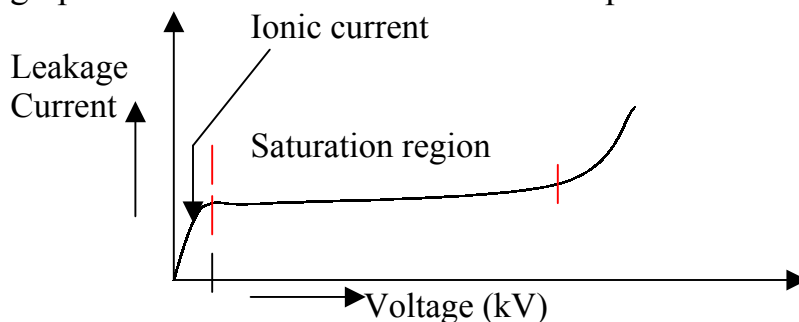
- a) A charging component flows into the capacitance of the winding.
- b) A polarization or absorption current involving in the insulation molecular mechanism.
- c) A leakage component over the surface between exposed conductor and ground which is highly dependent on the state of dryness of the winding.

The first two current components decay with time. The third component is determined by the presence of moisture or ground fault and relatively constant with time. Moisture may be with in the insulation or condensed on the end windings or connection surfaces, which are often dirty. If this leakage current is larger than the first two components then the total charging current will not change significantly with time. Thus to determine how dry and clean the winding, IR is measured after one minute and after 10 minutes. The ration of the 10 minutes reading over the one-minute reading is called the PI (Polarization Index).

PI value detects relative condition of insulation with respect to moisture and other contaminants.

- What is the generator IR value when generator is filled with stator water and hydrogen?

Generator IR when filled with stator water and hydrogen is about 100 k $\Omega$  only. That is because most of the gases and liquids are self-restoring insulators. As we are measuring insulation with 1 kV or 5 kV megger, the ionic current or leakage current will be same and the IR value will be approximately same. As we are increasing the test voltage to higher value say to 100 kV the breakdown point will occur as in the graph and insulators will breakdown or puncture.



Water and hydrogen are self-restoring insulators. First we are measuring insulation on 1 kV voltage i.e. 100 k $\Omega$ . As the field voltage and stator voltage raises the heat produced in the stator and rotor will increase the IR value of the machine in running condition.

So ionic current region needs 1 kV/cm, saturation region moderate voltage (1 kV to 70 kV), and breakdown region is above 70 kV voltage.

- What is the purpose of DC winding resistance test?  
To detect the shorting of winding and loose or poor connection of the windings.

- What are the types of Grounding?

**Equipment grounding** is the grounding on non-current carrying metal parts. This is done for personnel safety of the operator and for the equipment safety by blowing the fuse when earth fault current flows through the fuse.

**Neutral Grounding** is done to protect the equipment against arcing grounds, to protect system from lightning surges by passing surge current through the earth and to protect against unbalanced voltage with grounds. When fault occurs the system voltage increases  $\sqrt{3}$  times. This gives stress on the system and failure of the insulation if the neutral grounding not designed properly.

Mainly there are three types of neutral earthing

- a) Directly
- b) Resistance
- c) Reactance

- What is Arcing Grounds?

When earth faults occurs, arc with the ground and phase will occur. The arc extinguishes and restrikes as a repeated and regular manner. This is called Arcing Ground.

- How neutral grounding adopted?

For above 3.3 kV and below 22 kV resistance grounding is preferred. In this voltage level capacitive ground current is not large, so reactance grounding is not used.

For below 3.3 kV that for 415 V external resistance earthing is not necessary. Because normal earthing (plate earthing) gives  $1.5\Omega$  resistance. This limits current to  $\frac{E}{R_0}$

$$\Omega$$

$230/1.5=153\text{A}$ (Current limit without resistance).

For above 22 kV solid or direct grounding is used.

Reactance grounding is used where capacitive currents are large instead of resistance grounding in transmission lines, generators etc. to neutralize capacitive current by adding reactive current.

- How main generator earthing is done?

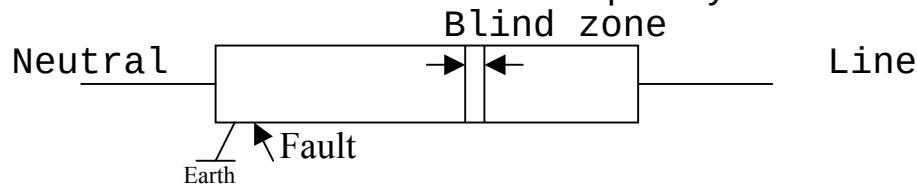
Generator neutral earthing is done through transformer and earth fault current is limited through resistance, which is connected across the secondary of the transformer. Generator 16.5 kV earth fault current is isolated from 220 kV through GT. Only star point of the generator is grounded.



- How generator earth fault relay works?

100% earth fault relay works on the principle involving monitoring of neutral side and line side components of 3<sup>rd</sup> harmonic voltages produced by generator in service. Since the machine is grounded with reactance  $X_L$  (transformer), a flow of 3<sup>rd</sup> harmonic current is there in between ground and the machine neutral. Under healthy condition the line and neutral impedance  $Z$  are fixed. Thus the 3<sup>rd</sup> harmonic voltage ( $V_s$ ) at machine line ( $V_{L3}$ ) and neutral end ( $V_{N3}$ ) should bear a constant ratio. When a fault occurs in the machine winding the distribution of  $V_{L3}$  and  $V_{N3}$  undergoes a change from that a healthy condition. In the extreme case if a fault occurring on the machine neutral side,  $V_{N3}$  becomes zero and  $V_{L3}$  becomes  $V_s$  and vice versa.

The fault in Blind zone will be detected by  $V_{L3}$  neutral displacement module, which is tuned to find frequency.



- How generator protections are classified in nuclear power station?

Classification of generator protection in nuclear power station.

**1. MAIN Protection**

Stator E/f  
Loss of Excitation  
Pole slipping  
Differential  
Inter turn  
Unbalance current

**3. START UP Protection**

Phase o/c during startup  
E/F during startup

**2. BACKUP Protection**

Back up Impedance  
Over Voltage  
Under Freq.  
Over freq.

**4. EXCITATION Protection**

Excitation transformer over current  
Rotor E/f. and Rotor o/v  
48 V DC fail  
more than 3 Bridge fail (¾ logic)  
Manual channel fails  
Transformer over temperature (Class –B)

- State torque formula.

$$\text{Torque (T)} = k_T * S * I_R * \cos\theta$$

Where T = Torque in pound – feet

$k_T$  = Torque constant.

S = stator flux

$I_R$  = Rotor current

$\cos\theta$  = Rotor power factor

- How main generator protection grouped?

The various protections associated with the generator, Generator transformer and Unit transformer are connected to a trip unit through trip relays 86A, 86B and 86C.

The protective levels of generator are in three classified groups Class A, Class B and Class C protections which involve fault in the generator, Generator transformer and requires high speed clearance are grouped under Class A. These are routed through trip relays 86A. This trips generator transformer HV side breaker, generator field breaker, and LV side breaker of UT and Turbine simultaneously.

Certain protections such as loss of excitation, negative sequence protection, over-fluxing etc., can tolerate sequential tripping of turbine followed by the generator such that the entrapped steam in the turbine is fully spent before generator is tripped and reduces the risk of over speeding of the turbine. These protections are classified as Class B. These are connected to operate on trip relay 86BG. This relay initiates the tripping of turbine (closure of stop valves) and also the LV side breaker of UT through trip relay 86B1 and 86B2. After turbine stop valves are closed and the entrapped steam is spent, the output power of the generator will come down and is sensed by under power relay 32A and 32B. These interlocks are wired in series with the Class B trip relay 86B, which is wired to trip the generator breaker, generator field. Obtaining better security, the Under Power interlock circuits are duplicated. Some protections such as Bus bar differential, generator under frequency etc, requires tripping only of the 220 kV side of the generator transformer to isolate the external fault. These are classified as Class C. These protections are wired to trip relay 86C, which initiate only the tripping of the generator transformer HV side breaker. During Class C trip, the generator will come on House load mode of operation.

- What are the generator protection parameters?  
Generator protection parameters are as follows.

**GENERATOR PROTECTION SCHEME**

| CLASS A1                                     | CLASS A2                            |
|----------------------------------------------|-------------------------------------|
| Gen. rotor earth fault (64F2)                | Stator O/C during start (50S ABC)   |
| 100% stator earth fault (64A)                | Stator E/F during start (64 C)      |
| GT restricted earth fault (64 GT)            | Stator backup E/F (64 B)            |
| UT restricted earth fault LV A (64 UT A)     | GT backup O/C (50/51 GT)            |
| UT restricted earth fault LV B (64 UT B)     | GT backup E/F (51 N GT)             |
| Gen. differential (87 G)                     | Gen. backup impedance (21G – 1 ABC) |
| Gen. interturn (87 IT)                       | Gen. field fail with U/V (27/40G)   |
| GT overall differential (87 GT)              | UT backup O/C (51 UT ABC)           |
| UT differential (87 UT A/B/C)                | UT backup E/F LV-A (51N LV-A)       |
| Reverse power (37 G)                         | UT backup E/F LV-B (51N LV-B)       |
| GT buchholz, OLTC oil surge, fire (30 A/G/D) | LBB protection (50 Z)               |
| UT buchholz, fire (30 A/D)                   |                                     |
| Excitation O/C stage – 2                     |                                     |
| Rotor + & - ve over voltage                  |                                     |
| Excitation 48 V DC fail                      |                                     |
| More than 3 bridge fails (3/4 logic)         |                                     |

| CLASS B                                  | CLASS C                                  |
|------------------------------------------|------------------------------------------|
| Gen. field failure without U/V (40 G)    | Gen. backup impedance stage – 2(21G – 2) |
| Gen. negative phase sequence (46 G/GT)   | Gen. pole slip (78G)                     |
| Gen. over frequency (81 – 3)             | Gen. under frequency (81 – 1 / 2)        |
| GT over fluxing protection (99 GT)       | GT backup earth fault (51N GT)           |
| GT oil temp / winding temp high (30 C/E) |                                          |
| UT oil temp / winding temp high (30 C/E) |                                          |
| Low forward power (32 B/A)               |                                          |
| Turbine process parameter trip (86 BG)   |                                          |
| Excitation transformer temp high         |                                          |
| Manual channel fails                     |                                          |
| Excitation transformer O/C stage – 1     |                                          |
| Regulation under test                    |                                          |

- State class – B process side trip parameters.

| Sl  | Parameter                  | Normal Value             | Low Value                | High Value | Trip Value                |
|-----|----------------------------|--------------------------|--------------------------|------------|---------------------------|
| 1.  | Reactor trip +             |                          |                          |            | 200 milli sec             |
| 2.  | Reheater steam Pr. High    | 5.4 kg/cm <sup>2</sup> c |                          |            | 5.75 kg/cm <sup>2</sup>   |
| 3.  | Exhaust hood steams temp.  | 93°C                     |                          |            | 149°C                     |
| 4.  | Lub. oil Pressure low      |                          |                          |            | ≤0.35 kg/cm <sup>2</sup>  |
| 5.  | Relay oil pressure low     | 21 kg/cm <sup>2</sup>    | 17.38 kg/cm <sup>2</sup> |            | ≤ 3.5 kg/cm <sup>2</sup>  |
| 6.  | Trust bearing ΔP high      |                          |                          |            | ±9.114 kg/cm <sup>2</sup> |
| 7.  | Condenser vacuum low       | 696.5 mm Hg              | 660 mm Hg                |            | 559 mm Hg                 |
| 8.  | Stator water cond. High    | 5 μ Mho / cm             |                          | 13.3μ Mho  | 20 μ Mho                  |
| 9.  | Stator water flow low      | 30 M <sup>3</sup> / hr   | 21 M <sup>3</sup> / hr   |            | 17 M <sup>3</sup> / hr    |
| 10. | Boiler level high 2/3 trip |                          |                          |            |                           |

- What are the manual trips required from the generator side?

| Quantity                                                           | 1 <sup>st</sup> ann. | Action/2 <sup>nd</sup> ann. | Action              |
|--------------------------------------------------------------------|----------------------|-----------------------------|---------------------|
| Bearing babbitt temp. high                                         | 75°C                 | 80°C                        | >80°C manual trip   |
| Bearing outlet oil temp. high                                      | 60°C                 | 65°C                        | >65°C manual trip   |
| Generator seal oil inlet temp                                      | 45°C                 |                             | >45°C manual trip   |
| Presence of liquid in Gen.                                         |                      |                             | Manual trip         |
| DM water outlet temp                                               | 85°C                 | Unload                      | >85°C Rundown trip  |
| Stator winding temp high                                           | 75°C                 | Unload                      | >75°C Rundown trip  |
| Hot gas temp high                                                  | 75°C                 | Unload                      | >75°C Rundown trip  |
| Stator core temp high                                              | 95°C                 | Unload                      | >105°C Rundown trip |
| Rotor winding temp high                                            | 110°C                | Unload                      | >110°C Rundown trip |
| Temp of cold hydrogen gas                                          | 55°C                 | Unload                      | >55°C Rundown trip  |
| Temp of inlet water to gas coolers                                 | 37-48°C              | Unload                      | >48°C Rundown trip  |
| Temp of inlet water to stator winding                              | 44-48°C              | Unload                      | >48°C Rundown trip  |
| Generator seal oil outlet temp                                     | 65°C                 |                             | >65°C manual trip   |
| Purity of hydrogen in casing                                       | <97%                 | <95%                        | <95% manual trip    |
| *Unload – Decreasing load to a lower value manually                |                      |                             |                     |
| *Rundown – Reducing load to no-load condition (manually/automatic) |                      |                             |                     |

- Why boiler level high trip has been provided in turbine?

In condition of boiler level high moisture contents in the steam will rise and rise in moisture content is harmful to turbine.

- What are the characteristics of protection system?

### **CHARACTERISTICS OF PROTECTIVE SYSTEM**

Protective relaying is an important requirement in power generation, transmission and distribution, which identifies the exact location of the fault and give command for isolating the faulty portion very close to the fault by sensing variations in electrical quantities for ensuring safe operation. The protective relay should have the following characteristics:

#### **a) Reliability**

The protective relay should operate positively and isolate the faulty portion of the power system as and when required.

#### **b) Selectivity**

Protection is arranged in zone, which should cover the power system completely, having no part unprotected. When a fault occurs the protection is required to select and trip the only the nearest circuit breaker.

#### **c) Stability**

This term, applied to protection on distinct from power network, refers to the ability of the system to remain inert to all load conditions and fault external to the relevant zone.

#### **d) Speed**

The function of automatic protection is to isolate fault from the power system in a very much shorter time than could be isolated manually, even with great deal of supervision.

#### **e) Sensitivity**

Sensitivity is a term frequently used when referring to the minimum operating limit of a complete protective system. A protective system is said to be sensitive, if the primary operating current is low.

- What are the working principles of generator main protections?

## **GENERATOR START UP PROTECTIONS**

### **SUPPLEMENTARY PROTECTION OF GENERATOR**

The generator is normally expected to run rated speed before excitation power is applied by closing the field breaker. However the residual magnetism in the field circuit may provide small voltage build up even when the machine is run upto its rated speed without excitation. At this stage fault if any in the generator stator circuit may not be sensed by the regular protection, as most of the relays are having higher current ranges. Hence separate protection (Phase & Ground) are provided with low current ranges.

#### **a) PHASE OVER CURRENT PROTECTION**

The CT current is stepped down by an internal CT and converted to voltage signal. The signal is compared with the internal reference. The protection is interlocked with the auxiliary relay for the generator transformer breaker closed position to ensure that the protection is inoperable when the machine is synchronized to grid.

#### **b) GROUND FAULT PROTECTION DURING START UP**

The generator neutral current as measure in series with the resistance of the secondary of the earthing transformer is fed to the relay through CT. CT current is converted to a voltage. This is compared with the internal resistance references. This protection also interlocked with generator breaker position to ensure that the protection is inoperable when the machine is connected to grid.

**OTHER PROTECTIONS****a) STATOR EARTH FAULT PROTECTION (64A, 64B, 64C)**

The conventional unit type generator has the neutral earthed through a resistance loaded distribution type transformer. For a single ground fault near the neutral end of the winding, there will be proportionately less voltage available to drive the current through the ground, resulting in a lower fault current and lower neutral bus displacement voltage.

Low magnitude of fundamental ground current may flow under normal conditions, possibly due to generator winding imbalance or due to fault on HV side of generator transformer or on the secondary of generator PT. Under these conditions, the generator should not be removed from service. To allow for these low magnitude earth fault current, trip setting of the overvoltage ground relay are set to detect neutral displacement voltage in excess of 5-10% of the phased neutral voltage.

If an earth fault occurs and undetected because of its location or otherwise, the probability of second earth fault occurring is much greater. The second earth fault may result from insulation deterioration caused by transient over voltage due to erratic, low current, unstable arcing at first fault point. The second point may yield current of larger magnitude.

A 100% stator earth fault protection is designed to detect earth fault occurring in the region of the machine windings close to the neutral end. Composite static modular relay that gives 100% earth fault protection of the machine, whose neutral is directly earthed. It works on the principle of monitoring the neutral side and the line side of the component of third harmonic voltage produced by the generator in service.

## **OPERATING PRINCIPLE**

Alternating Current generator in service produces a certain magnitude of third harmonic voltage in their winding. However no third harmonic voltage appear across the star/delta connected generator, though there will be a certain magnitude of third harmonic voltage between each phase and ground of the machine output. This voltage in case of machine earth through high impedance can cause the flow of third harmonic current between the ground and the neutral. In fact under normal healthy operating condition the third harmonic voltage generated in the machine is shared between the phase to ground capacity impedance at the machine terminal and neutral to ground impedance at the machine neutral.

The figure-1 shows the third harmonic voltage distribution during normal working conditions.

$V_3$  = Generated third harmonic voltage.

$VL_3$  = Third harmonic voltage at machine line end.

$VN_3$  = Third harmonic voltage at machine neutral end

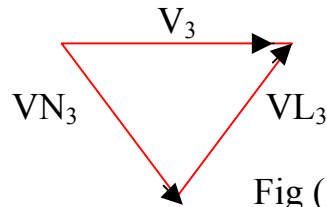


Fig (1)

Whenever fault occurs at the point (Figure-2) say F on the machine winding, the voltage distribution  $VN_3 / VL_3$  undergoes a change from that during the running condition. In the extreme case of a fault occurring on the machine neutral, the  $VN_3$  becomes zero and  $VL_3 = V_3$ . Similarly when the fault occurs on the phase terminal,  $VN_3$  become equal to  $V_3$ . The change in 3<sup>rd</sup> harmonic voltage will sense the relay and trip the generator.

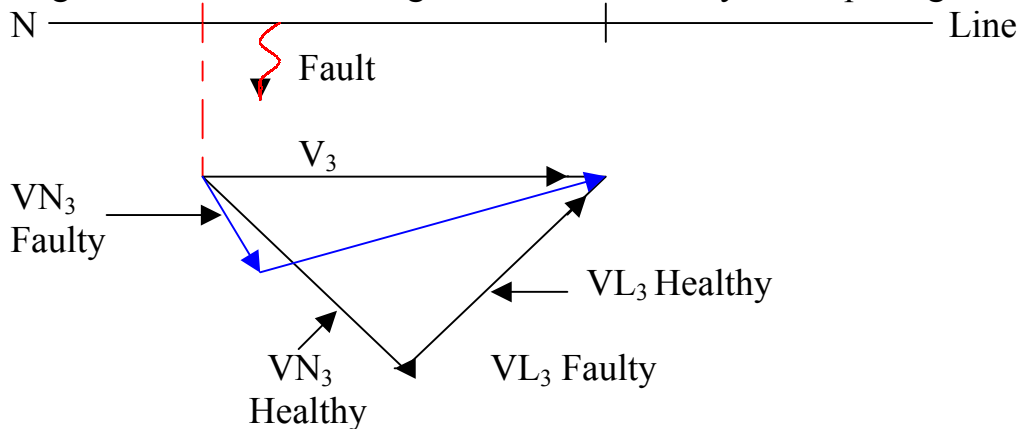
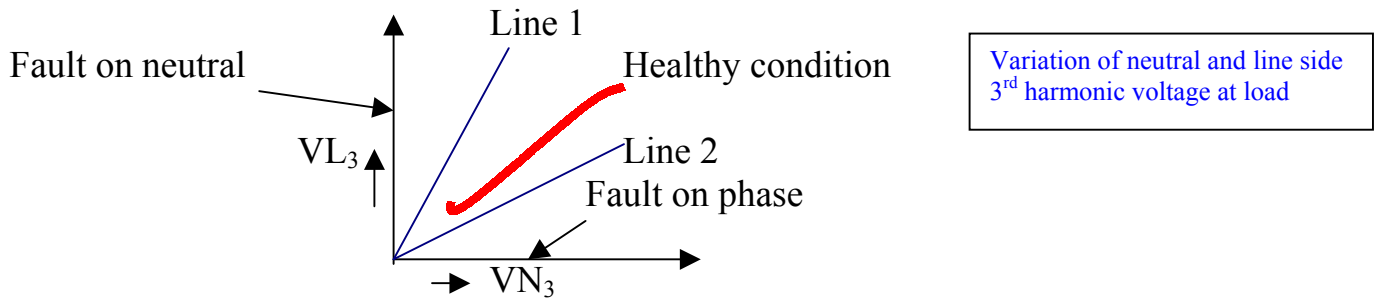




Fig (2) 3<sup>rd</sup> harmonic voltage distribution during healthy and faulty condition.

Figure-3 shows the  $VN_3$  Vs  $VL_3$  plot under healthy condition, it is clear that in order to remain stable under healthy condition, the relay should restrain within the two lines  $L_1$  &  $L_2$ . The slopes of two lines are suitably set to ensure stability.



The fault scheme of main generator is having first relay 64A, covers 100% of the stator winding, the 2<sup>nd</sup> relay 64B covers 0-90% of stator winding from phase terminals. The 3<sup>rd</sup> relay 64C used for the protection of stator earth fault during start-up.

**b) GENERATOR UNBALANCE PROTECTION (46)**

Negative phase sequence current in the stator of generator due to unbalance load, fault, induces double frequency eddy currents in the rotor. This current if allowed to persist, can cause serious over heating. The unbalance protection relay disconnects the machine before such excess over heat. In order to avoid unnecessary tripping of the machine, the time characteristics of the relay should match the heating characteristics of the machine. The neg. phase sequence current creates magnetic flux wave in the air gap, which induces current in the rotor body iron. These currents with twice rated frequency tend to flow in the non-magnetic rotor wedges and retaining rings. Heating occurs in these areas due to watt loss and quickly raises the temp.

**DESCRIPTION**

Figure-1 shows the block diagram of the unbalance protection relay. The input from the CT which are connected in the each phase of the generator supply (Fig-2) are fed to a negative sequence filter (Fig-3) which gives an a.c. output voltage proportional to the negative sequence current. This voltage is rectified, smoothened and fed to the squaring unit of the main measuring element, the time delay circuit and the alarm unit.

The output of the squaring circuit is proportional to the square of the input voltage and is applied directly to the main timing circuit to give the required relation ship between  $I^2t$  and relay operating time (t).

The voltage upto, which the timing capacitor charge depends upon the voltage, applied from the squaring circuit. This means that even when the negative current is less than the relay setting, the timer circuit will partially charges and reduces the relay operating time when the current exceeds the setting value.

When the output exceeds the reference voltage it provides one of the input to a 2-input AND gate. The other input comes from the 0.3-sec timer, which is activated by the timer starter unit when the relay setting exceeds the relay setting. When the both inputs to the AND gate are present the relay will operate and trip the generator from fault.

**OPERATING PRINCIPLE**

The negative sequence filter shown in Figure-2 is connected in delta to eliminate the effect of zero sequence currents. A fourth auxiliary transformer is provided to get a phase shift of  $180^\circ$  Ic – A in figure-3. Vector diagram of both positive and negative sequence current in the filter are shown in figure-4&5. It can be seen that the output produced when negative sequence current is present, but zero when the current are of positive sequence.

**c) GENERATOR FIELD FAILURE PROTECTION (40)**

Loss of field supply to a synchronous generator can be caused by a fault in the excitation circuit or by incorrect opening of field breaker. On loss of field, the machine operates as an induction generator excited by the reactive power drawn from the system to which it connected. This could result in instability of power in the system and overheating the rotor.

One parameter which changes significantly when the machine is subject to severe loss of excitation is the impedance measured at the terminals and it move into the negative reactance area. The relay is set to detect this abnormal operating condition using its circular impedance characteristics, which lies in the negative reactance area.

**OPERATION**

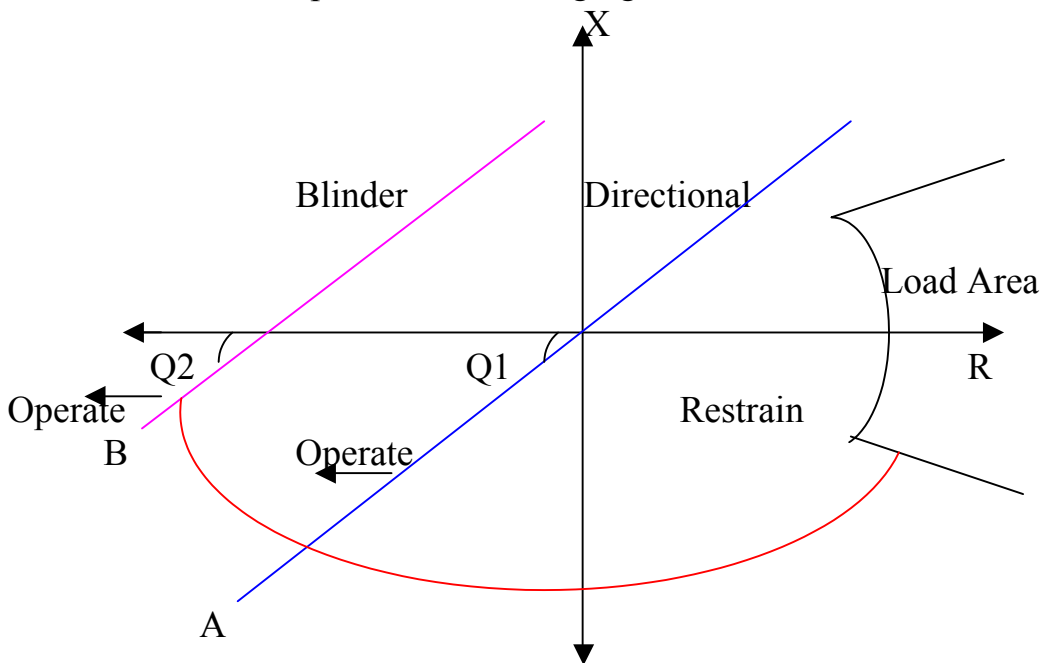
Figure-1 shows the fundamental block diagram of the relay vector  $V$  and  $I$  are voltage and current input to relay terminal. The input to the relay current circuit is through a CT ( $T_1$ ), which is tapped on the both the primary, and the secondary windings to give a course ( $K_3$ ) and medium reach ( $K_2$ ) setting of the relay. The relay characteristic angle is continuously variable from  $45^\circ$  to  $75^\circ$  lagging by means of a potentiometer ( $Q$ ). The forward reach of the relay ( $Z$ ) is continuously variable by means of potentiometer ( $K_1$ ) in the voltage-restrained circuit of mixing transformer ( $T_3$ ).

Output vector  $S_2$  proportional to the vector  $V \pm I Z$  of the voltage mixing transformer ( $T_2$ ) forms the second input signal of the phase angle comparator. The comparator is a 2-input block average comparator and operates by comparing the signal vector  $S_1$  &  $S_2$ . The output of the comparator is fed into a squaring amplifier whose output switches ON for a positive input and OFF for a negative input. The output waveforms of the amplifier are varying mark/space square wave, mark/space being equal for  $90^\circ$ -phase angle difference between two inputs. The squared output is averaged by an auxiliary element set to just to operate for an equal mark/space ratio. The current build up in the inductive auxiliary coil to reach the operate level only if the ON period are longer than the OFF period. The L/R ratio of the auxiliary coil and pick up level are accurately set. The output auxiliary relay then picks up if the phase angle between the signal vector  $S_1$  &  $S_2$  are  $90^\circ$  or more as shown in figure-2. Fig-3 shows the typical circuit connection for field failure protection of generator.

## d) GENERATOR POLE SLIPPING PROTECTION (78)

Sudden occurrence in the electrical grid such as rapid load changes, short circuit interruptions, which destroy the equilibrium of the energy balance are usually followed by oscillations. If the system stability is retained, the stationary stage will take over. If the oscillations are not stable, a loss of synchronism of one or more machine will result. If the angular displacement of the rotor exceeds the stable limit, the rotor will slip a pole pitch. Pole slip occurs and excitation is maintained the machine will oscillate strongly on reactive and active power side.

This relay operates on the principle of measuring impedance course on R-X diagram and operates to trip on pole slipping condition. The scheme consists of two numbers angle impedance relay and a timer to distinguish between pole slipping and power swing blocking condition. When gen. Losses synchronism the resulting high current picks and off freq. Operation can cause winding stresses, pulsating torque and mechanical resonance that have potential of damaging the Turbine Generator.



Generator pole slipping protection

## e) GENERATOR DIFFERENTIAL PROTECTION (87G)

This is a high-speed differential protection, the relay of high impedance is provided for this protection. The high impedance principle is used for thorough fault stability even under current transformer saturation.

This protection has an operating time of 25 millisecond at 5 time's current setting. A non- linear resistance is connected across the relay to limit the over voltage during internal fault.

This protection covers phase to phase and 3-phase faults. It does not cover phase to ground fault as the ground fault current is limited to a very low value. This protection energizes Class-A trip.



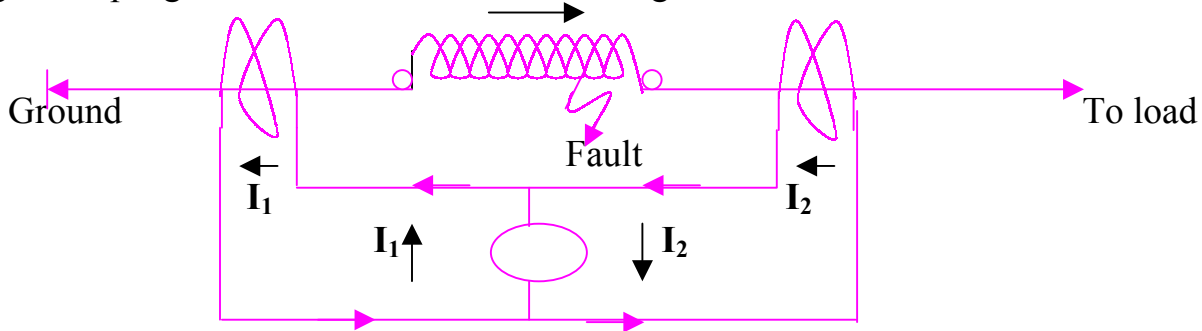
**f) GENERATOR INTER TURN DIFFERENTIAL PROTECTION: (87 GI)**

This protection is by means of a differential current relay connected across cross-connected CT on the two parallel winding of each of the phase of the generator as shown in figure-2. The relay which is used for the protection is of high impedance circulating current type with an operating speed of 25 millisecond at 5 times the current setting. A non-linear resistance is connected across the relay to limit the over voltage during the internal fault. This protection energizes Class-A trip.

**PRINCIPLE OF OPERATION (DIFFERENTIAL)**

Fig-3 shows the simplified diagram of differential current protection of generator winding, the CT's of both end of the generator winding will sense the current which is flowing through the stator winding. During normal balanced condition the current vector  $I_1$  &  $I_2$  are equal and opposite so the resultant forces experiences in the coil of the relay  $R$  is zero.

When the fault 'F' occurs on the stator winding, the differential current will be sensed by the CT and these differential current passes through the operating coil of the relay which gives trip signal to the circuit breaker of the generator.



**$I_1 + I_2 = 0$  Normal condition**

**$I_1 + I_2 = I_3$  Faulty condition**

## **GENERATOR BACK UP PROTECTIONS**

### **a) UNDER FREQUENCY PROTECTION (81)**

The U/F limitations however are less restrictive than the limitations on the turbine. A turbine blade is designed to have its natural frequencies sufficiently displaced from rated speed and multiples of N (speed) to avoid a mechanical resonant condition that could result in excessive mechanical Stresses in blades

This is a three stage under frequency protection, which consists of a time delay unit and 3 timer. The three stages of frequencies are ranging from 47 to 50 Hz. The timer which gives the cumulative operating time of turbine during under frequency which calls for turbine inspection/maintenance as per the design formula.

$$(48.5-F) t < 3.$$

Where F is the frequency,

t is the timer duration in seconds.

From the above formula, it can be seen that the turbine can be operable at 48.5 Hz continuously at rated load. The cumulative timer which gives alarm in Data acquisition system then call for turbine inspection.

### **OPERATING PRINCIPLE:**

The operating principle of the relay is the comparison of the incoming frequency with that of a pre-set value of time derived from the oscillator of the relay.

The incoming frequency signal is connected to an input circuit, which then drive an impulse generator to produce pulse at the beginning of each period of the input voltage.

The preset time interval is obtained from an oscillator and counter, adjustment is achieved using selector switches, which drives the decoder circuit.

A comparator compares the two-time interval and this triggers an adjustable timer, which then operate the output voltage. An under voltage detector inhibits the relay when the incoming signal drops below the preset value.

### **b) OVER FREQUENCY PROTECTION (81)**

Generator over frequency protection is provided to limit the over speeding of turbine, which leads to greater vibration due to resonance. The over speeding and vibration leads to mechanical damage of turbine bearings and blades. This protection schemes also similar to under frequency. The preset time of over frequency operation is more than the preset time of under frequency protection.

### **c) GENERATOR OVER VOLTAGE ALARM (59)**

This protection give time delayed alarm for continuous operation of the generator at more than permissible voltage of AVR failure or during manual control of excitation.

### **d) GENERATOR ANTIMOTURING PROTECTION (32)**

Motoring results from low prime mover input to generator. While generator is still in line. When this input is less than no load losses deficiency is supplied by absorbing real power from the system. Since the field excitation should remain same, The same reactive power would flow as before the motoring and generator will operate as a synchronous motor driving the turbine. Generator will not be harmed by this action but turbine can be harmed through over heating. It is detected by low forward power relay.

### **EXCITATION SYSTEM PROTECTIONS**

The generator is provided with static excitation, which obtains the necessary excitation power from the excitation transformer, which rectifies and feed the AC power through controlled rectifier circuits.

#### **a) EXCITATION TRANSFORMER OVER CURRENT PROTECTION:**

Time delayed over current protection with instantaneous high set unit is provided for the short circuit protection of the excitation transformer, which trips the field breaker by energizing class-B trip.

#### **b) ROTOR OVER VOLTAGE PROTECTION:**

This protection is envisaged to limit over voltage occurring in the field circuit during excitation of the field an air gap arrestor with a series resistor is connected across the field. On overvoltage the gap flasher over and the arrestor connects the resistor directly across the field.

This over voltage is not due to the field forcing. Field forcing will happen only when PT actual voltage value comes down due to the PT fuse drop or due to any other reason. At that time PT voltage is 110 V – drop. That is actual voltage value is less and field forced to increase the voltage. Field forcing value is twice the actual value after looking the system healthiness. Means in some earth faults in the grid, the voltages may come down to 110 kV and PT will sense this voltage as the generator is synchronised with the grid. This will force the field of the generator to match the generator actual voltage. If the fault not cleared the generator will trip after some time delay. This is generator field forcing. But in some grid disturbances or power swing conditions the stator and rotor voltage and current changes. This will induce some voltage in rotor. This protection is used to protect machine from this type of over voltage.

#### **c) ROTOR 1<sup>ST</sup> EARTH FAULT PROTECTION**

A single earth fault is not in itself dangerous since it does not cause fault current, but a second earth fault effectively short circuits parts or all of the field system and the unbalancing of the magnetic forces causes. That force may be sufficient to spring the shaft and make it eccentric. If the condition were allowed to persist, however it might lead to severe mechanical damage.

The method of detecting rotor first earth fault using the principle of negative biasing, where by an earth fault anywhere in the field circuit can be detected. The dc injection supply establishes a small bias on the alternator field circuit so that all points are negative with respect to earth.

The rectified output of the supply provides a biasing potential of approximately 65V. This is connected with a positive terminal to earth and negative terminal to the positive terminal of the field circuit through a relay. When the fault occurs, the current flows through the relay coil which intern operate the circuit breaker. This relay will not operate



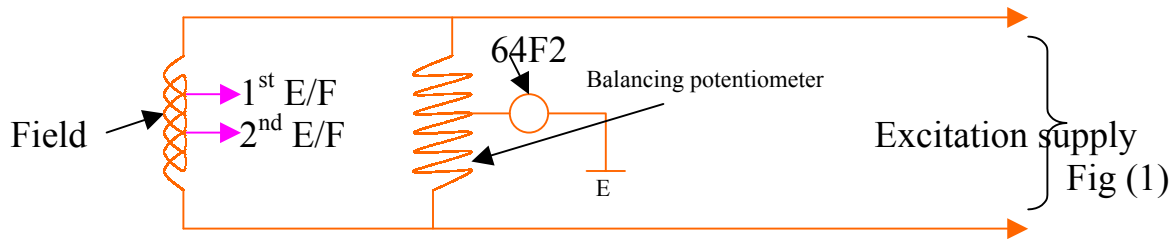
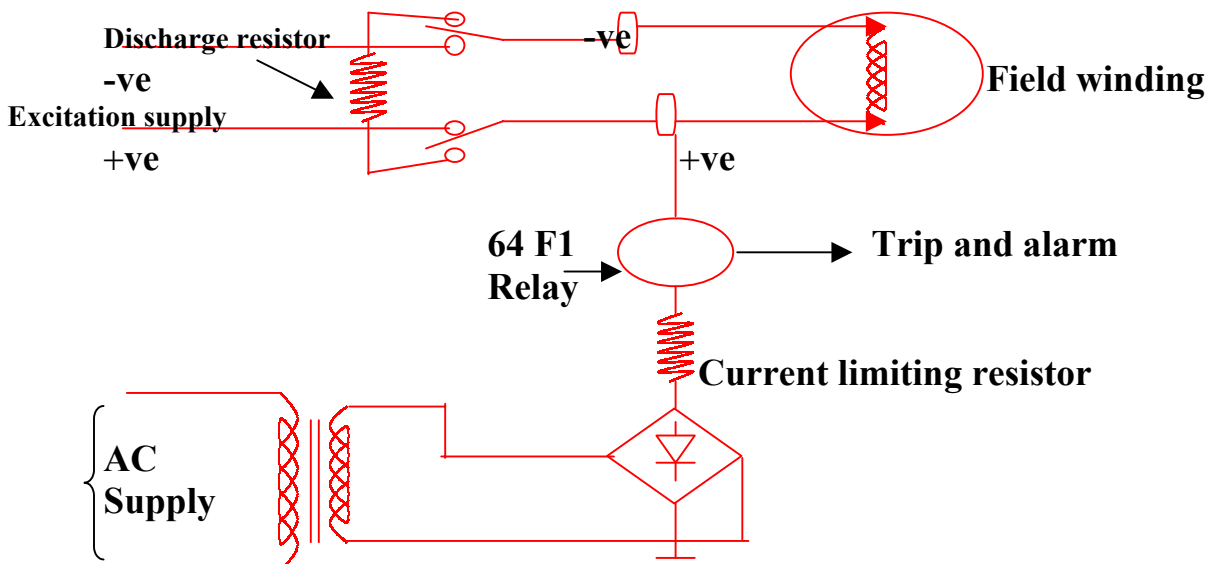
on auxiliary supply failed condition, during that time the relay will give annunciation in main control room.

**d) ROTOR 2<sup>ND</sup> EARTH FAULT (64F)**

While the machine is continuous in service with one earth fault, appearance of 2<sup>nd</sup> earth fault will severely affect the magnetic balance in the air gap and result in rotor distortion and severe damage. Hence it is advisable that the machine taken out of service as early as possible after appearance of 1<sup>st</sup> earth fault. However, to take care of the situation of 2<sup>nd</sup> earth fault appearing immediately after 1<sup>st</sup> stator earth fault before the machine is taken out, 2<sup>nd</sup> rotor earth fault protection is provided. This protection system normally disconnect the field effect and has to be switched ON when 1<sup>st</sup> earth fault appears.

The scheme consists of a bridge circuit which to be balanced manually with the 1<sup>st</sup> rotor earth fault in the machine. This balance is disturbed when the 2<sup>nd</sup> earth fault appears and the bridge null deflector initiate tripping of the circuit.

It can be seen in the below diagram the protection of the field winding on either side of the first earth fault and the balancing potentiometer forms a dc bridge with 64F2 (Relay) connected across the pair of opposite nodes.

**Fig (1)****Fig (2)**



## TRANSFORMER PROTECTIONS

### **a) OVERALL DIFFERENTIAL PROTECTION (87 GT)**

This protection which is used as the differential protection of the transformer, also covers the generator and unit transformer. The differential transformer protection measuring circuit is based on the well-known MERZ-PRICE circulating current principle.

Fig-1 shows the relay functional block diagram. The output from each bias resistance transformer  $T_3$  to  $T_5$  proportional to the appropriate primary line currents, are rectified and summed to produce a bias resistance voltage. Any resulting difference current is circulated through the transformer  $T_1$  &  $T_2$ . The output from  $T_1$  is rectified and combined with the bias voltage to produce a signal, which is applied to the amplitude comparator. The comparator output is in the form of pulses which vary in width depending on the amplitude of the combined bias and difference voltages where the measurement of the interval between these pulse indicate less than a preset time, an internal fault is indicated and a trip signal initiated after a short time delay ( $1/f$  sec), level set by the bias.

An unrestrained high set circuit, which monitors the differential current, will over ride the amplitude comparator circuit and operate the relay output element when the difference current is above the high set settings.

Fig-2 shows the basic circuit diagram of the differential protection and fig-3 shows the current direction of the restraint/differential transformers in the relay. The currents  $I_1$ ,  $I_2$ , &  $I_3$  are the output of generator CT, UT CT and GT CT respectively. These currents is passing through the star connected restraint transformer, the algebraic sum of vector ( $I_1 + I_2 + I_3 = I_4$ ) is passing through the differential transformer, which will give the output for operating the relay (87).

### **b) OVER FLUXING PROTECTION (59V/F)**

This is designed to protect the transformer from damages caused by the flux density in the core exceeds the designed value. The excessive flux can cause serious overheating of metallic parts and in extreme case can cause localized rapid melting of generator and transformer core laminations. Over fluxing can be caused by regulator failure, load reduction or excessive excitation with generator off-line it can also result from decreasing speed while the regulator or the operator attempts to maintain rated stator voltage. Its main application is to protect the transformers where, unless considerable care is taken, the flux density can become excessive during the running up or running down sequence. The flux density in the core depends on the ratio of terminal voltage (V) divided by the frequency (f). Normally the over fluxing withstand characteristics of the transformer are

120% over fluxing for 2 minutes

135% over fluxing for 1 minutes

140% over fluxing for 5 seconds.

Whenever the  $v/f$  ratio of the transformer exceeds the pre-set time, the relay will operate and initiate

- Running down the AVR if the machine is off the bus bar.
- Tripping the GT breaker.



**OPERATING PRINCIPLE:**

The basic principle of the relay is to produce an alternating voltage, which is proportional to the ratio of voltage & frequency, and to compare this with a fixed voltage. When the peak of the alternating voltage exceeds the fixed dc reference, the first timer is started. At the end of the fixed timer cycle the second adjustable timer is initiated.

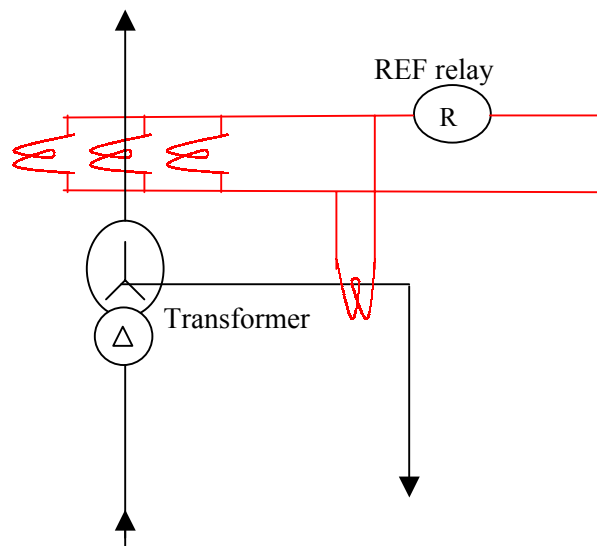
To obtain the correct measuring quantity the applied voltage  $V$  is converted to a current by means of a resistor  $R$ . This  $V/R$  is arranged to flow through a capacitor  $C$  to produce an output voltage

$$V/2 \pi f RC.$$

Over fluxing relay which consists of Voltage/Frequency measuring circuit, which output is given to a comparator, compares with dc reference and to give an output after a fixed time delay of 0.5 to 1.0 seconds. After the end of fixed time delay, the 2<sup>nd</sup> variable timer initiates. The fixed time auxiliary has one of its two pairs of contact wired out which is normally arranged to operate a follower.

**c) GENERATOR TRANSFORMER RESTRICTED EARTH FAULT PROTECTION (64)**

In addition to overall differential protection, a restricted earth fault protection covering the transformer HV winding only is provided. The zone of protection extends from CT provided on the transformer neutral end to the CT provided on the transformer bushings. The relay is high impedance type and high speed of operation. A non-linear resistance is connected across the relay terminal to limit the voltage developed during serial internal fault. This protection energizes Class-A trip of the turbo-generator.



SCHEME OF RESTRICTED E/F PROTECTION

**d) GENERATOR TRANSFORMER BACK-UP OVER CURRENT PROTECTION FOR PHASE FAULT (51)**

This protection consists of a 3 phase over current relay. The relay is 3-pole version of very inverse time over current relay plus high set instantaneous over current relay. This will act as the back up protection for the transformer fault due to the fault current flowing from system side. This may also serve limited back up protection function for fault external to the transformer. This will energize Class-A trip.

e) GENERATOR TRANSFORMER BACK UP EARTH FAULT PROTECTION (51N)

This is a simple inverse type over current relay connected to the neutral CT of transformer. This relay provided back up function for fault both internal and external to the transformer, This protection energizes Class-A trip.

## f) OVER LOAD MONITORING (49)

Measuring oil temperature and winding temperature indirectly monitors the loading of the generator transformer. The oil and winding temperature indicators are provided with contacts for initiating alarms as a first stage and tripping as the second stage whenever the oil and winding temperature limits are exceeded. The oil temperature /winding temperature trips are routed through Class-C trip.

## g) GAS PROTECTION (63)

A Buchholz relay is supplied along with the transformer. The relay has two contacts one closes on slow gas formation and initiate alarm. The second contact closes of sudden surge of oil flow in case of severe internal fault and this contact is wired for tripping the unit in Class-A trip.

The relay consists of two float switches contained in a closed housing, which is located in the pipe from transformer to conservator tank. Any internal fault in the transformer comes, the oil decomposes and the generating gases which passes up the pipe towards the conservator and is trapped in the relay. In this two float relay the top float responds the slow accumulation of gas due to mild and incipient fault, the lower float being deflected by the oil surges caused by a major fault. The float control contacts, in the first stage give an alarm and second case to isolate the transformer.



- What are the set values of generator protection?

#### TYPE OF PROTECTION AND ITS SET VALUES

| No. | Type of Protection                            | Set Values                                                   | CT/PT Ratio         | Time Delay      | Class                                |
|-----|-----------------------------------------------|--------------------------------------------------------------|---------------------|-----------------|--------------------------------------|
| 1.  | <b>Generator differential</b>                 | <b>0.5A(10%)</b>                                             | <b>10000/5</b>      | <b>Inst.</b>    | <b>Class-A1</b>                      |
| 2.  | <b>Generator Inter turn</b>                   | <b>0.5A(10%)</b>                                             | <b>5000/5</b>       | <b>Inst.</b>    | <b>Class-A1</b>                      |
| 3   | <b>Generator reverse power</b>                | <b>0.5%</b>                                                  | <b>10000/5</b>      | <b>5 sec</b>    | <b>Class-A1</b><br>(stage 2 Tx trip) |
| 4.  | <b>100% Stator Earth Fault</b>                | ND = $\frac{5V(3^{rd} \text{ harmonic } 70 \text{ } 100\%)}$ | <b>16.5 kV/110V</b> | <b>1.0 sec</b>  | <b>Class-A1</b>                      |
| 5.  | <b>2<sup>nd</sup> Rotor Earth Fault</b>       | <b>1.0 mA</b>                                                | <b>---</b>          | <b>---</b>      | <b>Class-A1</b>                      |
| 6.  | <b>Over Frequency</b>                         | <b>51.5 Hz</b>                                               | <b>16.5 kV/110V</b> | <b>0.1 sec</b>  | <b>86 BG</b>                         |
| 7.  | <b>Over Voltage</b>                           | <b>120%</b>                                                  | <b>16.5 kV/110V</b> | <b>2.0 sec</b>  | <b>Class-A</b>                       |
| 8.  | <b>Overall Differential</b>                   | <b>1.0A</b>                                                  | <b>10000/5A</b>     | <b>Inst.</b>    | <b>Class-A1</b>                      |
| 9.  | <b>GT Restricted E/F</b>                      | <b>0.1A</b>                                                  | <b>800/1A</b>       | <b>Inst.</b>    | <b>Class-A1</b>                      |
| 10. | <b>GT Gas Protection</b>                      | <b>---</b>                                                   | <b>----</b>         | <b>Inst.</b>    | <b>Class-A1</b>                      |
| 11. | <b>GT Fire</b>                                | <b>---</b>                                                   | <b>---</b>          | <b>Inst.</b>    | <b>Class-A1</b>                      |
| 12. | <b>GT Over Current</b>                        | <b>PSM-1.0</b><br><b>Inst. – 8.0</b>                         | <b>800/1 A</b>      | <b>TMS=0.4</b>  | <b>Class-A1</b>                      |
| 13. | <b>GT Earth Fault</b>                         | <b>PSM-0.2</b><br><b>TMS-0.52</b>                            | <b>800/1A</b>       | <b>2.0 sec</b>  | <b>Class-A1</b>                      |
| 14. | <b>Impedance Protection Stage-1</b>           | <b>---</b>                                                   | <b>10000/5A</b>     | <b>2.0 sec</b>  | <b>Class-A2</b>                      |
| 15. | <b>Generator Over Current During Starting</b> | <b>50 mA</b>                                                 | <b>10000/5A</b>     | <b>Inst.</b>    | <b>Class-A2</b>                      |
| 16. | <b>Generator Back-up Earth Fault</b>          | <b>PSM-5.4V</b>                                              | <b>16.5 kV/110V</b> | <b>TMS =0.3</b> | <b>Class-A2</b>                      |
| 17. | <b>Stator Earth Fault During Starting</b>     | <b>100 mA</b>                                                | <b>300/1A</b>       | <b>Inst.</b>    | <b>Class-A2</b>                      |
| 18. | <b>Low Forward Power</b>                      | <b>0.5% of FP</b>                                            | <b>10000/5A</b>     | <b>2.5 sec</b>  | <b>Class-B1</b>                      |
| 19. | <b>GT Over Fluxing Stage-1</b>                | <b>120%</b>                                                  | <b>---</b>          | <b>2 min</b>    | <b>Class-B</b>                       |
| 20. | <b>GT Over Fluxing Stage-2</b>                | <b>135%</b>                                                  | <b>---</b>          | <b>1 min</b>    | <b>Class-B</b>                       |
| 21. | <b>Negative Sequence</b>                      | <b>5%</b>                                                    | <b>10000/5A</b>     | <b>Inverse</b>  | <b>Class-B</b>                       |
| 22. | <b>Field Failure</b>                          | <b>---</b>                                                   | <b>10000/5A</b>     | <b>Inverse</b>  | <b>Class-A2</b>                      |
| 23. | <b>Under Frequency</b>                        | <b>47.77 Hz</b>                                              | <b>16.5 kV/110V</b> | <b>4 sec</b>    | <b>Class-C</b>                       |
| 24. | <b>GT Winding Temp. High</b>                  | <b>130<sup>o</sup> C</b>                                     | <b>---</b>          | <b>---</b>      | <b>Class-C</b>                       |
| 25. | <b>GT Oil Temp. High</b>                      | <b>90<sup>o</sup> C</b>                                      | <b>---</b>          | <b>---</b>      | <b>Class-C</b>                       |

- What is arc and what is spark?

Spark - the heat produced that ignites, due to the rubbing of two metals is called the spark.

Arc – the electrical discharge between two electrodes is called the arc. Arc is the self-sustained discharge of electricity between electrodes in a gas or vapour, which has a high voltage discharge at the cathode.

- What precautions should be taken while meggering main generator?

All PT's are racked out.

Earthing transformer grounding terminals disconnected.

Barring gear shall be kept off.

Stator water shall be drained fully and hot air blown through conductors.

Generator flexible lines shall be disconnected to isolate GT/UT.

- What is the speed equation for AC machine?

$$N = 120 f / P$$

N – Speed in RPM

f - Frequency in Hz

P – Number of poles

- What is emf equation of alternator?

$$\text{Emf} = 4.44 k_c k_d f \phi T \text{ volts.}$$

$$K_d = \text{Distribution factor} = \frac{\sin m \beta/2}{m \sin \beta/2}$$

$$k_c/k_p = \text{Coil span factor / Pitch factor} = \cos \alpha/2$$

$$k_f = \text{Form factor} = 1.11$$

$$\begin{aligned} \therefore \text{Average emf induced / Cycle} &= \phi N P / 60 \\ &= \frac{\phi P * 120 f}{60 * P} \\ &= 2 f \phi \text{ volt} \end{aligned}$$

If Z is the number of conductors = 2T (T = two sides of conductor)

$$\text{emf induced} = 2 f \phi Z = 2 f \phi 2T = 4 f \phi T$$

$$\begin{aligned} \therefore \text{RMS value of emf induced} &= \text{form factor} * \text{emf} \\ &= 1.11 * 4 f \phi T \\ &= 4.44 f \phi T \text{ volts.} \end{aligned}$$

- What is the emf equation for DC generator?

$$\frac{P * \phi * Z * N}{60 * A}$$

A = number of parallel paths. That is for lap winding it is equal to Z and for wave winding it equal to 2.

- What are the factors, which varies terminal voltage of generator?

a) Voltage drop due to resistance ( $R_a$  drop). This is negligible.

b) Voltage drops due to leakage reactance ( $X_L$ ).

c) Voltage drops due to armature reaction.

- What is meant by Armature reaction?

The effect of armature flux on the main field flux is called Armature reaction, where armature flux weakens the main field flux. In Alternator power factor contributes more importance in Armature reaction.

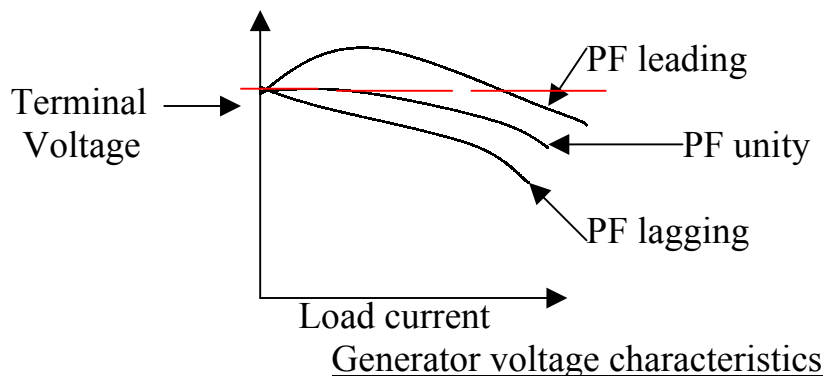
- a) In Unity power factor field strength is average and effect is distortional. So voltage variation will not be too much.
- b) In lagging power factor armature flux is directly opposite to the main field flux. That is armature flux is lagging  $90^\circ$  by main field flux. So the result is demagnetizing the field. Due to less field flux less voltage at the alternator terminals and excitation required is more.
- c) In leading power factor armature flux is leading by  $90^\circ$  to the main field flux. The result is additive and main field strength is more and excitation has to be reduced. Otherwise end parts or overhang portion of the generator will heat.

- What is meant by voltage regulation?

If there is a change in load, there is a change in terminal voltage. This change not only depends upon the load but also on power factor. The voltage regulation is termed as the rise in voltage when full load is removed divided by rated terminal voltage (Excitation and speed remains constant).

$$\therefore \text{Regulation in \%} = \frac{E_0 - V}{V}$$

In case of leading power factor terminal voltage will fall and regulation is negative.



- Why double squirrel cage motor used in barring gear? Why?

To have high starting torque.

In AC motors torque is directly proportional to  $\phi$  (flux),  $I_2$  and  $\cos \phi_2$ .

$$\text{i.e } T \propto \phi (\text{flux}) * I_2 * \cos \phi_2.$$

$$\therefore T = k * \phi (\text{flux}) * I_2 * \cos \phi_2.$$

Rotor at standstill  $E_2; \phi$  (flux)

$$\therefore T = k * E_2 * I_2 * \cos \phi_2.$$

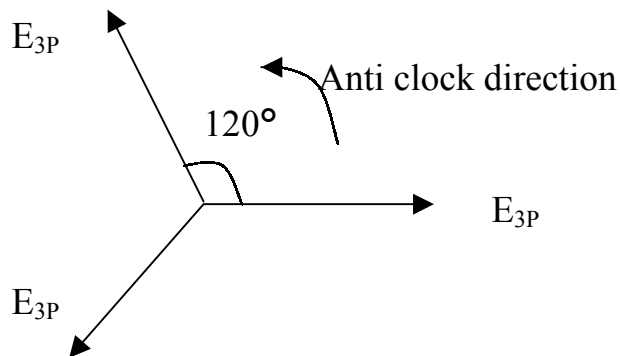
In double squirrel cage motor inner cage is low resistive and high inductive. The outer cage is high resistive and low inductive. In case of inner cage  $Z$  (impedance) is less ( $X_L = 2\pi f L$ ). If the rotor is having high inductance at starting  $I_2$  will lag  $E_2$  by large and  $\cos \phi_2$  (Rotor PF =  $R_2 / Z_2$ ) is very less. So torque is less.

At starting rotor torque is proportional to the rotor resistance. At starting inductance is high and the  $Z$  is--  
-----

- What are the logics adopted to close the field breaker?
  - a) Turbine speed 2880 rpm.
  - b) Class A, B and BG trip reset.
  - c) Auto/manual reference minimum.
  - d) Auto/manual channels supply normal.
  - e) FB closing circuit healthy.
- What you mean by positive sequence, negative sequence and zero sequence of voltage?

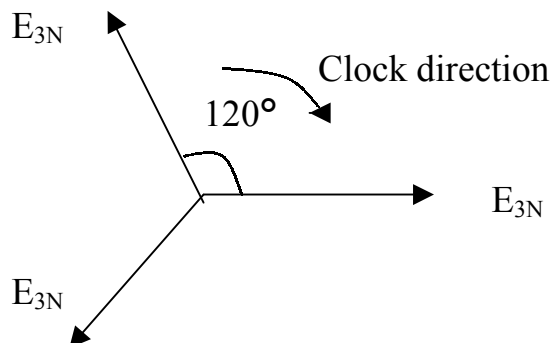
### **Positive phase sequence**

A system of vectors is said to have positive sequence if they are all of equal magnitude and are displaced by  $120^\circ$  with same time interval to arrive at fixed axis of reference as that of generated voltage. The positive phase sequence is represented below and the vectors arrive along X-axis in order 1, 2, 3 and conscript P has been used to designate as positive sequence.



### **Negative phase sequence**

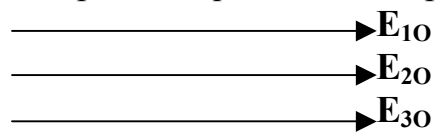
A system of vectors is said to have a negative phase sequence if they are of equal magnitude displaced at an angle of  $120^\circ$  but arrive at the axis of reference at the regular interval same as that of positive phase sequence but in order of 1, 3, 2. That is the order is reversed.



### **Zero sequence**

A system of vectors in a phase system is said to have zero phase sequence if all the three vectors are not displaced from each other and there will be no phase sequence

in such cases. The current or voltages in the 3-phase circuit vary simultaneously in all the 3- phases. Such phase sequence is zero phase sequence.



- What is rotor and stator resistance values?

Rotor resistance =  $98.1 \text{ m}\Omega$

Stator winding resistance's

R  $\phi = 3.1\Omega/3.1\Omega$

Y  $\phi = 3.1\Omega/3.1\Omega$

B  $\phi = 3.1\Omega/3.1\Omega$

- What is the rating of generator PT fuse?

24 kV, 3.15 Amps.

- What is the wearing rate of generator Slipring?

Generator Slipring wearing rate is  $0.025 \text{ mm /1000 hrs.}$

- What is the brush pressure on Slipring?

Recommended brush pressure in the Slipring is  $150 \text{ to } 200 \text{ gms/cm}^2$  (0.9 to 1 kg).

- What are the properties of hydrogen and DM water?

Hydrogen

- Windage losses are less. Hence efficiency increased.
- Heat transfer is more. Hence output per volume is increased.
- No corona discharge, which makes insulation life long.
- Lesser denser and penetration and cooling more.
- No fire risk at purity 4% to 74%.

DM Water

- Non toxic and low viscosity.
- High thermal conductivity.
- Low conductivity.
- Freedom from fire risk.
- External heat exchanger used.

- What are the chemical tests on hydrogen and DM water?

**Hydrogen**

- Hydrogen purity in % (volume/volume).
- Relative humidity in % (30% is nominal).

**DM water**

- PH of DM water (less than 6.5 is acidic and more than 7 is alkaline where oxygen is not forming). PH is also called IP (isotopic purity).
- Conductivity.
- Copper traces.
- Dissolved oxygen (to trace corrosion and 1.2% is more).





- What are the logic's adopted in barring gear motor?

**For start permission**

- Local or remote start.
- JOP is running.
- Motor hand barring is permissive.
- 42 contactor in MCC is off.
- Turbine speed is <100 rpm.

**Start permission (42S of MCC)**

- All above
- Bearing oil pressure is >0.35 kg/ cm<sup>2</sup>.
- No thermal over load of 42S.
- No one-DG condition.

**Start permission (42 of MCC)**

- Start permissive of 42S.
- Barring gear engage or motor speed reached to 1475 rpm.
- Turbine speed is <100 rpm.
- Bearing oil pressure is >0.35 kg/ cm<sup>2</sup>.
- No thermal over load of 42.
- No one-DG condition.

- What is the equation for resistance measurement of PT 100 thermocouple?

$$^{\circ}\text{C} = (\text{R}-100) / 0.39$$

- What are the requirements for synchronization and setting for generator?
  - Same phase sequence.
  - Voltage should in-phase and angle should not be more than 10°.
  - Voltage value must be same and difference of 5% is allowed.
  - Frequency should be same and difference of 0.1% i.e. 0.05 Hz is allowed.

- What is the recommended IR value for generator?

Main generator is class B insulated machine. Without stator water recommended insulation value for the generator is  $R_{60} = \text{kV} + 1 \text{ M}\Omega$

$R_{60}$  – minimum recommended IR in  $\text{M}\Omega$  of entire winding at 40 ° C of 60 Sec.

kV – rated voltage.

For the IR measurement 1 kV megger should be used.

- What is the type turbine installed in KGS?

Tandem compounded to expansion of steam, impulse reaction type.

- State HP & LP turbine steam values.

|    |    |
|----|----|
| HP | LP |
|----|----|

|               | Pressure                | Flow     | Temp   |               | Pressure                 | Flow | Temp     |
|---------------|-------------------------|----------|--------|---------------|--------------------------|------|----------|
| I/L           | 40 kg/cm <sup>2</sup>   | 1333 t/h | 250 °C | I/L           | 5.664 kg/cm <sup>2</sup> |      | 232.9 °C |
| O/L           | 6.02 kg/cm <sup>2</sup> |          |        | O/L           |                          |      |          |
| Wetness (I/L) |                         | 0.26%    |        | Wetness (I/L) |                          |      |          |
| Wetness (O/L) |                         | 11.058%  |        | Wetness (O/L) |                          |      |          |

- State turbine governor setting.  
On 2560 rpm turbine governor becomes effective and on 2760 rpm is turbine governor take over speed.
- What is requirement of speeder gear assembly?  
To bring the turbine to synchronous speed and get tight lock with grid by grid frequency. BPC signal is given in Auto mode to the speeder gear motor.
- What is the purpose of LLG?  
To ensure that the turbine load never exceed the reactor output, to incorporate turbine follow reactor feature governing system.
- What is the purpose of OSLG?  
This gear mainly used to control the steam flow so as to limit the machine from over speeding. On following occasions the over speed limiting gear acts.
  - a) When the flow of steam corresponds to load is 2/3 and
  - b) Electrical power on generator falls 1/3 of full load.
- What is the logic in lubrication oil pump system?  
Normally main oil pump (MOP) will feed the required lub oil to turbine governor and lubrication. If the pressure drops to 5.3 kg/cm<sup>2</sup> 6.6 kV 373 kW Aux. Oil Pump will start. If further pressure falls to <0.65 kg/cm<sup>2</sup> Flushing Oil Pump will start. If further pressure drops <0.35 kg/cm<sup>2</sup> Emergency Oil Pump will start.  
Lubricating oil inlet temperature will be 40°C and outlet temperature will be 70°C.
- What is the purpose of TOPP (turbine oil purification plant)?  
The purpose of TOPP is to remove the water ingress in turbine oil system from the gland leaks, cooler leakage, and solid metal particles, which are produced due to rust, wear of bearings and to normalize the low quality oil.  
The remove capacity of TOPP is, for solids – 5 microns and for water – 300 to 500 parts per milli.

## RELAYS

- Write down the relay numbers and their designation.

|    |                                        |     |                                       |
|----|----------------------------------------|-----|---------------------------------------|
| 1  | MASTER ELEMENT                         | 51  | AC TIME OVER CURRENT RELAY            |
| 2  | TIME DELAY STARTING OR CLEARING        | 52  | AC CIRCUIT BREAKER                    |
| 3  | CHECK OR INTERPOSING RELAY             | 53  | EXCITER OR DC GENERATOR               |
| 4  | MASTER CONTACTOR                       | 54  | SPARE                                 |
| 5  | STOPPING DEVICE                        | 55  | POWER FACTOR RELAY                    |
| 6  | STARTING CIRCUIT BREAKER               | 56  | FIELD APPLICATION RELAY               |
| 7  | ANODE CIRCUIT BREAKER                  | 57  | SHORT CIRCUITING DEVICE               |
| 8  | CONTROL POWER DISCONNECT DEVICE        | 58  | RECTIFICATION FAILURE RELAY           |
| 9  | REVERSING DEVICE                       | 59  | OVER VOLTAGE RELAY                    |
| 10 | UNIT SEQUENCE RELAY                    | 60  | VOLTAGE OR CURRENT BALANCE RELAY      |
| 11 | SPARE                                  | 61  | SPARE                                 |
| 12 | OVER SPEED RELAY                       | 62  | TIME DELAY STOPPING OR OPENING DEVICE |
| 13 | SYNCHRONISING SPEED DEVICE             | 63  | LIQUID OR GAS OR VACCUUM RELAY        |
| 14 | UNDER SPEED DEVICE                     | 64  | GROUND PROTECTION RELAY               |
| 15 | SPEED OR FREQUENCY MATCHING DEVICE     | 65  | GOVERNOR                              |
| 16 | SPARE                                  | 66  | NOTCHING OR JOGGING RELAY             |
| 17 | SHUNTING OR DISCHARGE SWITCH           | 67  | AC DIRECTIONAL OVER CURRENT RELAY     |
| 18 | ACCELERATING OR DE-ACCELERATING DEVICE | 68  | BLOCKING RELAY                        |
| 19 | STARTING OR RUNNING TRANSITION DEVICE  | 69  | PERMISSIVE CONTACT DEVICE             |
| 20 | ELECTRICALLY OPERATED VALVE            | 70  | RHEOSTAT, ELECTRICALLY OPERATED       |
| 21 | DISTANCE PROTECTION RELAY              | 71  | LIQUID OR GAS LEVEL RELAY             |
| 22 | EQUALIZER CIRCUIT BREAKER              | 72  | DC CIRCUIT BREAKER                    |
| 23 | TEMPERATURE CONTROL DEVICE             | 73  | LOAD RESISTOR CONTACTOR               |
| 24 | SPARE                                  | 74  | ALARM RELAY                           |
| 25 | SYNCHRONISING DEVICE                   | 75  | POSITION MECHANISM                    |
| 26 | APPARATUS THERMAL DEVICE               | 76  | DC OVER CURRENT RELAY                 |
| 27 | UNDER VOLTAGE RELAY                    | 77  | PULSE TRANSMITTER                     |
| 28 | FLAME DETECTOR                         | 78  | PHASE ANGLE OR OUT OF STEP RELAY      |
| 29 | ISOLATING CONTACTOR                    | 79  | AC RECLOSING RELAY                    |
| 30 | ANNUNCIATOR RELAY                      | 80  | SUPPLY FAIL                           |
| 31 | SEPARATE EXCITATION DEVICE             | 81  | FREQUENCY RELAY                       |
| 32 | DIRECTIONAL POWER RELAY                | 82  | DC RECLOSING RELAY                    |
| 33 | POSITION SWITCH                        | 83  | AUTOMATIC SELECTION                   |
| 34 | MASTER SEQUENCE DEVICE                 | 84  | OPERATING MECHANISM                   |
| 35 | SLIP RING SHORT CIRCUIT DEVICE         | 85  | CARRIER OR PILOT WIRE RECEIVER RELAY  |
| 36 | POLARITY OR POLARIZING VOLTAGE DEVICE  | 86  | LOCK OUT RELAY                        |
| 37 | UNDER CURRENT OR UNDER POWER RELAY     | 87  | DIFFERENTIAL PROTECTION RELAY         |
| 38 | BEARING PROTECTIVE DEVICE              | 88  | AUXILIARY MOTOR OR MOTOR GENERATOR    |
| 39 | MECHANICAL CONDITION MONITOR           | 89  | LINE SWITCH                           |
| 40 | FIELD RELAY                            | 90  | REGULATING DEVICE                     |
| 41 | FIELD CIRCUIT BREAKER                  | 91  | VOLTAGE DIRECTIONAL RELAY             |
| 42 | RUNNING CIRCUIT BREAKER                | 92  | VOLTAGE & POWER DIRECTIONAL RELAY     |
| 43 | MANUAL TRANSFER OR SELECTOR DEVICE     | 93  | FIELD CHANGING RELAY                  |
| 44 | UNIT SEQUENCE STARTING RELAY           | 94  | TRIPPING OR TRIP FREE RELAY           |
| 45 | ATMOSPHERIC CONDITION MONITOR          | 95  | SUPERVISION RELAY                     |
| 46 | CURRENT UNBALANCE RELAY                | 96  | SPECIAL APPLICATION                   |
| 47 | POLE DISCREPANCY                       | 97  | FUSE FAIL RELAY                       |
| 48 | INCOMPLETE SEQUENCE RELAY              | 98  | SPECIAL APPLICATION                   |
| 49 | THERMAL OVER LOAD RELAY                | 99  | OVER FLUXING RELAY                    |
| 50 | INSTANTANEOUS OVER CURRENT RELAY       | 100 | SPECIAL APPLICATION                   |

## General Description of Relays

### NOMENCLATURE FOR ENGLISH ELECTRIC RELAY

| FIRST LETTER – OPERATING QUANTITY |                         | SECOND LETTER – MOVEMENT                            |                            |
|-----------------------------------|-------------------------|-----------------------------------------------------|----------------------------|
| A                                 | PHASE ANGLE COMPARISON  | A                                                   | ATTRACTED ARMATURE         |
| B                                 | BALANCED CURRENT        | B                                                   | BUCHHOLZ                   |
| C                                 | CURRENT                 | C                                                   | INDUCTION CUP              |
| D                                 | DIFFERENTIAL            | D                                                   | INDUCTION DISC             |
| E                                 | DIRECTION               | G                                                   | GALVANOMETER (MOVING COIL) |
| F                                 | FREQUENCY               | T                                                   | TRANSISTOR                 |
| I                                 | DIRECTIONAL CURRENT     |                                                     |                            |
| K                                 | RATE OF RISE OF CURRENT |                                                     |                            |
| N                                 | MANUAL                  |                                                     |                            |
| O                                 | OIL PRESSURE            |                                                     |                            |
| P                                 | POLY PHASE VA           |                                                     |                            |
| R                                 | REACTIVE VA             |                                                     |                            |
| S                                 | SLIP FREQUENCY          |                                                     |                            |
| T                                 | TEMPERATURE             |                                                     |                            |
| V                                 | POTENTIAL               |                                                     |                            |
| W                                 | WATTS (POWER)           |                                                     |                            |
| Y                                 | ADMITTANCE              |                                                     |                            |
| Z                                 | IMPEDANCE               |                                                     |                            |
| THIRD LETTER – APPLICATION        |                         |                                                     |                            |
| A                                 | AUXILIARY               | R                                                   | RE CLOSING                 |
| B                                 | TESTING                 | S                                                   | SYNCHRONISING              |
| C                                 | CARRIER (COUNTING)      | T                                                   | TIMER OR TRANSFORMER       |
| D                                 | DIRECTIONAL             | U                                                   | DEFINITE TIME              |
| E                                 | EARTH (GROUND)          | V                                                   | VOLTAGE TIME               |
| F                                 | FLAG & ALARM INDICATOR  | W                                                   | PILOT WIRE                 |
| G                                 | GENERAL OR GENERATOR    | WA                                                  | INTERPOSING                |
| H                                 | HARMONIC RESTRAINT      | WJ                                                  | INTER TRIPPING             |
| I                                 | INTERLOCK OR INDUSTRIAL | X                                                   | SUPERVISORY                |
| J                                 | TRIPPING                | Y                                                   | FLASH BACK (BACK FIRE)     |
| JE                                | TRIPPING (ELECT. RESET) | Z                                                   | SPECIAL APPLICATION        |
| JH                                | TRIPPING (HAND RESET)   | ZS                                                  | ZERO SEQUENCE              |
| JS                                | TRIPPING (SELF RESET)   |                                                     |                            |
| JC                                | CONTROL                 |                                                     |                            |
| K                                 | CHECK ALARM             |                                                     |                            |
| L                                 | LIMITING                |                                                     |                            |
| M                                 | SEMAPHORE OR MOTOR      |                                                     |                            |
| N                                 | NEGATIVE SEQUENCE       |                                                     |                            |
| O                                 | OUT OF STEP             |                                                     |                            |
| P                                 | POTENTIAL FAILURE       |                                                     |                            |
| Q                                 | ALARM                   |                                                     |                            |
| FOURTH LETTER                     |                         |                                                     |                            |
| M – SPECIAL VARIATION             |                         |                                                     |                            |
| Sl. No.                           | E E Relay               | Application                                         |                            |
| 1                                 | CTM                     | Motor protection                                    |                            |
| 2                                 | CTU                     | Locked rotor. Thermal alarm                         |                            |
| 3                                 | CDG                     | I.D.M.T. over current or earth fault of transformer |                            |
| 4                                 | CAG                     | Instantaneous over current or earth faults.         |                            |

|   |      |                              |
|---|------|------------------------------|
| 5 | VAGM | Under voltage                |
| 6 | WDG  | Under /Over power for DG set |
| 7 | FTG  | Under frequency              |
| 8 | VAPM | Fuse failure                 |

- What is Knee point voltage?  
EMF applied to secondary of current transformer (CT) which, when increased by 10% voltage causes the excitation current to increase by 50%.
- What is I.D.M.T?  
Inverse time relay with definite minimum time is called IDMT.
- What is Negative sequence reactance?  
Negative sequence can arise whenever there is any unbalance present in the system. Their effect is to setup a field rotating in opposite direction to the main field.
- What is Zero sequence reactance?  
If a machine is operating with an earthed neutral, a system earth fault will give rise to zero sequence current in the machine.
- Purpose of over current relay (Inverse); type- CDG  
It is a self powered inverse time over current and earth fault relay, used for selective phase and earth fault protection in time graded systems for A.C. machines, transformers, feeders etc. A non-directional heavily damped induction disc relay, which has an adjustable inverse time/current characteristic with a definite minimum time. The relay has a high torque movement combined with low burden and low overshoot. The relay disc is so shaped that as it rotates the driving torque increases and offsets the changing restraining torque of the control spring.
- Purpose of Directional inverse Over current & earth fault relay; type- CDD  
Directional phase or earth fault protection of ring-mains, parallel transformers, transformer feeders, parallel feeders etc., employing the time graded principle.; This relay comprises an inductive disc over current unit with wound shading coils and a directional high speed induction cup unit. The cup-unit contact is wired across the shading coils so that no torque is exerted on the disc of the over current unit until the cup unit contact closes. The inductive disc unit is thus directionally controlled and it operates only when the current flows in the tripping direction. The directional unit is a high speed, low inertia four pole induction cup movement designed to give a high, steady and non-vibrating torque. its current coil is connected in series with the operating coil of the induction disc unit. The directional unit is normally provided with voltage polarising coils.
- Purpose of Over current & earth fault relay; type- CAG  
This relays are designed for instantaneous phase or earth fault protection and instantaneous high set over current protection.; A standard hinged-armature unit forms the basic movement for this relay. It consists an operating coil mounted on a cylindrical iron core bolted to a frame at one end. This frame extends along the side



of the coil, with its end forming a knife-edge on which the armature is pivotally mounted. The armature is 'L' shaped and pivoted at its corner so that one arm can be attracted to the end of the core while the other arm to operate a set of contacts.

- **Purpose of Local breaker back-up relay; type -CTIG**  
To safe guard against the drastic consequences of failure to clear faults rapidly, many power supply authorities install 2 independent systems of protection for major transmission lines. There remains however the possibility of the circuit breaker itself failing to operate and this hazard is traditionally covered by remote breaker back-up.; CTIG relay is a 3 phase or 2 phase and earth fault instantaneous over current unit intended for use with a time delay to give back-up protection in the event of a circuit breaker failure. A particular feature of the CTIG relay is a fast reset, which enables the time delay to be set closer to the breaker trip-time.
- **Purpose of Battery earth fault relay; type- CAEM-21**  
The battery earth fault relay is used to detect earth faults and deterioration of wiring insulation in either pole of battery. The scheme consists of a centre tapped resistor, a measuring relay, plug setting bridge, auxiliary relay and rectifier bridge to provide unidirectional supply to the measuring relay coil. For different battery voltages different values of centre tapped resistors are used. Variable sensitivities are provided by means of the tapped coil whose taps are connected to the plug setting bridge. The centre tap of resistor is brought to one terminals of the relay and this terminal is either directly earthed or earthed through a centre zero milli ammeter. Under healthy condition no current flows through the measuring relay coil and in any pole of the battery or wiring insulation failure, current flows through the measuring relay coil and the relay operates.
- **Purpose of Rotor earth fault relay (type- CAEM-33)**  
When a single E/F is detected in the DC field circuit of a machine, the machine has to be taken out of service at the first opportunity. This is because, if allowed to run with an E/F on the rotor, a subsequent second E/F can cause severe damage to the machine. However, a relay like CAEM-33 which can detect such a second E/F and trip out the machine can make it possible to run the machine even with a single E/F, without any such risks, thus helping to preserve the generation capacity. The start of the second rotor earth fault detection scheme is a very sensitivity transducer element. The AC winding of the transducer is connected in series with a rectified AC voltage relay. The Dc winding of the transducer on the other hand is connected in series with the rotor E/F circuit. Under normal conditions- i.e. with no DC flowing, the AC wining of the transducer presents a high impedance, and the AC voltage applied is mostly dropped across this winding. Hence the relay remains de-energised. When a second rotor E/F occurs, a DC current flows through the transducer dc winding which causes the impedance of the AC winding to reduce considerably by driving the transducer core into saturation. Hence, the applied voltage is fully available across the relay and it operates.

- Purpose of Sensitive earth fault relay (type - CTUM-15 & CTIGM-15)

It may not be always possible to detect high resistance faults by conventional earth fault relaying. In such cases a very sensitive current relay will be required for this purpose. It can be connected residually since it has an adjustable definite time delay provided to take care of transient spills in the residual circuit due to CT mismatch. Also, its low burden enables it to be used with existing CT's/ Relays without affecting the performance.; The incoming current is stepped down by an internal current transformer and converted to a voltage by a variable resistor network. The signal is compared with an internal reference. When this reference level is exceeded, a time delay is initiated, after the time delay has elapsed, a relay operates.

- Purpose of Negative phase sequence current relay; Type- CTN/CTNM

Negative phase sequence current in the stator of a generator, caused due to unbalanced loads or faults, it induces double frequency eddy current in the rotor. These currents, if allowed to persist, can cause serious overheating and the purpose of this relay is to disconnect the machine before such excess temperature is reached. The inputs from the current transformers, which are connected in each phase of the generator supply, are fed to a negative sequence filter which gives an AC output voltage proportional to the negative sequence current. This voltage is rectified and smoothed and fed into the squaring circuit of the main measuring element, the definite time delay circuit and the alarm element. The output from the squaring circuit is proportional to the square of the input voltage and is applied directly to the main timing circuit to give the required relationship between  $I^2t$  and the relay operates time  $t$ .

- Purpose of definite time Over current & earth fault relay: Type-CTU

This relay can be used for definite time over current protection against phase and Earth faults on medium and low voltage distribution systems. The definite time relay offers a considerable advantage over inverse time relays in instances where there is a wide variation in line impedance. Another application is in the field of stalling protection of motors. When the thermal overload relay does not provide protection against stalling, separate definite time O/C relay type CTU can be used to provide the same. This relay comes in following nomenclature: CTU-12/22/32/52/62/15. CTU relay combines the advantage of complete static measurements with characteristic of the robust, well proved attracted armature unit. These relays measure current and time accurately, imposes low burden on CT's. Each phase comprises a static overload detector and timer, which is accurate over a 10:1 time setting range. When the positive peak of the input signal exceeds the reference level, the time delay circuit starts and after a preset time, drives the output relay. Instantaneous high set unit when fitted uses alternate half cycle for measurement and through a separate level detector drives a separate output relay.

- Purpose of Motor protection relay: Type- CTMM/CTMFM  
This relay contains all the protection factors to protect the motor, from Thermal overload ( $I_{th}$ ), Instantaneous over current ( $I_1$ ), Instantaneous or time delayed unbalance element, Earth fault Element ( $I_0$ ) & Stalling protection ( $I_1(t)$ )

- Purpose of Overfluxing Relay: Type-GTTM

Transformers need protection against the risk of damage, which may be caused when the transformers are operated at flux density levels significantly greater than the design values. The overfluxing withstand time is generally found to be varying inversely with the working flux density in the core, having higher withstand times during extreme overfluxing conditions.

The overfluxing condition can occur during system over voltage or under frequency conditions.

The basic operating principle is to produce an ac voltage, which depends upon the ratio between AC input voltage and the frequency. The AC input voltage is fed to a step-down transformer, which also provides isolation and the stepped down voltage is fed to a V/F ratio detector circuit. This circuit is a simple operational amplifier integrator with the provision for V/F pickup adjustment. The AC voltage is rectified by true RMS. to dc converter. This circuit gives a frequency output and this frequency increases rapidly with the increase in voltage. The frequency output is given to a curve shaping circuit, which involves counter and comparators. The counter counts the frequency output and the number of counts required for final trip condition is changed by the comparator circuits to get the required timing characteristic.

- Purpose of Biased Differential Relay: Type-MBCH

This relay is suitable for protection of two or three winding power transformers, auto transformers or generators transformer units.

The differential transformer protection measuring circuit is based on the well-known Merz-price circulating principle.

- Purpose of Digital frequency relay: Type-MFVUM

This relay is used to monitor the frequency of an electrical system. The relay are suitable for any application in industrial plants and to generators where definite time under or over frequency protection is required.

The operating principle of the relay is the comparison of the time interval of the incoming frequency with that of a preset time derived from an accurate oscillator within the relay. The incoming frequency signal is connected to an INPUT CIRCUIT, which then drives an IMPULSE GENERATOR to produce a pulse at the beginning of each period of the input voltage. The preset time interval is obtained from an OSCILLATOR and COUNTER and adjustment is achieved using SELECTOR switches, which drive a DECODER circuit. A COMPARATOR compares the two-time interval and this triggers an adjustable TIMER which then operates the output relay and latched light emitting diode (LED) glows.

- Purpose of Stator Earthfault Relay: Type-PVMM

A 100% stator earthfault protection is designed to detect earthfault occurring in the regions of machine winding close to the neutral end. This relay is a composite modular relay that gives 100% stator earthfault protection for machines, whose neutral are not directly earthed. It works on the principle involving monitoring of the neutral side and line-side components of the third harmonic voltages produced by AC generators in service.

- Purpose of Voltage regulating relay and line drop compensator: Type-VTJCM & CIJC.  
This relay is used with on load transformer tap changers and induction regulators to provide close and accurate automatic voltage regulation on power systems of any voltage.  
When the regulated voltage moves outside a dead band, set by the sensitivity control, the volts high or volts low circuits are initiated and after a time delay, determined by the response characteristic, the appropriate tap changer control auxiliary relay closes its contact to initiate a tap change.
- Purpose of Directional power relay: Type-MWTU.  
This relay setting ranges from 0.25% to 18.56% of rated power. This makes the relay suitable for sensitive reverse power applications. For example with turbo-generator, where the detection of 1% or 2% reverse power is necessary to prevent the synchronous machine from motoring in the event of the power from the prime mover becoming too low. It is also suitable for low forward power interlock and under power protection.
- Purpose of Check synchronising relay: Type-SKD/SKE.  
This relay is used to prevent interconnection of badly synchronised supplies. Type SKD relay are used for auto reclosing sequence, type SKE relay are used to safeguard manual synchronising of generators. Phase measurement is achieved by algebraically subtracting the 2 supply voltage waveforms and comparing the resultant modulated beat waveform envelope with a Dc reference voltage. The DC reference is proportional to the sum of the peaks of the 2 supply voltages to provide phase measurement independent of supply voltage variation.
- Purpose of Static distance protection: Type-SHPM.  
This relay (QUADRAMHO) is a static distance protection relay specially designed for comprehensive high-speed protection of HV & EHV distribution/transmission lines. 3 zones of protection are included, each employing separate measuring elements, one element each for 3 phase-to-phase and 3 phase-to-earth faults. Thus a total; of 18 elements are provided thereby increasing the reliability of the protection. Poly phase measuring elements are not used in QUADRAMHO as in some of the contemporary schemes. The relay is suitable for both three poles & single-and-three-pole tripping of the circuit breaker.
- Purpose of Static offset MHO relay: Type- YTGM.  
This relay is a static single phase, single step, and distance protection with MHO offset MHO characteristic. With suitable current/voltage input selection, the relay can be made to have the required characteristic in the R-X plane for various applications such as Generator Field failure protection, Generator backup impedance

protection and as offset MHO relay for use in conjunction with generator pole slipping protection.



- Purpose of sensitive power relay: Type-WCD.  
This power relay is a sensitive Poly phase induction cup unit, providing under power, reverse power and over power protection. This relay detects a reversal of current flow, caused by insufficient driving power from the prime mover, preventing the generator operating as a synchronous motor. The electrical quantities energize windings on an eight pole laminated stator. The moving contact is operated by a cup shaped Aluminium rotor, which turns on jewelled bearings in an air gap between the stator and a fixed center core. Only a small arc of rotation is needed to cause contact closer. Low rotor inertia and very high driving torque ensures a high speed operations.
- Purpose of pole slipping relay: Type-ZTO.  
This pole slipping relay has been designed to protect synchronous Generators against the possibility of the machine running in the unstable region of the power angle curve which would result in power oscillations and pole slip. The relay consists basically of one directional relay and one blinder relay operating in conjunction with a 40-80 milli seconds static timer. Intended primarily for installation between the generator and associated transformer (preferably on the generator terminals)
- Purpose of fuse failure relay: Type - VAPM  
This relay detects a failure or inadvertent removal of voltage transformer secondary fuses and prevention of incorrect tripping of circuit breakers. This relay consists of a rectified AC voltage operated hinged armature unit. Three coils for the three phases are wound over a single core producing in effect a common relay for the three phases. Each coil is connected across one of the voltage transformer secondary fuses and under healthy conditions, this coil is short circuited by the fuse and cannot be energized. When one or more fuses or are removed the appropriate coil(s) is energized under relay operates immediately to open the trip circuit.

## GENERATOR PROTECTION

| Sl | Des      | Description                        | CT ratio | Type       | Setting                                                                         | Remarks |
|----|----------|------------------------------------|----------|------------|---------------------------------------------------------------------------------|---------|
| 1  | 87G      | Generator Differential Protection  | 10000/5  | CAG-34     | P/S = 10% or 0.5 A SR = 143 Ohm                                                 |         |
| 2  | 87GI     | Generator Inter Turn fault         | 5000/5   | CAG-34     | P/S = 10% or 0.5 A SR = 86.72 Ohm                                               |         |
| 3  | 32A      | Low Forward Power Protection       | 10000/5  | WCD-13     | 0.5% Fixed                                                                      |         |
|    | 2/32A    | Timer                              |          | VTT-11     | 2.5 Sec                                                                         |         |
| 4  | 32B      | Low Forward Power Protection       | 10000/5  | WCD-13     | 0.5% Fixed                                                                      |         |
|    | 2/32B    | Timer                              |          | VTT-11     | 2.5 ec                                                                          |         |
| 5  | 32C      | Under Power Over speed limit       | 10000/5  | WCD-12     | 30% Fixed                                                                       |         |
|    | 27 A,B   | Under Voltage Relay                |          | VAGM-22    | 73.2 V                                                                          |         |
| 6  | 37       | Reverse Power Protection           | 10000/5  | WCD-11     | 0.5% Fixed                                                                      |         |
|    | 2A/37    | Timer                              |          | VTT-11     | 10 Sec                                                                          |         |
|    | 2B/37    | Timer                              |          | VTT-11     | 5 Sec                                                                           |         |
| 7  | 21G1     | Generator Back-up Impdence Stage-1 | 10000/5  | YTGM-15    | K1=7.0, K2=1.0, K3=2.0,<br>K4=1.0, K5=1.0, K10= 0<br>Zf=14.0 Ohm, Zr= NA        |         |
|    | 2/21G    | Timer                              |          | VTT-11     | 1.5 Sec                                                                         |         |
| 8  | 21G2     | Generator Back-up Impdence Stage-2 | 10000/5  | YTGM-15    | K1=1.65, K2=1.0, K3=2.0,<br>K4=1.0, K5=5, K10= -1<br>Zf=3.3 Ohm, Zr=10 Ohm      |         |
|    | 2/21G2   | Timer                              |          | VTT-11     | 2.0 Sec                                                                         |         |
| 9  | 40G      | Generator field failure            | 10000/5  | YTGM-15    | K1=6.175, K2=1.0, K3=4.0,<br>K4=1.0, K5=1.06, K10=+1<br>Zf=24.7.0 Ohm, Zr= 4.24 |         |
|    | 2A/40G   | Timer (TDDO)                       |          | VTT-11     | 2.5 Sec                                                                         |         |
|    | 2B/40G   | Timer                              |          | VTT-11     | 2.0 Sec                                                                         |         |
|    | 27/40G   | Under Voltage Relay                |          | VAGM-22    | 73.2 V                                                                          |         |
| 10 | 59G      | Over voltage Protection            |          | VTU - 21   | Setting=120% + 2.0 Sec                                                          |         |
| 11 | 78GY     | YTGM With pole slipping relay      | 10000/5  | YTGM-15    | K1=4.45, K2=1.0, K3=1.0,<br>K4=1.0, K5=5, K10= -1<br>Zf=4.45 Ohm, Zr=5.0 Ohm    |         |
| 12 | 78G      | Pole Slipping Protection           | 10000/5  | ZTO        | K1=0.98, K2=0.67, K3=4.0<br>Q1=Q2=75 degree,<br>Timmer =54mSec                  |         |
|    |          | Over current Starter               |          | CAG-19     | Current Setting=5.5A                                                            |         |
| 13 | 64A      | 100% Stator E/F Protection         |          | PVMM-163   | Vs=5.0 V, N=3                                                                   |         |
|    |          | Neutral Displacement Module        |          |            |                                                                                 |         |
|    |          | Third harmonic Module              |          |            | VRL=70% Time=1.0 Sec                                                            |         |
|    |          | Third harmonic comporator unit     |          |            | This is to be set during<br>commissioning by Alstom engineer                    |         |
| 14 | 64B      | 95% E/F Protection                 |          | VDG-14     | PSM=5.4 V, TMS=0.3                                                              |         |
| 15 | 64C      | Stator E/F during Starting         | 300/1    | CTIGM-15   | Setting = 0.1 A                                                                 |         |
| 16 | 46G      | Gen. Negative phase sequence       | 10000/5  | CTNM-31    | I2S=5%, K1=6.7, K3= 1<br>Alarm=70%                                              |         |
|    | 2/46G    | Timer                              |          | VTT-11     | 120.0 Sec                                                                       |         |
| 17 | 50 ABC   | Instantaneous Over current         | 10000/5  | CAG-39     | P/S = 5 A                                                                       |         |
| 18 | 49 G     | Generator Over load protn.         | 10000/5  | CTMM - 104 | Ith=4.4A, Thermal Ref. Curve=2a                                                 |         |
| 19 | 50 S ABC | Stator O/C Protn during starting   | 10000/5  | CTIGM-15   | Setting = 0.05 A                                                                |         |
| 20 | 64 F1    | First rotor E/F protection         |          | VAEM - 21  | Setting = 1.1 mA fixed                                                          |         |
| 21 | 2/64F1   | Timer                              |          | VTT-11     | Setting = 2.0 Sec                                                               |         |

|    |        |                             |                                    |       |                                                      |                        |                  |
|----|--------|-----------------------------|------------------------------------|-------|------------------------------------------------------|------------------------|------------------|
| 22 | 64F2   | Second rotor E/F Protection |                                    |       | CAEM-33                                              | Setting = 1.0 mA fixed |                  |
| 23 | 81 - 1 | 81-1RL1                     | Under Frequency Stage - 1          | MFVUM | Setting = 47.96 Hz + 1.1 Sec                         |                        | Window annun     |
|    |        | 81-1RL2                     | Under Frequency Stage - 2          |       | Setting = U#1=47.6 Hz +2Sec,U#2=47.7Hz+3 Sec         |                        | SUT breaker trip |
|    |        |                             |                                    |       | Setting = U#1=47.6 Hz +4 Sec,U#2=47.7Hz+ 4sec Sec    |                        | 86C Operation    |
| 24 | 81 - 2 | 81-2RL1                     | Under Frequency Stage - 3          | MFVUM | Setting = 47.5Hz +0.1Sec                             |                        | SUT breaker trip |
|    |        |                             |                                    |       | Setting = 47.5Hz +0.6 Sec                            |                        | 86C Operation    |
| 25 | 81 - 3 | 81-3RL1                     | Over Frequency Stage - 1           | MFVUM | Setting = 51.0 Hz + 1.1 Sec                          |                        | Window annun     |
|    |        | 81-3RL2                     | Over Frequency Stage - 2           |       | Setting = U#1=51.5 Hz + 15 Sec,U#2=51.65 Hz + 15 Sec |                        | 86BG Operation   |
| 26 | 81 - 4 |                             | Rate of rise of frequency ( df/dt) | MICOM | Setting = 50.01+2.0Hz/Sec + 0.2Sec                   |                        | SUT breaker trip |
|    |        |                             |                                    |       | Setting = 50.01+2.0Hz/Sec + 0.5Sec                   |                        | 86C Operation    |
|    |        |                             | Over Frequency ( f+t)              |       | Setting = 51.5 Hz + 0.2 Sec                          |                        | SUT breaker trip |
|    |        |                             |                                    |       | Setting = 51.5 Hz + 0.5 Sec                          |                        | 86C Operation    |

### GENERATOR TRANSFORMER PROTECTION

| Sl | Designation | Description                      | Type    | Setting                           |
|----|-------------|----------------------------------|---------|-----------------------------------|
| 1  | 87GT        | Over all Differential Protection | MBCH-13 | Settings = 20%                    |
| 2  | 50/51GT     | Back-up O/C HV side              | CDG-63  | PSM=1.0, TMS=0.4, Inst = 800%     |
| 3  | 50Z         | GT Breaker L.B.B. Protn.         | CTIG-39 | Setting = 5%                      |
|    | 2/50Z       | Timer                            | VTT-11  | Setting = 250 mSec                |
| 4  | 64GT        | G.T. H.V. REF                    | CAG-14  | Setting = 0.1 A, SR=185 Ohms      |
| 5  | 51 NGT      | G.T. B/U E/F Protn.              | CDG-11  | PSM=0.2, TMS=0.52                 |
|    | 2/51NGT     | Timer                            | VTT-11  | Setting = 1.0 Sec                 |
| 6  | 30 FG       | WTI Alarm                        |         | WTI Set 90 degree C alarm         |
| 7  | 30EG        | WTI Trip                         |         | WTI Set 100 degree C trip         |
| 8  | 30 HG       | OTI Alarm                        |         | OTI Set 70 degree C Alarm         |
| 9  | 30GG        | OTI Trip                         |         | OTI Set 80 degree C Alarm         |
| 10 | 99G1        | GT Over flux Stage-1             | GTTM-22 | Setting K1=1.1, K2=1.3            |
|    | 2/G1A       | Timer                            | VTT-11  | Setting = 10.0 Sec                |
| 11 | 99G2        | GT Over flux Stage-2             | GTT-21  | Setting V/F=1.15, 99G2A=1.0Sec    |
|    | 2/G2A       | Timer                            | VTT-11  | 99G2T=120 Sec<br>Setting=10.0 Sec |

### UNIT AUXILIARY TRANSFORMER PROTECTION

| Sl. No | Designation       | Description                 | Relay Type | Settings                           |
|--------|-------------------|-----------------------------|------------|------------------------------------|
| 1      | 87 UAT            | UAT Differential Protection | MBCH-13    | Setting=20%                        |
| 2      | 64UAT A / 64UAT B | UAT REF Protection          | FAC-14     | Setting=125 V                      |
| 3      | 50/51 UT          | UAT B/U O/C Protection      | CDG-63     | PSM=1.0, TMS= 0.32, Inst= 600%     |
| 4      | 51SN1/51SN2       | B/U E/F UAT LV-A            | CDG-11     | PSM=0.2, TMS= 0.44.                |
| 6      |                   |                             |            | WTI Set 88 degree C alarm          |
| 7      |                   | WTI Trip                    |            | WTI Set 93 degree C Trip           |
| 8      |                   | OTI Alarm                   |            | OTI Set 80 degree C Alarm          |
| 9      |                   | OTI Trip                    |            | OTI Set 90 degree C Trip           |
| 10     | AVR               | Automatic Voltage Regulator | VTJCM-13   | 1. Regulated voltage=110 V         |
|        |                   |                             |            | 2. Sensitivity: Dead band=+/- 2.5% |
|        |                   |                             |            | 3. Selected Characteristics "c"    |
| 11     | 50 RYB            | OLTC O/C Protection         | CAG-39     | 95% I.e., 0.95A                    |

| <b>START-UP TRANSFORMER PROTECTION</b> |                    |                             |                   |                                       |
|----------------------------------------|--------------------|-----------------------------|-------------------|---------------------------------------|
| <b>Sl. No.</b>                         | <b>Designation</b> | <b>Description</b>          | <b>Relay Type</b> | <b>Settings</b>                       |
| 1                                      | 87 SUT ABC         | Differential Protection     | MBCH-13           | <b>Setting = 20%</b>                  |
| 2                                      | 64 HV              | REF Protn. HV Side          | FAC-14            | <b>Setting = 25V</b>                  |
| 3                                      | 64LVA/LVB          | REF Protn. LV Sides         | FAC-14            | <b>Setting = 125 V</b>                |
| 4                                      | 67 ABC             | Directional O/C Protection  | CDD-41            | <b>PSM=0.75, TMS=0.4, Inst=600%</b>   |
| 5                                      | 67 N               | Directional E/F Protection  | CDD-41            | <b>PSM=0.2, TMS=0.4, Inst=200%</b>    |
| 6                                      | 99SUT              | Over fluxing Protection     | GTTM-22           | <b>Settings K1=1.1, K2=1.23</b>       |
| 7                                      | 51SNA/51SNB        | LV Side B/U E/F Protn.      | CDG-11            | <b>PSM=0.2, TMS=0.4.</b>              |
| 8                                      | 50Z                | Local Breaker B/U protn.    | CTIG-39           | <b>Setting=0.2A</b>                   |
|                                        | 2/50Z              | Timer                       | VTT-11            | <b>Setting = 0.25 Sec</b>             |
| 9                                      | WTI                | Winging Temperature         |                   | <b>95 degree C Alarm</b>              |
|                                        |                    |                             |                   | <b>105 degree C Trip</b>              |
| 10                                     | OTI                | Oil Temperature             |                   | <b>85 degree C Alarm</b>              |
|                                        |                    |                             |                   | <b>95 degree C Trip</b>               |
| 11                                     | AVR                | Automatic Voltage Regulator | EMCO EE-301-M     | <b>1. Regulated Voltage = 110 V</b>   |
|                                        |                    |                             |                   | <b>2. Nominal Value = 110 V</b>       |
|                                        |                    |                             |                   | <b>3. L Setting = 2.75V (2.5%)</b>    |
|                                        |                    |                             |                   | <b>4. R Setting = 2.75 V (2.5%)</b>   |
|                                        |                    |                             |                   | <b>5. Time delay setting = 20 Sec</b> |
| 12                                     | 81-5               | SUT Over Frequency Protn.   | MFVUM-22          | <b>52.0 Hz + 20.0 Sec</b>             |

### **CT's, PT's and PROTECTION**

- What is the inrush current peak of the transformer?  
6 to 8 time that of full load current.
- Why REF is now is used for HV side also in GT/SUT?  
The E/F setting of differential is poor.
- Why IDMT over current relay is always used as backup?  
Because setting has to be 200% to emergency loading and TMS be large to grade with feeder. Therefore very slow for internal faults/terminal faults/uncleared LV faults.
- Purpose of standby E/F protection in SUT/UT?  
Back up for LV winding, LV neutral CT- CDG 12 – resistance earthing – relay set high time delay to discriminate with LV feeder and trip transformer if sustained E/F, also protects neutral earthing resistor.
- Why do we use O/C & E/F protection on both sides of transformer?  
Power in feed exists on both ends.
- Why in DG E/F protection, we do not open class IV CB's or supply CB's?  
Delta of aux. Transformer prevents E/F currents from grid into DG neutral.
- Why 100% winding protection is felt essential for main generator stator E/F protection? (Used in NAPS onwards?)  
At MAPS 4% of winding is not protected. Earlier felt that the Electro magnetic stress due high external fault currents near 4% of neutral may not be high to cause E/F here. But now felt that the mechanical stress can leads to E/F.
- How 100% winding protection is given there?
  - a) Inject sub harmonic AC current into generator neutral. Monitor its amplitude. E/F impedance reduces so current drawn increases and trips (Not used).
  - b) 3<sup>rd</sup> harmonic voltage monitored on neutral, fault near neutral upto 25% winding. 3<sup>rd</sup> harmonic voltage reduces to zero. Above this 3<sup>rd</sup> harmonic voltage increases, so combined both 3<sup>rd</sup> harmonic and zero sequence relays for 100% covering, no blind zone.
- What is the basic purpose of class-B protection?  
Class-B avoids load rejection. For modern machines, the inertia is less and easily gets damaged on overload. Therefore trip only for internal faults.  
Low forward interlock prevents the risk of run away if a CIES valve fails to close.



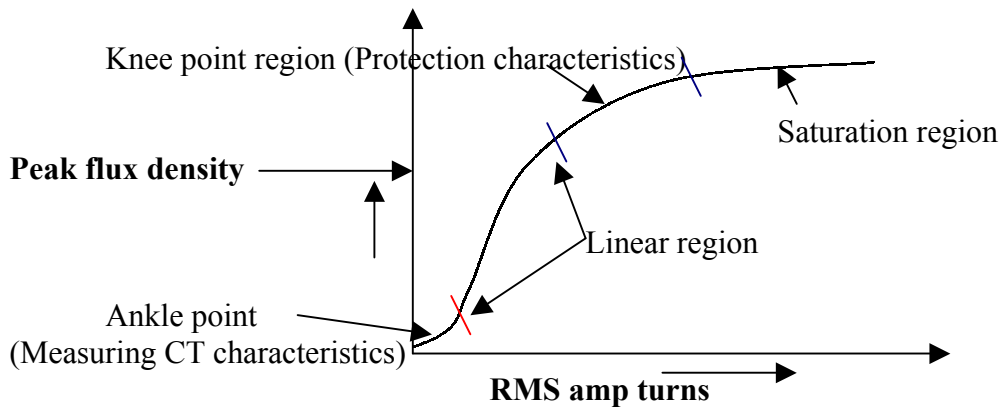
- What are the effects of GT over fluxing?
  - a. Eddy current circulation.
  - b. Magnetising current increases
  - c. Winding temp increases
  - d. Transformer noise/vibration increases.
  - e. Over heating of non laminated metal parts (affected by stray fluxes)
- Why stabilising resistor in REF or residual E/F scheme?  
Required against CT saturation under heavy through fault currents.
- Why in transformer the LV CB also be tripped along with HV CB for a primary side fault?  
Auxiliary transformer 415v delta star transformer, if HV CB alone tripped then back feeding from LV side (say DG runs parallel with transformer)—arcing voltage at the fault on primary—fault fed for more time – more damage.
- Why high impedance circulating current differential?  
Under through faults, CT's of different phases saturates differently. Net spill current will operate low impedance CAG relay, so high impedance scheme with CAG relay and stabilising resistor used.
- How to reduce the CT error?  
Error reduces if load increases.
- What is the advantage of housing CT's with in bushings?  
Bushing acts as a primary insulator for the CT.
- Why the earthing transformer primary voltage is 16.5 kV rated in main generator even though actual voltage during the E/F is root 3 times less?  
The transformer should not saturate during E/F otherwise it will cause ferroresonance with the GT winding capacitance. Dangerous O/V and neutral shifting will occur. During loss of load or field forcing conditions, the transformer voltage increases to cause saturation. Saturation can also occur due to point on wave of application causing flux doubling.
- Where are the following relays used?
  - a) Very inverse b) extremely inverse relays c) definite time O/C Relay d) instantaneous O/C Relay.
  - a) Very Inverse – Used where inverse protection reduces substantially as distance from source increases, operating time doubles for a fault current reduction from 7 in to 4 in, used where the short ckt current is independent of generating conditions.

- b) Extremely inverse – Used for feeders subjected to peak making currents. Grade with HRC fuses, e.g. Refrigerator, pumps.
- c) Definite time O/C Relay – Where neutral is resistance earthed- fixed ground current.
- d) Instantaneous O/C Relay – Used along with inverse O/C relay – to get higher grading margin. Disadvantage – Under minimum generation it may not operate.



- Why delta – delta CT's are used for star – star transformer differential protection?  
Say primary neutral is not solidly earthed. Then for any earthfault on secondary terminal, the primary current distribution is so for external fault, the differential is likely to operate if sequence current from flowing into relay. The 2:1:1 distribution is possibly only for core type or delta tertiary.

- Show the CT characteristics.



- What is knee point?  
Knee point is the region, where 10% increase in flux causes 50% increase in exciting ampere-turns.
- When will you say that the CT is saturated?  
When checking the CT with the secondary injection method a 10% increases in the voltage causes a 50% increase in the current the CT is said to be saturated.
- What is the problem anticipated due to CT saturation?  
The CT will not be able to drive the current through the circuit causing non-operation of relays. In some other case when the currents in the two phases are compared for relay operation the relay may operate due to unbalance.
- How can you de-saturate the CT?  
Pass ac current through the primary and vary the current from zero to maximum with secondary in shorted condition.  
Pass dc current in the secondary and vary it from zero to maximum.
- Why CT should not be open circuited?  
Very high voltage will be induced in secondary due to less back emf resulting in the failure of the insulation.
- What precaution should be taken while removing a current operated relay when the equipment is in service?

Ensure that the CT is not getting opened by shorting the appropriate terminals. (Eventhough the terminals are automatically shorted once relay is removed the above point may carried out to ensure the same)

- What do 10p15 mean?  
When the current passed through the CT is 15 times the rated current then the secondary current will have a composite error of 10%
- Where core balance CT's are used?  
In earth fault protection used. It senses the zero sequence current.
- What are the specifications of CT?  

|                        |                               |
|------------------------|-------------------------------|
| Protection CT          | - Error. Alf. KpV.            |
| Metering CT            | - Error. Burden.              |
| Differential CT        | - Class PS.                   |
| Core balance or E/F CT | - 5-p type.                   |
| Primary current        | -                             |
| Rating of CT           | - 1. 15 ( full load current ) |
| Short time rating      | - 1 sec.                      |
- Why differential protection for PHT motors?  
For more than 2500 kW motors it is required to provide differential protection. It is biased Relay against internal phase fault or earth fault very fast. Insensitive to starting current and stalling current.
- What are the errors of the following CT' s 5p. 10p. 15p. At rated current?  

|     |                                            |
|-----|--------------------------------------------|
| 5p  | - 1 % Ratio error $\pm$ 60 min phase error |
| 10p | - 3 % Ratio error $\pm$ 60 min phase error |
| 15p | - 5 % Ratio error $\pm$ 60 min phase error |
- What is the operating point in the Magnetising characteristic of protection CT & measuring CT?  
 Protection CT – Operation at ankle point only.  
 Measuring CT – Operation from ankle to knee point
- What is over voltage interturn test for CT?  
With secondary open, pass rated current in primary for 1 min. Then check secondary for insulation.
- A CT has 2 – secondary windings. If we use only one secondary winding can we keep the unused secondary winding short circuited?  
No. If it is short-circuited then the ratio will not get correctly. The turns of primary winding will be shared between 2 secondary windings. So the unused secondary winding should kept open.
- But is it advisable to keep the secondary of CT in open conditions? Will not induce very high voltage?

If the CT has only one secondary winding, we should keep it always short cktd for safety, but if the CT has multiple secondary, then if one secondary voltage is kept limited by suitable loading, then the other secondary voltage is eventually limited proportionately.

- Why PT fuse fails protection?  
Mho relays will mal-operate if PT voltage is lost to the relay, so tripping blocked by sensing PT fuse failure.
- What is the 2 stage stalling protection for PHT motor?  
Because locked rotors withstand time of motor is less than starting time of motor under reduced voltage conditions.  
Stage 1 = 350% 6 sec for starting at rated voltage  
(Because starting time = 6 sec + hot stall time = 7 sec)  
Stage 2 = 175% 15 sec to permit 14 seconds starting time under reduced voltage condition  
(Since starting current is less, stage 1 will not operate)
- Purpose of start up protection? Is it always in service?  
Trips the generator. If generator is excited with internal fault the over current 50s trip the generator to prevent major damage. The earth fault relay 64c also. The relays are polarised dc armature type, sensitive to all frequencies, since the frequency need not to be 50 Hz initially during start up. Start up protection is cutout as soon as generator CB is closed.
- What is the standard CT polarity?  
Primary current enters at P1 and secondary current leaves at S2.
- Does over load relay give 100% guarantee against the single phasing?  
No. It depends on the motor load and the motor winding (star or delta).
- What are the effects of single phasing?
  - a. Current will increase  $\sqrt{3}$  times.
  - b. More heat in stator and rotor parts.
  - c. Insulation failure and short circuit & Ground fault may occur.
- What is the purpose of CT & PT?  
For transformation of current, voltage to a lower level for the purpose of Measurement, Protection and Control.
- Where CT secondary of 1A we are using?  
For long distance current transmission, to reduce the IR drop.
- What is the nomenclature of English electric relay?
  - a) First letter-operating quantity
  - b) Second letter-movement
  - c) Third letter-application

d) Fourth letter-special variation.

- Define knee point voltage.  
The voltage applied to secondary of CT keeping the primary open at which 10% increase in voltage causes 50% increase in excitation current.

- What is differential protection?  
It is the current balance type protection, in which vector difference between current entering the winding is used for relay operation.
- What are the checks on CT & PT?
  - a) Polarity checks
  - b) Insulation checks
  - c) Ratio checks
  - d) Knee point voltage (only for PS class CT)- magnetising characteristic test.
- What is Local Breaker Back up protection?  
In case of local breaker fails to operate during fault due to mechanical failure this protection will protect the system from sever damage. It will trip all the other breakers in that bus after time delay.

## **TRANSFORMERS**

- Give transformer nameplate details of GT, SUT, UAT, SET, 415 V Aux transformer and Lighting transformer.

|              | GT                | SUT                               | UAT                                | SET            | 415V Aux trans. | L Trans.          |
|--------------|-------------------|-----------------------------------|------------------------------------|----------------|-----------------|-------------------|
| USI          | 5210              | 5120                              | 5220                               | 4120           | 5242            | 5231              |
| Make         | Telk              | Telk                              | BHEL                               | BHEL           | EE              | Square Automation |
| STD          | IS – 2026         |                                   | IS– 2026                           |                |                 |                   |
| Type         | WFOC              | Oil immersed                      | Oil immersed                       | DRY RESIN CAST | DRY RESIN CAST  | DRY RESIN CAST    |
| Cooling      | OFWF              | ONAF / ONAN                       | ONAF / ONAN                        | AN             | AN              | AN                |
| VA           | 260/260 MVA       | 35/20/20/12 MVA<br>24.5/14/14 MVA | 35/20/20 MVA<br>24.5/14/14 MVA     | 3150 kVA       | 1800/1200 kVA   | 250 kVA           |
| Volts        | 235/16.5 kV       | 220/6.9/6.9/11 kV                 | 16.5/6.9/6.9 Kv                    | 16500/575 V    | 6600/435 V      | 415/415V          |
| Amps         | 639/9098 A        | 64/1172/440 A<br>91/1675/629 A    | 1266/858A<br>1676/1172 A           |                | 157.5/2400 A    | 630/250,125A      |
| No of $\phi$ | 3                 | 3                                 | 3                                  | 3              | 3               | 3                 |
| Frequency    | 50 Hz             | 50 Hz                             | 50 Hz                              | 50 Hz          | 50 Hz           | 50 Hz             |
| Impedance    | 13.13 (14) %      | 9.75% / 18.82%                    | 10 $\pm$ 10% HV<br>22 $\pm$ 10% LV |                |                 |                   |
| Vector       | YNd11             | Yn yno yno (d1)                   | D yn1 yn1                          | Dyn            | Dyn11           | Dyn11             |
| Oil          | 42000 Lt.         | 25260 Lt.                         | 19750 Lt.                          |                |                 |                   |
| Tap change   | Off load          | ON load HV                        | ON load HV                         |                |                 |                   |
| Tapchange%   | 10 steps of 2.5 % | $\gamma$ 12% in 1.5% steps        | $\gamma$ 12% in 1.5% steps         |                |                 |                   |

- What is the use of Tertiary winding?  
Star connected circuit, which has an isolated neutral there can be no zero sequence components. Since the zero sequence components are by definition in time phase with another their sum can not be zero at the junction point as per kirchoff's law. It follows that there are limitations upon the phase loading of a bank of transformers connected in star – star unless the neutral points are connected to the source of power in such a manner that the zero sequence components of current have a return path or unless the transformer are provided with tertiary winding.
- What is E/F current limit for SUT and UT?  
400a limited by 10 ohms resistor.
- What is the coverage of differential protection for SUT?  
Covers from 230 kV bushing to 6.6 kV breaker end.
- What are the advantages of dry type transformer?  
No fire hazard.  
It can be mounted indoor.



- During unit operation, can we parallel 2 SUT?  
No, due to switchgear limitation.

- Why 6.6 kV transformer is resistance grounded by 10 ohms and current limited to 400 A?
  - a) To reduce burning and melting in faulted switchgear or machine.
  - b) To reduce mechanical stresses in equipment.
  - c) To reduce the electrical hazards by stray ground fault currents in the ground return path.
  - d) To reduce momentary line voltage dip due to ground fault.
  - e) The current is limited to 400A, that is  $\frac{1}{4}^{\text{th}}$  of the load current to reduce the size of the screen in 6.6 kV XLPE (cross-linked polyethylene). Therefore the cost of the cable decreases.
- During unit operation can we have one UT feeding both unit 6.6 kV loads?  
No, logically prevented.
- During unit operation, can we parallel UT & SUT continuously?  
No, due to switchgear limitation.
- What is the design basis of 6.6 kV aluminium bus bars?
  - a) Temperature rises not exceed 90 °C.
  - b) Withstand short ckt stresses.
  - c) Take care of thermal expansion.
- Why 2 types of earth fault relays in 6.6 kV side of transformers?  
I – Trips 6.6 kV breakers only. It gives primary protection for 6.6 kV bus bars.  
I<sub>1</sub> – Trips the both HT and LT breakers. It acts as a backup to ref and also acts as backup to bus bar earthfault relay.
- Why core balance CT is preferred over residual connected CT's to sense earth fault in 6.6 kV feeders?
  - a) To avoid relay mal-operation due to CT saturation
  - b) Better sensitivity is got.
  - c) High pickup and TMS avoided in IDMT earth fault relay.
- How selection of cooling fluid in GT done?
  - a) There are 5 factors are there.
  - b) Density
  - c) Coefficient of thermal expansion
  - d) Viscosity
  - e) Specific heat
  - f) Thermal conductivity.
- What are the ranges in which each type is effective?

ONAN – Natural cooling – up to 15 MVA.

ONAF – Air forced radiators cooling – 10 to 100 MVA depending on availability of area.

OFWF = oil forced and water forced used in more than 100 MVA.

- Why off load tap changer was chosen for GT?  
Because our plant works on base load always.
- What are the advantages of OFWF?  
Ensure the differential temperature between top and bottom of transformer is minimum and Effect of ambient air temperature is minimum.
- What is the type of lightning arrestor for GT?  
Zn O (zinc oxide) types.
- What is the purpose of header breaker in water circuit?  
The header breaker ensures oil pressure greater than that of water pressure always. Therefore there is no leak of water into oil.
- Why thermosyphon filter required?  
To keep required dryness/improve dryness of the transformer insulation, internal part of transformer. When transformer operates, due to pressure head between top and bottom small quantity of oil flows through filters (absorbent material activated alumina grade g-80 removes the moisture from oil). Absorbent material remove slag, acids, peroxides, ionic impurities from oil, which otherwise accelerate against of oil. Absorbent unit is reactivated at regular intervals.
- What is the purpose of pronol conservator (KAPP)?  
Flexible separator avoids direct contact with atmosphere. Efficient barrier between oil and air. Ensures the protection against water vapour, suppression of gas bubbles formation in the oil.
- Why main generator/UT is not provided with separate overfluxing protection?  
Since GT is provided with overfluxing protection, it is adequate to protect main generator / UT also. Main generator can withstand higher degree of overfluxing. If a generator CB is used, separate overfluxing protection is essential for main generator.
- What is the advantage of Pressure relief device in TELK type GT over explosion vent of BHEL, even though in both cases oil will be expelled out during sudden pressure rise?  
During internal fault, the internal pressure rise is relieved by the expelling out of oil through Pressure relief device /explosion vent. However the Pressure relief device closes back when the pressure drops. Hence the oil exposure to atmosphere is minimised, thus saving large quantity of costly transformer oil from oxidation and moisture absorption. Fire hazard due to transformer oil does not exist after the closure of Pressure relief device.

- To reduce tower-footing resistance, which are better to use a) chemical, b) ground rods, c) counter poise?  
B & C

- Why tap changer is kept at neutral end?
  - a) To reduce insulation cost of tap changer.
  - b) But reactance changeover the tap range increases.
- Why guard connection is given for megger?

For true measurement of IR value of HV to earth of a transformer, connect line to HV, earth to transformer tank and guard to LV. Therefore leakage current from HV to LV is not included.
- Why lighting isolation transformer is req.?
  - a) 3 wire to 4 wire conversion, since neutral is required for lighting load.
  - b) Prevents transfer of E/F currents
  - c) Reduces the fault level on secondary side and permits use of small sized cables / CB's / fuses.
- Why neutrals are solid grounded above 33 kV?
  - a) Less transient over voltage due to arcing grounds.
  - b) Voltage of phases are limited to phase to ground voltage. (No neutral shifting)
  - c) Allows graded insulation of transformer (low cost)
  - d) Fast E/F protection.
- Why SET is chosen as Dyn 11?

To have smooth commutation in generation in between stator and rotor.
- Why all 415V transformers are chosen Dyn 11? What are the protections provided for the 415V transformers?
  - a) To facilitate interchange.
  - b) To have momentary parallel during changeover.

Protections

  - a) Door interlock to trip HT and LT breakers.
  - b) LT breaker can on only after HT breaker is in on position.
  - c) Instantaneous O/C and inverse O/C (50 + 51).
  - d) Instantaneous E/F (50N).
  - e) IDMT E/F and restricted E/F (51N + 64).
  - f) Winding temp high trip (140°C trip and 130°C alarm)
- What is the instrument name used for thermograph?

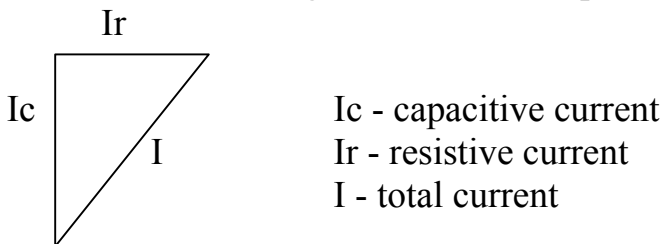
Infrared camera.
- Why neutrals are solid grounded below 600v?

Human safety

Permits enough E/F current because ground resistance is large in less than 415v,  
hence fast fault clearance,

Equipment safety against over voltage.

- What are the advantages of ungrounded system?  
Supply is maintained even with fault on one line  
Less interference to communication lines because of absence of zero sequence currents.
- Why resistance grounding preferred for less than 33 kV and more than 415 V?  
a) To limit the earth fault current for equipment safety else, high short ckt forces dislocate in windings/bus bars etc,  
b) Over voltage due to arcing ground reduced  
c) Permits earth fault protection (not possible in ungrounded system)
- What is meant by tan-delta measurement?  
It is the tan of the angle between the capacitive current and the total current.



As the value of tan delta increases the resistive component of the current is increasing. Hence it shows a weak insulation.

- What is the vector group of GT, UT, SUT?  
Yd11  
Dy1  
Yy0
- Why all the transformers are having different vector group?  
UT and SUT are getting paralleled at 6.6 kV bus. Hence they should have voltage of same phase relationship. This is achieved by assigning different vector group to the transformers.
- What are the built in protections for transformers?  
a) Buchholz relay  
b) Explosion vent or relief valve  
c) Gas operated relay for on load tap changers.
- Why water pressure is kept below the oil pressure? How it is maintained?  
In case of a heat exchanger tube failure the water should not go inside the transformer. For this purpose the oil pressure is kept above the water pressure.



- What is the requirement oil in a transformer?  
Oil is used removal of heat produced in the transformer and also as insulating medium.

- What is meant by over fluxing of transformer?  
When the voltage is increased and the frequency is reduced the transformer will draw high magnetising current. This will result in higher core loss and subsequent heating of core and ultimate failure of transformer. Hence over fluxing protection is provided for the transformer.
- What type oil pumps are used?  
Canned rotor pumps.
- What is oil reclaiming and reconditioning?  
In reclaiming process the oil treated to remove all its impurities like acidity, sludge, sediments, moisture etc. The treated oil will be in par with the new oil. In reconditioning process (filtering of oil) only moisture and suspended impurities and sediments are removed.
- Why there is no mixing of oil of tap changer and transformer?  
When the tap changing takes place arc is struck between the contacts. Due to this the oil inside the tap changer will be highly carbonised. If both oil get mixed up the quality of transformer tank oil will come down. This is not advisable. Hence both oils are kept separately.
- Why the tap changers are always connected to HV side of the transformer?  
During tap changing action the load current has to be shifted from one tap to another tap. In case HV winding the load current will be less. Hence lesser arcing will take place.
- What is the purpose of conservator?  
To accommodate the change in volume of oil during increase in temperature.
- Why the neutral is earthed through earthing resistance in case of UT and SUT?  
This is done to limit the earth fault current.
- Why REF is provided in the LV side of SUT and UT?  
The LV sides of the two transformers are earthed through the resistance. This will limit the flow of current in case of LV earth fault. Hence the differential protection may not act for a LV earth fault. Hence ref protection is provided.
- Why twin secondary SUT?  
As per is, the rating single secondary power transformer is limited to 25MVA (6.6 kV) or 40 MVA (11 kV), in order to limit the 3 phase symmetrical fault level with in 26-40 kA (contribution from grid and local machines)

- How 6.6 kV-bus supply was chosen?  
11 kV was rejected in view of the high insulation cost with 11 kV motors.  
3.3 kV was rejected, since max motor size with 3.3 kV bus is limited to 2 MW. But we are having the motors having rating more than 2 MW, which cannot suit to 3.3 kV bus. 6.6 kV bus we can start upto 5 mw size motor.

- Why oil transformers are out door?  
Oil fire point = 170 °C easy catching of fire.
- What are the I.S used in transformers?  
IS – 1866 FOR MAINTENANCE AND SUPERVISION OF OIL  
IS – 10593 FOR GAS ANALYSIS  
IS – 1886 FOR INSTALLATION AND MAINTENANCE
- When oil filtration is required?  
On reweaving oil test results.  
Draining of oil for maintenance  
Topping up of transformer oil
- Why oil filtration is required?  
To remove water, sediments, sludge etc.
- What are the types of oil used for in transformer for cooling?  
Paraffin based and naphtha based (in INDIA)
- What are the types of bushing used in transformer?  
Condenser type bushing  
Porcelain type bushing
- What are the precautions to be taken while terminating the bushings?  
Contact surfaces with intermediate plates,  
Mating surfaces should be identical.
- How bushings are terminated inside the transformers?  
By grooving method or by binding wire method.
- Why ICT are used?(INTERPOSING CT)  
To correct the system primary CT errors in case of high current faults out side CT zone (ICT's primary CT is 800/1, but in fault current may go to thousands of amps. This ICT will take care of those errors.  
a) Matching the ratios.  
b) Matching the phase angle differences.
- How CT is connecting in ckt?  
If the primary of CT is delta connected load the CT will be in star connection and vice versa. This is because to have square root 3 time compensation.

- What type of gasket and adhesive are used in transformer?  
Gasket – Neoprene based rubberised cork type RC70-C. (IS4253)  
Adhesive –Dunlop adhesive S-758  
These are recommended by TELK

- What are the precautions to store the Gasket?
  - a) Stress free storage
  - b) No folding
  - c) No reuse
  - d) Replace with same thickness
- What is the in built protection for transformer?  
PRV to protect from over pressurization of tank due to the release of gases, oil etc.  
This is the replacement for the explosion vent.
- Why UT, SUT secondary is rated for 6.9kV where as bus voltage is 6.6kV?  
The no load secondary 6.9kV voltage level adequately takes into account voltage drop during loaded condition to cater station buses at 6.6kV level.
- Why our GT having off load tap changer?  
Because our station is base load station.
- Why vector group of SUT is chosen as Yn-Yo-Yo?  
To facilitate momentary paralleling of SUT with UT on 6.6kV buses.
- Grounding of various transformers.
 

|     |    |                                                     |
|-----|----|-----------------------------------------------------|
| GT  | HV | solidly grounded                                    |
|     | LV | (delta)                                             |
| UT  | HV | (delta)                                             |
|     | LV | cast stainless steel 9.95 ohms 400A for 10 seconds. |
| SUT | HV | solidly grounded                                    |
|     | LV | cast stainless steel 9.95 ohms 400A for 10 seconds. |
- What are the protections for GENERATOR TRANSFORMER?
  - a) Differential protection
  - b) Restricted earthfault protection
  - c) Backup earthfault protection
  - d) GT phase back up protection
  - e) Overfluxing protection
  - f) Oil surge (gas) protection
  - g) High winding temperature and oil temperature protection.
- What are the protections for SUT?
  - a) Over current protection for phase and earth fault
  - b) Differential protection
  - c) HV and LV restricted earthfault protection

- d) HV side directional back up over current protection for phase and earth fault.
- e) LV back up over current and earth fault protection
- f) Over fluxing protection
- g) Buchholz and high oil, winding temperature protection.

- What are the protections for UT?
  - a) Differential protection
  - b) LV restricted earthfault protection
  - c) LV back up earthfault and over current protection
  - d) Buchholz and high oil, winding temperature protection.
- What is the purpose of carona ring?

To minimize the arcing current during switching operations of disconnecting switches.
- What are the various tests on transformers?
  - a) Tan delta and capacitance dissipation factor
  - b) Tests on cooling fans
  - c) Tests on OLTC
  - d) Vector group test
  - e) Short circuit test
  - f) Open circuit test
  - g) Insulation resistance test
  - h) Turns ratio test
  - i) Winding resistance test.
- Why input transformer of PUPS module 1 is delta-delta and module 2 is delta-star?

With the help of this arrangement, combined DC output from both chargers is equivalent to that from a 12-pulse rectifier. Advantage of 12-pulse rectifier is that the mains current is fairly close to sine wave. Harmonics injected into system by rectifier are low. The phase angle difference 30-degree between module 1 output and module 2 output give 12-pulse output.





## MOTORS AND MCC

- What is Motor?

It is a device, which converts electrical energy into mechanical (rotating) energy.

### **Definition of terms used in Motor:**

- 1) Duty Cycle rating: Most motor has a continuous duty rating to permit continuous operation at a rated load. However motors may be rated as intermittent duty, periodic duty or varying duty and must be turned off and allowed to cool after a fixed operating time.
- 2) Full- Load current: The current required to produce full-load torque.
- 3) Jogging: The starting and stopping of a motor at frequent intervals.

- What is Motor controller?

A device that controls some or all of the following functions: starting, stopping, overload protection, over current protection, reverses, changing of speed sequence control and running/jogging.

- What is Motor speed?

The shaft speed of the three-phase squirrel cage motor is determined by the frequency of the supply voltage and the number of poles in the motor. A two-pole motor runs at a speed of 3000 rpm on 50 cycles per second.

$$\text{rpm} = \frac{\text{cycles per second} \times 60}{\text{Poles}} - \text{slip}$$

(Where slip is the difference between the speed of the rotating magnetic field and the speed of the rotor.)

- Why Over current protection used?

A fusible disconnect or circuit breaker used to protect the branch circuit conductors, control devices and the motor from grounds and short circuits. the over current protection device must be capable of carrying the starting current to exceed 400% of the motor full load current.

- What is Overload?

Any excessive amount of current drawn by the motor is called overload. Overloads on a motor may be mechanical or electrical.

- What is Plugging?

The instant reversal of motor is called plugging. Damage to the driven machinery can be result if plugging is applied improperly.

- What is Sequence control?

The control of separate motors to operate in a predetermined pattern.

- What is Service factor?

The amount of overload that may be permitted without causing significant deterioration of the insulation on a motor. For example, if a 10 hp motor has a service factor of 1.15, the motor can be safely be subjected to an 11.5 hp load.

- What is Starting current or Locked rotor current?

The current flow in the motor at the instant of starting. This current can be 4-10 times the full load current of the motor. The most common locked rotor current is about 6 times the full load current. Such a motor will start with a 600% overload.

- What is Torque?

The twisting force produced by the motor is called torque. Its unit is in foot-pounds (ft-lb.), torque is related to horsepower by the following formula.

$$\text{Torque} = \frac{\text{horsepower} * 5252}{\text{Revolution per minute (rpm)}}$$

- Write details MCC construction.

a) MCC are made up of sheet steel enclosure, indoor floor mounting and free standing, Dust and vermin proof, modular type and of double front and single front (X1, Y1).

b) Degree of protection is IP 50 as per IS 2147.

c) 0.9 \* 0.8 \* 2.4 meters size (double front and single front) and top entry of cables.

d) 0.9 \* 0.6 \* 2.4 meters size (single front) and bottom entry of cables.

e) Parts are incoming panel, Cable entry, TB compartment, MCC module compartment.

f) MCC modules are fully drawn-out type.

g) Main buses are horizontally mounted and vertical buses are connected to MCC cells.

h) Stab – in contacts are used for power and wipe – in contacts are used for control circuits.

i) CT and PT are used for current and voltage measurements.

j) 3 $\phi$  indication lamps are provided for identification.

k) Voltage meter and ammeter are provided.

l) Panel space heater and emergency push button key operated are provided.

m) Control building and SRPH MCC are safety related and SB, TB, RAB, CWPH, DM Plant MCC's are non safety related.

- What is the maximum load on MCC?

3 Phase load upto 90 kW are fed by MCC.

- What are the types of MCC?

| Type | Application                                          | Protection  |
|------|------------------------------------------------------|-------------|
| A    | Receptacles, Cranes, Elevators, Local control panels | Fuse        |
| B    | Locally controlled heaters                           | Fuse, 49    |
| C    | Remote controlled heaters                            | Fuse, 49    |
| D    | Remote controlled loads <29 kW (49 in control panel) | Fuse        |
| F    | For valve motors                                     | Fuse, 49    |
| G    | Locally controlled loads <29 kW                      | Fuse, 49    |
| H    | Locally controlled loads >29 kW (RTM installed)      | Fuse, 49    |
| I    | DG MCC                                               |             |
| J    | Remote controlled loads <29 kW                       | Fuse, 49    |
| K    | Remote controlled loads >29 kW (RTM installed)       | Fuse, 49    |
| L    | Barring gear motor MCC                               | Fuse, 49    |
| SP   | For F/M supply and PHT S/D cooling pumps             | CT, PT Used |

- What is the operating life of bearings?
  - Continuous 24 hrs operation – 40000 to 50000 hrs.
  - Affected by load axially or radial.
  - Operating temperature.
- Give the 415 V MCC bus ratings and cable used.  
All MCC bus bars are made of aluminium. Short time current is 50 kA/sec and momentary rating is 105 kA.

| Type   | Bus Rating | Class | Location         | Cable Used |
|--------|------------|-------|------------------|------------|
| K1     | 1000 A     | IV    | TB 111 Mts.      |            |
| K2     | 1500 A     | IV    | TB 111 Mts.      |            |
| L1     | 1000 A     | IV    | RAB 108 Mts.     |            |
| L2     | 1000 A     | IV    | SB 106.5 Mts.    |            |
| L3     | 1500 A     | IV    | TB 111 Mts.      |            |
| M1     | 1000 A     | IV    | SB 106.5 Mts.    |            |
| M2     | 1500 A     | IV    | TB 111 Mts.      |            |
| N1     | 1000 A     | IV    | TB 111 Mts.      |            |
| N2     | 1000 A     | IV    | RAB 108 Mts.     |            |
| W1     | 1500 A     | IV    | CCW PH 98 Mts.   |            |
| W2     | 1000 A     | IV    | DM plant 98 Mts. |            |
| P1     | 1500 A     | III   | CB 100 Mts.      |            |
| P2     | 1500 A     | III   | CB 106.5 Mts.    |            |
| Q1     | 1500 A     | III   | CB 100 Mts.      |            |
| Q2     | 1500 A     | III   | CB 106.5 Mts.    |            |
| X1     | 600 A      | III   | SRPH 100 Mts.    |            |
| Y1     | 600 A      | III   | SRPH 100 Mts.    |            |
| PMCC S | 630 A      | II    | CB 106.5 Mts.    |            |

|               |              |           |                      |  |
|---------------|--------------|-----------|----------------------|--|
| <b>PMCC T</b> | <b>630 A</b> | <b>II</b> | <b>CB 106.5 Mts.</b> |  |
|---------------|--------------|-----------|----------------------|--|

- What are the types of isolators used?

| Isolator Range | Loads                 |
|----------------|-----------------------|
| 32 A           | ≤ 9.3 kW              |
| 63 A           | > 9.3 kW and ≤ 19 kW  |
| 125 A          | > 20 kW and ≤ 47 kW   |
| 250 A          | > 48 kW and ≤ 110 kW  |
| 400 A          | > 111 kW and ≤ 134 kW |
| 600 A          | ≤ 310 kW              |

- What are the ranges of fuse used?

| Fuse Range | Loads             |
|------------|-------------------|
| 2 A        | 10 to 280 watt    |
| 4 A        | 340 to 440 watt   |
| 6 A        | 500 to 700 watt   |
| 10 A       | 1000 to 1500 watt |
| 16 A       | 1.8 kW to 2.25 kW |
| 20 A       | 3 to 4 kW         |
| 25 A       | 5 to 8 kW         |
| 32 A       | 9 to 9.3 kW       |
| 50 A       | 9.6 to 15 kW      |
| 63 A       | 16 to 19 kW       |
| 80 A       | 22 to 24 kW       |
| 100 A      | 25 to 36 kW       |
| 125 A      | 38.6 to 45 kW     |
| 160 A      | 48 to 67.5 kW     |
| 200 A      | 72 to 80 kW       |
| 250 A      | 85 to 90 kW       |

- What is use of fuse in electric circuit, what are the materials used for fuse and what are their melting points?

Fuse is a weakest point in an electrical circuit, which breaks the circuit when abnormal current more than its rating flows through it. It works on principle of joule law ( $I^2Rt$ ). HRC fuse is filled with quartz powder to extinguish the arc generated in breaking the circuit or when fuse blown.

Current rating is depends on the type of material, cross section area, length and size of terminal (large size terminal dissipates more heat).

#### Formulae

$$H = I^2Rt/J$$

$$R = \rho l/a$$

$$a = d^2\pi/4$$

| Material | Melting point in °C |
|----------|---------------------|
| Silver   | 1830                |
| Copper   | 2000                |

|           |     |
|-----------|-----|
| Aluminium | 240 |
| Zinc      | 787 |
| Tin       | 436 |
| Lead      | 624 |



- What are the materials made of thermal overload relay? How OLR are selected?  
The bimetallic materials are Invar and brass. These materials having the differential coefficient of expansion. All bimetallic relays incorporate additional built in single phasing protection.  
The range of the relay provided for the feeders are such that the full load rating of the feeders is comfortably within the range of the relay (range will be at Centre) except in very minimum loads ranging from 0.1 – 0.16 A.
- What are the functions of arc chute?  
To increase the speed of rise of arc by magnetic action.  
It splits the arc by this arc resistance increases.  
Diagnosing the arc by cooling.
- What are IP (ingressive protection) and IC?  
IP means ingressive protection to the motor against the dust and water entry.  
The first digit indicates protection against accidental contact with live or moving parts (solid particles).  
The second digit indicates protection against ingress of water, foreign bodies (liquid particles).  
IC means instrument cooling to the motor (type of cooling)
- What are the classes of AC motors?  
*Depends on phases*
  - a. 1 $\phi$ .
  - b. 3 $\phi$ .*Depends on construction*
  - a. Squirrel cage induction motor for fixed torque.
  - b. Wound rotor motor for variable torque.*Depends on voltage*
  - a. LT motor - <200 kW.
  - b. HT motor - >200 kW.*Depends on torque and current*
  - a. Class – A (Normal torque and normal starting current. E.g. Fractional motors.) .
  - b. Class – B (Normal torque and low starting current).
  - c. Class – C (High starting torque and low starting current. E.g. Double sq. cage motor)
  - d. Class – D (high starting torque and high starting current).*Depends on mechanical characteristics*
  - a. Drip proof (IP 54). Safety against water or dust.
  - b. Splash proof.
  - c. TEFC (totally enclosed fan cooled).
  - d. TEOV (totally enclosed open ventilated).
  - e. TETV (totally enclosed tube ventilated. Principle is thermosymphony E.g. - CEP).
  - f. Explosion proof.

- What is the PI value required for motors?  
For class F insulation  $>2$  and for class B insulation 1.5 to 2.

- What are the enclosures used for HT and LT motors?

*LT motors (<200 kW)*

- a. Open drip proof.
- b. TEFC.
- c. Totally enclosed air over type.

*HT motors (>200 kW)*

- a. Open drip proof.
- b. Weather protected I
- c. Weather protected II
- d. Totally enclosed water-cooled.
- e. Totally enclosed pipe ventilated.

- What are the causes of motor failure?

- a. Corrosion or rust.
- b. Excessive moisture (winding IR low and bearing lubrication loss).
- c. High ambient temperature.
- d. Poor ventilation.
- e. Inadequate lubrication.
- f. Misalignment.
- g. Oil and dirt.
- h. Excessive starts and repetitive surges.
- i. Persistent over loads.
- j. Shaft currents (bearing pitting).
- k. Mis application.
- l. Manufacture defect or wrong design.
- m. Deterioration with age.
- n. Maintenance improper.

- What are the effects of excessive starts and repetitive surges?

Repetitive surges may give impact to the insulation of the motor and dielectric capability of the motor.

Excessive starts may subject stator winding to high current for more time. Subsequently in HT motor due to High Mass rotor bar and rotor short ring may loose or fail. Bearing also may damage.

- What are the effects of broken rotor bars and broken shaft parts?

*Broken rotor bars*

- a. High stator current and over heat of stator winding.
- b. More harmonic currents in end parts.
- c. High vibration.

*Broken shaft or parts*

- a. Stator winding loose bracing.
- b. Rotor high vibration and bearing vibration.
- c. Frame vibration and more harmonics in side bands.

- Give the relation between current and temperature in motors.

- a. Winding temperature is proportional to square of the current.
- b. 10% increase in current gives 30% increase in temperature.
- c. 10°C rise in temperature makes 50% life reduced.

- What are the effects of imbalance stator winding resistance?  
If the stator winding resistances are imbalance phase to phase give pulsating fluxes and pulsating torque on rotor and vibration may increase. For accurate resistance measurement Kelvin Bridge is used.
- What reflects the change in speed?
  - a. Supply frequency may vary the speed of the motor.
  - b. Load on the motor may vary the speed of the motor.
- What is use of BORESCOPE inspection?  
BOREScope inspection method makes it easy to observe the end winding condition of the motor. In this inspection winding ties, loose coils, dust etc can be observed.
- What you mean by CRAWLING and COGING?  
Crawling  
The motor fails to rotate at rated speed or motor rotates at ... or 20% speed is called motor crawling. This may be due to system imbalance or more pulsating torque.  
Coging  
Motor fail to start at all is called motor coging.
- Why motor starting current is high compared to transformer charging current?  
Transformer charging current is only 1% and that of motor starting current is 30 to 40%. Because of air gap between stator and rotor. If the air gap is more load taking capacity increases and if air gap is less the load taking capacity reduces.
- State construction details of the motor.  
**Stator or rotor core**  
Built from high quality low loss silicon steel laminations and flash enameled on both the sides made up of close-grained alloy cast iron.  
**Rotor conductor**  
Heavy bars of copper or aluminium alloy.  
**Stator**  
Copper conductor.
- What is the use of making rotor skewing?
  1. To run motor quickly by reducing magnetic hum.
  2. It reduces locking tendency with the stator.
- Why under voltage tripping of motor is incorporated in motor feeder breakers?  
The under voltage can occur in case of bus fault. If the motors are kept connected they will feed the fault which may cause the damage. Due to the back feeding from the motor the motor will slow down very fast. Hence process system will come to

halt very fast. (In case pht motor will not rotate for the designed 3 minute period in case of bus under voltage).

- What are the problems in station operation due to grid under voltage?
  - a) All the HT motors overloaded.
  - b) VAR load increases on generator leads to heating up of rotor
  - c) Stator current increases for same power export leads to stator over heating.
- What are the problems in station operation due to grid under frequency?
  - a) Turbine having under frequency limitation, house load happen if  $< 48$  Hz
  - b) Due to under frequency PHT flow reduces, therefore reactor power reduces, generator power reduces
  - c) If frequency is less than 48 Hz DG cannot be synchronised to grid, therefore DG kept on isolation running
  - d) GT overfluxing.
- What is the difference between fixed trip and trip free?  
Fixed trip: Breaker will trip only after closing even if trip impulses are existing.  
Trip free: Breaker is free to trip at any position.
- What is the making current capacity of a 3-phase breaker as derived from its symmetrical breaker capacity?  
Making capacity = 2.55 times symmetrical breaking capacity.
- Why intermediate contacts in English electric breaker?  
To prevent even slightest arcing on main contacts.
- Where preloaded ball bearings used?  
If more vibration exists even when machine is not in running conditions.
- Why do we grease the bearings?
  - a) Grease lubricant gives good protection against ingress of moisture and dirt into motor.
  - b) Easy to seal against leakage of grease into motor compared to oil.
  - c) Low friction torque at starting.
- Which bearings preferred for all large power motor?  
Plain bearings
- Which is more dangerous alkali or acid?  
It especially exposed alkali is more dangerous, use boric acid powder solution immediately.
- What FCN was implemented to avoid reactor trip on 220V-DC failure of PHT and PPP breakers?

The breaker close position supervision relay VAA 21 is changed by VAJC type, contacts position do not change if 220V-DC is lost now.



- Where oil lubrication is preferred over grease lubrication?
  - a) Determined by speed and operating temperature.
  - b) Oil lubrication recommended.
  - c) When speed and temperature is high.
  - d) When heat to be conducted away from bearing.
  - e) When adjacent machine components are oil lubricated.
  - f) High viscous oil for low speed machine, low viscous oil for high speed machine.
  - g) At temp < 125 °C, synthetic oils recommended.
  
- What are the causes of failure of bearings?
  - a) Faulty mounting
  - b) Faulty lubrication
  - c) Foreign matter in lubrication
  - d) Water in the bearing arrangement
  - e) Vibration
  - f) Inocurrences of form of shaft or housing seating.
  - g) Passage of electric current.
  - h) Metal fatigue.
  
- What does the bearing number mean?
 

**7318**      7      = single row angular contact ball bearings  
               3      = width of race  
               18 = 18 x 5 = 90 mm bore diameter.

**6310**      6      = single row deep groove ball bearings.  
               3      = width of race  
               10 = 10 \* 5 = 50 mm dia
  
- What is the purpose of static starter? How current setting adopted?
 

The static starter limits the starting current of the motor to 2.5 times the motor rated current instead of 6 times the rated current. If the motor is directly on UPS, the UPS fuse will blow, since the UPS cannot supply so much starting current. Hence the static starter is set to limit the starting current. This is achieved by firing angle control of back to back thyristor.
  
- What is the speciality of the inverter output transformer? Why it is provided?
  - a) This eliminates all 3<sup>rd</sup> harmonics in the output voltage.
  - b) Solid earthed neutral is required for the inverter output, hence the interconnected star winding is essential.
  - c) The primary has to be star (not delta), since 3 separate inverters operates on isolated primary winding.
  - d) Delta connection will cause circulating current between inverters during unbalanced faults. The inverters cannot withstand this.

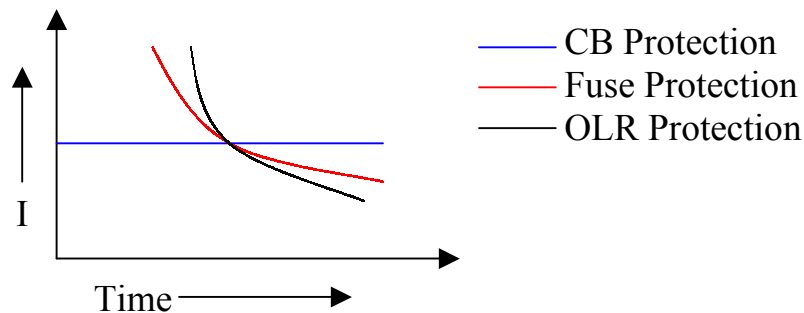
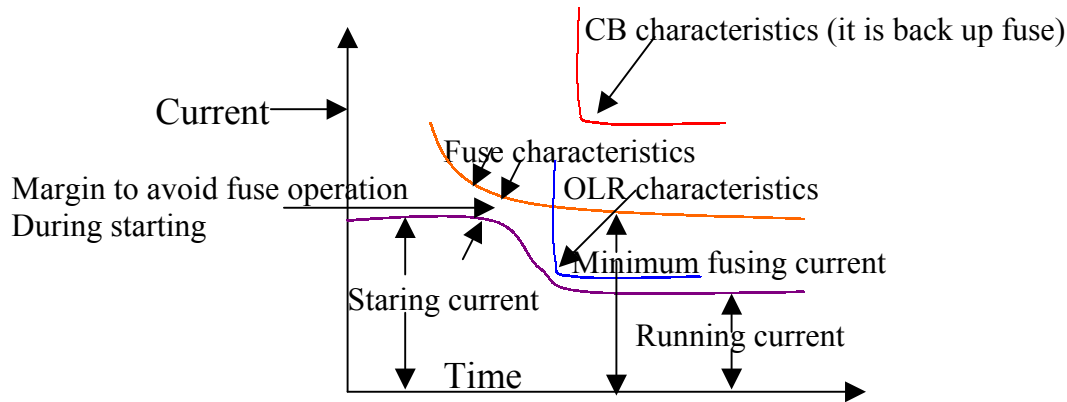


- Both silver and copper oxidise in air. Then why copper contacts are silver-plated?  
The silver plating avoids the oxidation of copper, especially in outdoors. Silver oxidises very readily. But its oxide is a good electrical conductor but copper oxide produce a film of insulation.
- When auto transfer is effected?
  - a) When any one module trips
  - b) When overload exceeds 175% for more than 40 msec. is existing.
  - c) When UPS output voltage varies beyond 415v +/- 10%
- When static bypass is fired? Why static bypass is required?  
For the same above 3 conditions, static bypass is also simultaneously fired along with a closing impulse.
- When the static bypass is blocked?  
When the phase error is more than 20°.
- What is phase lock mode?  
The inverter continuously follows the frequency and phase angle of classIII bus supply.
- What is the difference between a contactor and a breaker?  
Contactor is not designed to open on short circuit condition (fuse will take care of this situation). Breaker is having complicated mechanism for closing and tripping.
- What is the difference between isolator and contactor?  
*Contactor* is used for on load operation. Because they are fast acting devices. They posses arc chamber and arc chutes. Arc chamber and arc chute make it easy to extinguish the arc produced during on load operation.  
*Isolator* is off load devices. Because they are slow acting devices. The arc time is more in slow acting devices and operated only in off load.
- What are the protections provided for motor feeder?
 

|              |                            |
|--------------|----------------------------|
| $I_{th}$     | - Thermal over load        |
| $I_2S$       | - Unbalance load           |
| $I_0S$       | - Earth fault protection   |
| $I_{1t}$     | - Stalling protection      |
| $I_{1Inst.}$ | - Short circuit protection |
- What are the protections provided in PMCC circuit breakers?
  1. IDMT O/C (CDG 34).
  2. IDMT E/F (CDG 11).

3. Under voltage (40% of 110V).

- What is requirement of having DG's?  
To establish class III supply when class IV fails.  
Parallel operation with class IV 6.6 kV supply.  
DG to DG parallel operation.
- What are the characteristics of CB, OLR and HRC Fuse?



When CB is used the CB characteristics should be below the fuse, because the CB should operate first and then fuse. Not vice-versa. Because CB is the main protection or main breaking device.

- Why control transformer is earthed?  
If it is not earthed grounding of control circuit at two different places can cause bypassing of logics. In case of primary and secondary of the control transformer is getting the main fuse will blow off. (If secondary is not grounded then 415v will be superimposed in the control circuit during short circuit of primary and secondary winding)
- When the fuse will take over?  
When the current increases beyond 700% then the fuse will take over from the thermal overload protection.
- What is interlocks provided for the valve MCC

- a) Mechanical interlock, which will not allow the other contactor to close if one contactor, is closed.
- b) 42 auxiliary contacts are wired in the control ckt. 42-1 contact in 42-2 and 42-2 contact in 42-1.

- How to calculate the full load current of the motors?  
If kW is given, full load current = 1.5 times kW rating.  
If hp is given, full load current = 2 times hp rating.
- What is the safety interlock provided in MCC cell?  
The MCC cell door can't open if the cell is in on condition.
- How the fuse is selected?  
Fuse rating should be 2.5 times the full load current.
- How will you improve the IR value of a motor?  
By providing external heating. (By filament lamps)  
By providing internal heating by applying the low voltage.  
By circulating hot and dry air.
- Why 110V has been chosen in MCC cell?  
To isolate control circuit from power circuit for Human safety at control circuit side.
- What is the purpose of DIODE across the interposing coils in PLC?  
To dissipate the stored energy in magnetic field of the interposing coils (Free wheeling action). If it is not provided the stored energy will affect the PLC card circuit.
- What are the in-built protections provided in MCC cell?  
Fuses for short circuit protection.  
OLR for over load and single phasing protection.  
Electrical and Mechanical interlock in valve cell against short circuit.
- What is the plugging of an induction motor?  
It is an electrical braking of an induction motor by sudden reversal of phase sequence.
- Why CT operated over load relay is using for loads of high acceleration time upto 30 seconds? How it getting back?  
The saturable current transformers linearly transforms the current upto twice the set current, but above this value the transformer core gets saturated and the secondary current is proportionally less. Thus these relays permit heavy starting conditions of motors and offer dependable protection against overload.  
When current reduces the core gets de-saturated, as material design is such.
- How many earthing should be done for motors? Why?

Two. For reliability.

- What is the significance of frame size of motor?  
In order to make practical choice, interchangeability and large scale production possible.



- What is polarisation index?
  - a) It is defined as a ratio of 10 minutes resistance value to 1-minute resistance value.
  - b) It gives a quantitative information about the insulation with respect to moisture, dirt and other contamination.
  - c) A PI value of less than 1.0 indicates a need for immediate reconditioning.
- Why megger value of 1 minute is less than 10-minute value?  
 After 10 minutes the high voltage applied make the molecules such a way that stabilised in a good insulation. If insulation is weak it leads to more leakage current due to high potential.
- What is the classification of duty of rotating electrical machines?
  - S1 – Continuous operation at rated load (MCR) in 40 °C
  - S2 – Short time operation (STR) for 5 minute or 15 minutes or 30 minutes.
  - S3 – Intermittent periodic operation (resting and loading e.g. cranes, lifts etc)
  - S4 – As for S3 but with starting
  - S5 – As for S3 with electric braking
  - S6 – Continuous cyclic operation.
- What should be the value of insulation resistance of induction motor?  
 In  $R_m = kV + 1 \text{ M OHMS}$ .  
 Insulation resistance of any electrical machine (motor or generator) should be above 0.5-M ohms in all cases.
- What are the classes of insulation?
  - Y – 90°C (max) cotton, silk, paper, wood without oil impregnation
  - A – 105°C Materials of class Y impregnated with natural resins,insulating oils.
  - E – 120°C Synthetic resin enamels, cotton and proper laminations.
  - B – 130°C Mica, glass fibre, asbestos with suitable bonding substance.
  - F – 155°C Class B with more thermally resistant bonding materials.
  - H – 180°C Glass fibre and asbestos, mica with silicon resins.
  - C – >180°C Mica, ceramics, glass, quartz and asbestos without binders.
- What are the checks on the motor during the preventive maintenance?
  - IR Value
  - Resistance and Inductance measurement
  - PI value (should > 1.0)
- What are the tests pressures used in lyra contact testing?
  - 125 A    - 3 kg
  - 250 A    - 5 kg.



- What are the causes of motor vibration?
  - a) Broken rotor.
  - b) Slacked stator core.
  - c) Slacked rotor core.
  - d) Rotor winding unbalance.
- What are the causes for motor high current?
  - a) High frequency (51 Hz - 105% current)
  - b) Low frequency (48 Hz – 102% current)
  - c) High voltage
  - d) Low voltage
  - e) Mechanical over load
- What are the causes for motor unbalance current?
  - a) Loose connection
  - b) Voltage unbalance
  - c) Turns short circuit
- What are the sources of 240 V AC class I supply? What are the functions of each part of UPS?

Six sources.  
Three 20 kVA UPS for safety related loads.  
Two 60 kVA UPS for non-safety related loads.  
One 60 kVA UPS as a standby to safety related loads.  
These all UPS are back up by 220V DC batteries.

**Rectifier**

This converts AC to DC supply for inverter.

**Functions**

1. Produces DC voltage.
2. Supplies trickle charge to batteries.
3. Full load boost charge capacity.

**Inverter**

This converts DC to AC supply for loads.

20 kVA inverter is transistor based and 60 kVA inverter is thyristor based.

**Static switch.**

To take stand by UPS into service.

**Manual bypass**

To take main UPS to maintenance by putting stand by UPS into service.

- What is *station Black out* condition?

Simultaneous failures of class IV and class III supply is called Station Black out. In this condition class II power UPS will feed the necessary loads for a 30 minutes of duration. After that supplementary control room (SCR) 5 kVA UPS is used for secondary shut down system (SSS) ion chamber amplifier.

## **220 kV SYSTEM**

- What is meant by Dielectric strength?  
The maximum electrical potential gradient that a material can withstand without rupture usually specified in volts/millimeter of thickness. This also has known as electric strength.
- Give switchyard specification.
  1. Type : Out door.
  2. Scheme : Double main bus bar with bypass switching scheme is provided.  
This allows maintenance of one bus or one CB without interruption.
  3. Normal voltage : 220 kV.
  4. Rated voltage : 245 kV (400 kV)
  5. Impulse voltage : 1050 kV (peak)
  6. One-minute level : 460 kV (rms.)
  7. Dynamic current capacity: 102 kA (peak) and 40 kA for one sec.
  8. Rated current capacity : 2000 A for main and 1600 A for feeder bus.
  9. Clearances : Phase to earth – 2100 mm.  
Phase to phase – 2100 mm.  
Phase to ground – 5500 mm.  
Sectional clearance – 4300 mm.  
Creepage clearance – (Total) 5600 mm.  
– (Protected) 2800 mm.
  10. Maximum temperature rise above ambient - 45°C.
  11. CB – SF6
  12. Isolator – motor operated rotating type.
  13. Number of bays – 16 Nos.
- Give the details of switchyard 220 kV CB, Isolator, CT, CVT and lightning arrestor.
 

**220 kV SF6 Circuit Breaker**

  1. Make – ABB
  2. Air pressure blocking
    - a. Close Block – 17.3 bar.
    - b. Open block – 16.7 bar.
    - c. Auto reclose block – 19 bar.
  3. SF6 pressure block
    - a. Alarm – 5.2 bar.
    - b. Rated – 6 bar.
    - c. Limit – 5 to 6 bar.
    - d. Open block – 5 bar
  4. Weight of gas / pole : 20 kgs.
  5. Closing time : 130-milli sec.
  6. Method of closing : Electro-pneumatic.
  7. Compressor pressure : 20.5 kg/cm<sup>2</sup>.

**Isolator**

1. Type : High-pressure pressure relieving isolator (HPPR) central pole double break.
2. CB and Isolator clearances : Phase to Phase – 4500 mm.  
Phase to earth – 2300 mm.

**Current transformer**

1. Make : TELK made hermetically sealed.
2. Type : Single pole dead tank.

**Capacitor voltage transformer (CVT)**

This is capacitive potential divider and inductive medium mineral oil sealed.

ABB. make 245 kV/110  $\sqrt{3}$  V.

3 cores for metering and protection.

**Lightning arrester**

Type : WS surge arrester of ZODIVER type and SMX style.

Gapier zinc oxide arrester. Multi unit construction for transport, storage and erection.

Rated voltage : 216 kV rms.

Operating voltage : 184 kV rms.

- For a fault in switchyard lightning arrester, what protection will act?  
Bus bar differential protection.
- What is the purpose of the CVT?  
To provide synchronising signal  
To provide voltage indication  
To facilitate the carrier communication
- What is the purpose of wave trap?  
Carrier communication signals are sent through the lines. These are high frequency signals. This signal should be prevented from entering the switchyard. The wave trap is LC ckt, which is tuned for 50 Hz. Since it is connected in series with the line it will effectively block the carrier signal entering into the switchyard.
- What is the purpose of lightning arrester?  
Due to lightning and switching surges high voltages are induced in the lines. If equipment's. Connected is subjected to this high voltage the insulation will fail. In order to avoid the failure of insulation the LA is used. When the la is subjected to high voltage it will conduct and discharge the current to the earth.  
(It will divert the over voltages to earth and protect the substation)
- What is meant by restriking voltage?  
The high voltage that will appear across the contact just after the quenching of the arc is called restriking voltage.
- What does switching surges mean?

When a line is switched on high voltage will appear on the line due to its inductance and capacitance. This voltage is known as switching surges.



- What is the purpose of compressed air in SF6 breaker?  
This used for drive for opening and closing of the contacts.  
(Arc quenching is taken care by SF6 gas)
- Why switchyard is located indoors of coastal plants?  
Saline atmosphere will deposit on the insulators causing its flashover. The building kept under positive pressure compared with outside thus preventing the (saline) air entering from outside to inside the building.
- Why disc insulators grooved at bottom?  
To increase the creepage distance, reduce the chances of flash over.
- How cap and pin attached to insulator?  
By cementing.
- What is the material of cap, pin, and insulator?  
Cap = galvanised cast iron  
Pin = forged steel pin  
Insulator = porcelain.
- Why insulators are glazed?  
If not glazed, it will absorb water, resistance comes down, leakage current through porcelain, temperature increases till porcelain is puncture
- What is the station ground resistance?  
Less than 0.5 ohms.
- What is the various design of CT's in switchyard?  
Bus coupler CT's- live tank design 2000-1000A/1A  
All other CT's- dead tank design 800-600-400A/1A - lines and GT.  
125A/1A – SUT
- Advantage of CVT over EMPT.  
Used as coupling capacitors for PLCC.
- What are the main parts of 220 kV Circuit Breaker?  
Pole column filled with SF6  
Pneumatic drive system with compressed air circuit  
Control cubicle unit
- What is the type of 220 kV circuit breaker?  
220 kV, SF6 breaker, single pole, puffer type.

- What are the levels of SF<sub>6</sub> gas in 220 kV breaker and their significance?  
7 kg/cm<sup>2</sup> - normal pressure  
5.2 bar - alarm  
5.0 bar - closing/tripping operation blocked.

- What is the difference between circuit breaker and isolator?  
Isolator is a disconnecting switch which is not having the making and breaking capacity.  
Bus coupler      - 2000A  
Feeders            - 1600 A
- What is the purpose of ground switch?  
To discharge the trapped electrical charges to ground to give complete isolation.  
(To discharge the residual potential)
- What is the type of Lightning Arrestor?  
Station type, heavy duty, gap less zinc oxide.
- What is the purpose of grading ring?  
This assembly is provided to have uniform voltage gradient.
- What are the properties of SF<sub>6</sub> gas?  
Physical properties
  1. Colourless
  2. Odorless
  3. Non-toxic. Pure SF<sub>6</sub> gas is not harmful to the health.
  4. Non-inflammable.
  5. Density- more gas density, 5 times that of air at 20°C and at atmospheric pressure. The gas starts liquefying at certain low temperature. The temperature of liquefaction depends on pressure. At 15 kg f / cm<sup>2</sup> the gas starts liquefying at 10°C. Hence this gas is not suitable for high pressures >15 kg f / cm<sup>2</sup>
  6. The heat transferability of SF<sub>6</sub> gas is 2 to 2.5 times that of air at same pressure. Hence for equal conductor size the current carrying capacity is relatively more.Chemical properties
  1. Stable upto 500°C.
  2. Inert gas due to the chemical inertness. The life of the metallic parts, contacts is longer in SF<sub>6</sub> gas. The components do not get oxidised or deteriorated. Hence the maintenance requirement is reduced. However moisture is very harmful to the properties of the gas. In the presence of the moisture, hydrogen fluoride is formed during arcing which can attract the metallic and insulating parts in the circuit breaker.
  3. Electro negative gas – Ability of an atom to attract means carrying a negative electric charge.These advantages offer increased safety, reduction in size, weight, noiseless operation, easy installation, handling and maintenance.

- What are the protections are there for BUSBAR?  
Instantaneous over current protection  
Bus bar differential protection  
Local breaker back up protection

- What are the protections are there for lines?  
 Directional earthfault protection  
 Directional over current protection  
 Local breaker back up protection  
 Pole discrepancy  
 Main protection (distance protection)

## Directional OverCurrent Relay For Line-1&2

### MICOM-P127

(This relay is in addition to the existing electro-mechanical directional O/C relay)

### Setting Details

CTR= 600/1A

VTR= 220kV/110V

#### Directional Over Current Setting

| Description                             | Symbol in Relay | Set value                                                  | LED Indication |
|-----------------------------------------|-----------------|------------------------------------------------------------|----------------|
| IDMT Directional over current (Stage#1) |                 | Secondary 1.33Amps Primary<br>(800Amps) TMS = 0.1          | (67ABC)        |
| Directional O/C(Stage#2)                |                 | Secondary 3.33Amps<br>Primary (2000Amps)<br>Instantaneous. | (67ABC)        |
| Directional O/C(Stage#3)                |                 | Secondary 5Amps<br>Primary (3000Amps)<br>Instantaneous.    | (67ABC)        |

#### Directional Earth Fault Current Setting

| Description                                    | Symbol in Relay | Set value                                               | LED Indication |
|------------------------------------------------|-----------------|---------------------------------------------------------|----------------|
| IDMT Directional Earth Fault current (Stage#1) |                 | Secondary 0.2Amps Primary<br>(120Amps) TMS = 0.1        | (67N)          |
| Directional Earth Fault (Stage#2)              |                 | Secondary 4Amps<br>Primary (2400Amps)<br>Instantaneous. | (67N)          |
| Directional Earth Fault (Stage#3)              |                 | Secondary 6Amps<br>Primary (3600Amps)<br>Instantaneous. | (67N)          |

**MICOM-P127****Directional OverCurrent Relay For Line-3&4**

Setting Details

CTR= 800/1A

VTR= 220kV/110V

Directional Over Current Setting as on 07/09/2002

| Description                             | Symbol in Relay | Set value                                                                | LED Indication |
|-----------------------------------------|-----------------|--------------------------------------------------------------------------|----------------|
| IDMT Directional over current (Stage#1) |                 | Secondary 1.0Amps Primary<br><b>(800Amps)</b> TMS = 0.2                  | <b>(67ABC)</b> |
| Directional O/C(Stage#2)                |                 | Secondary 0.94 Amps<br>Primary <b>(750Amps)</b><br><b>Instantaneous.</b> | <b>(67ABC)</b> |
| Directional O/C(Stage#3)                |                 | Secondary 2.5Amps<br>Primary <b>(2000Amps)</b><br><b>Instantaneous.</b>  | <b>(67ABC)</b> |

**Directional Earth Fault Current Setting**

| Description                                    | Symbol in Relay | Set value                                              | LED Indication |
|------------------------------------------------|-----------------|--------------------------------------------------------|----------------|
| IDMT Directional Earth Fault current (Stage#1) |                 | Secondary NOT USED<br>Primary TMS =                    | <b>(67N)</b>   |
| Directional Earth Fault (Stage#2)              |                 | Secondary NOT USED<br>Primary<br><b>Instantaneous.</b> | <b>(67N)</b>   |
| Directional Earth Fault (Stage#3)              |                 | Secondary NOT USED<br>Primary<br><b>Instantaneous.</b> | <b>(67N)</b>   |

## 220KV SWITCH YARD LINES

| DESCRIPTION          | LINE-01                            | LINE-02  | LINE-03  | LINE-04  | REMARKS                                                      |
|----------------------|------------------------------------|----------|----------|----------|--------------------------------------------------------------|
| LINE LENGTH<br>IN KM | 13                                 | 16       | 62       | 62       |                                                              |
| CT RATIO             | 600/1 A                            | 600/1 A  | 800/1 A  | 800/1 A  |                                                              |
| 01                   | DISTANCE<br>RELAY<br>SETTINGS.(21) |          |          |          |                                                              |
| Relay character      | QUAD                               | QUAD     | LENT     | LENT     |                                                              |
| K1                   | 1                                  | 2        | 4        | 4        |                                                              |
| K2                   | 0                                  | 0        | 0.8      | 0.8      |                                                              |
| K3                   | 32                                 | 32       | N/A      | N/A      |                                                              |
| K4                   | 0                                  | 1        | 4        | 4        |                                                              |
| K5                   | 0.7                                | 0.4      | 0.3      | 0.3      |                                                              |
| K6                   | 0                                  | 0        | 0.02     | 0.02     |                                                              |
| K11                  | 1                                  | 1        | 1        | 1        |                                                              |
| K12                  | 0.6                                | 0        | 0.3      | 0.3      |                                                              |
| K13                  | 0.08                               | 0.04     | 0.02     | 0.02     |                                                              |
| K14/24               | 1                                  | 1        | 1        | 1        |                                                              |
| K15                  | 1                                  | 1        | 1        | 1        |                                                              |
| K21                  | 4                                  | 2        | 2        | 2        |                                                              |
| K22                  | 0.5                                | 0.6      | 0.5      | 0.5      |                                                              |
| K31                  | 6                                  | 3        | 4        | 4        |                                                              |
| K32                  | 0.9                                | 0.9      | 0.5      | 0.5      |                                                              |
| K33                  | 1                                  | 1        | 1        | 1        |                                                              |
| K35                  | 1                                  | 1        | 2        | 2        |                                                              |
| K36                  | 0                                  | 0.2      | 0.7      | 0.7      |                                                              |
| K37                  | 1                                  | 0.5      | 0.25     | 0.25     |                                                              |
| A/b                  | N/A                                | N/A      | 1        | 1        |                                                              |
| Z-2 TIME(m sec)      | Inst.                              | Inst.    | 400      | 400      | L#2- Z-2 & Z-3<br>changed on<br>18/6/02 & L#1 on<br>21/06/02 |
| Z-3 TIME(m sec)      | 120                                | 120      | 800      | 800      |                                                              |
| Tp                   | ALL LEFT                           | ALL LEFT | ALL LEFT | ALL LEFT |                                                              |
| Td                   | ALL LEFT                           | ALL LEFT | ALL LEFT | ALL LEFT |                                                              |
| SW-1                 | RIGHT                              | RIGHT    | RIGHT    | RIGHT    |                                                              |
| SW-2                 | LEFT                               | LEFT     | LEFT     | LEFT     |                                                              |
| SW-3                 | RIGHT                              | RIGHT    | RIGHT    | RIGHT    |                                                              |
| SW-4                 | RIGHT                              | RIGHT    | RIGHT    | RIGHT    |                                                              |
| SW-5                 | RIGHT                              | RIGHT    | RIGHT    | RIGHT    |                                                              |
| SW-6                 | RIGHT                              | RIGHT    | RIGHT    | RIGHT    |                                                              |
| SW-7                 | LEFT                               | LEFT     | LEFT     | LEFT     |                                                              |
| SW-8                 | LEFT                               | LEFT     | LEFT     | LEFT     |                                                              |
| SW-9                 | RIGHT                              | RIGHT    | RIGHT    | RIGHT    |                                                              |
| Z-1                  | LEFT                               | LEFT     | LEFT     | LEFT     |                                                              |
| Z-2                  | LEFT                               | LEFT     | LEFT     | LEFT     |                                                              |
| Z-3                  | RIGHT                              | RIGHT    | RIGHT    | RIGHT    |                                                              |
| ANGLE (Ph-Ph)        | 80                                 | 80       | 85       | 85       |                                                              |
| ANGLE (Ph-N)         | 80                                 | 80       | 75       | 75       |                                                              |
| TEST OPTION          | 0                                  | 0        | 0        | 0        |                                                              |

| DESCRIPTION | LINE-01                                       | LINE-02     | LINE-03    | LINE-04    | REMARKS                                                   |
|-------------|-----------------------------------------------|-------------|------------|------------|-----------------------------------------------------------|
| 2           | DIRECTIONAL<br>OVER CURRENT<br>(67 A,B,C.)    |             |            |            |                                                           |
| CT RATIO    | 600/1 A                                       | 600/1 A     | 800/1 A    | 800/1 A    | L#2 Settings<br>changed on<br>18/6/02 & L#1 on<br>21/6/02 |
| PSM         | 1.25 (750A)                                   | 1.25 (750A) | 1.0 (800A) | 1.0 (800A) | L#2 Settings<br>changed on<br>18/6/02 & L#1 on<br>21/6/02 |
| TMS         | 0.1                                           | 0.1         | 0.2        | 0.2        |                                                           |
| High set    | 5A                                            | 5A          | 5A         | 5A         |                                                           |
| 3           | DIRECTIONAL<br>EARTH FAULT<br>(67N)           |             |            |            |                                                           |
| PSM         | 0.2A                                          | 0.2A        | 20%(0.2A)  | 20%(0.2)   | L#2 Settings<br>changed on<br>18/6/02 & L#1 on<br>21/6/02 |
| TMS         | 0.1                                           | 0.1         | 0.225      | 0.225      |                                                           |
| High set    | 2A                                            | 2A          | 400%(4A)   | 400%(4A)   |                                                           |
| 4           | LBB<br>PROTECTION<br>(50Z)                    |             |            |            |                                                           |
| PSM         | 0.2                                           | 0.2         | 0.2        | 0.2        |                                                           |
| KNOB        | 1                                             | 1           | 1          | 1          |                                                           |
| 2/50Z       | 0.25 sec                                      | 0.25 sec    | 0.25 sec   | 0.25 sec   |                                                           |
| 5           | POLE<br>DISCRIPENCY<br>(47)                   |             |            |            |                                                           |
| 2/47T       | 0.1 sec                                       | 0.1 sec     | 0.1 sec    | 0.1 sec    |                                                           |
| 6           | ISOLATOR<br>PARALLEL(29)                      |             |            |            |                                                           |
| TIMER(29)   | 25 sec                                        | 25 sec      | 25 sec     | 25 sec     |                                                           |
| 7           | POWER RELAY<br>(32)                           |             |            |            |                                                           |
| PSM         | N/A                                           | N/A         | 10 ma      | 10 ma      |                                                           |
| TIME        | N/A                                           | N/A         | 0          | 0          |                                                           |
| 8           | INST, OVER<br>CURRENT<br>RELAY<br>(50A,,B,C.) |             |            |            |                                                           |
| KNOB        | N/A                                           | N/A         | 94%        | 94%        |                                                           |
| 2/50 ABC    | N/A                                           | N/A         | MIN. sec   | MIN. sec   |                                                           |



## **BATTERIES**

- What are the disadvantages of the maintenance free battery?  
The life of battery is only five years.  
The state of charge of a battery not knowing by the specific gravity of a battery. We can know by voltage only.
- What are the problems of hydrogen concentration?  
If the concentration of hydrogen more than 4% and less than 74% explosion problems will be there. Therefore the concentration of hydrogen is restricted to less than 1% by air changer ventilation system.
- Why lead acid battery requires so much large initial charging?  
Initially for a new battery, negative plate will be PbO instead of Pb. To convert all of them back to Pb, we need so much prolonged initial charging.
- What are the protections adopted in UPS or PMCC supply?  
LV (incomer) or UPS input  
CTZM, Over current, Short circuit protections  
PMCC S or T input or UPS output  
Under voltage (27), 51RYB, 51N protections.
- Write chemical equation for lead acid cell.  
 $\text{PbO}_2 + \text{H}_2\text{SO}_4 \rightarrow \text{PbSO}_4 + 2\text{H}_2$  (during discharge)  
 $\text{Pb} + \text{SO}_4 \rightarrow \text{PbSO}_4$  (during charge)
- Is the chemical reaction of plante cells same as tubular lead acid cells?  
No. Plante cells having both electrodes are lead (Pb) only.  
During charging,  $\text{H}_2\text{O} \rightarrow \text{H}_2 + \text{O}_2$   
 $\text{O}_2$  react with Pb to form  $\text{PbO}_2$  + (+ve plate)  
  
During discharge,  $\text{Pb} + \text{c} \rightarrow \text{PbSO}_4$  (on -ve plate)  
While  $\text{PbO}_2 \rightarrow \text{Pb} + \text{O}_2$  (on +ve plate).  
That is converted back to lead.  
Therefore  $\text{PbSO}_4$  formed only on -ve plate. That is sulphation problem are reduced by 50%
- What are the advantages of plante type batteries?  
Plante plate type batteries have longer life and can with stand rapid discharge.
- Why battery room should be located separately in a power station?  
Possibility of battery explosion  
Corrosive atmosphere by acid spray.  
Fire hazard.

- What are the disadvantages of nickel cadmium battery?  
Status of charge not known  
Number of cells are more  
Cost very high  
Environmental protection agency considers cadmium as a hazardous material, difficult to discard at the end of life.
- What are the effects of temperature in lead acid battery?  
Higher electrolyte temp - ah capacity increases but life reduces.  
Lower electrolytic temp - ah capacity reduces since chemical reaction rate reduces.
- Why ventilation is essential for Ni-Cad also?  
Gases evolved  $H_2$   $O_2$  can form explosive mixture.
- How  $H_2$   $O_2$  generated in lead acid battery?  
At end of charge, when most of the Pb is converted.  $H_2$   $O_2$  generated from  $H_2O$ .  $O_2$  appears as gas at positive plate.  $H_2$  at negative plate, i.e. gassing starts.
- Why current reduced after gassing?  
Excessive gassing shortens the life of battery by scouring the active materials at the surface of the plates.
- Why aged battery consumes more water?  
As aging increases, antimony migrates to negative plate → secondary cell reaction. Therefore more charging current require → more water consumption.
- What happens after aging?  
Shedding of active material during charging.  
Shedding increases with overcharging, heavy discharge, batteries short ckt.
- What is the other effect of low temperature?  
When specific gravity decreases, acid freezing point increases, soon reached at low temperature, volume increases container cracks.
- Why temperature correction required?  
As temperature increases, specific gravity decreases. The hydrometer immersion is more, showing lower readings. Therefore  $10^\circ C$  raises, 7 points to be added, corrected to get  $27^\circ C$  reading.
- What is meant by sulphation of the cell?

During the discharge lead sulphate is produced and during the charging the same is converted back into lead and lead peroxide. If the cell is left under charged, lead sulphate would form which will not reverse back into lead and lead peroxide during charging. Due to this the cell will loose its original capacity.

- What you meant by shedding?  
During the charging and discharging the active materials will undergo volumetric changes. Due to this some of the material may not be retained with the parent material and will shed and collected at the bottom of the container. This loss of active material is called shedding. Due to this the cell will loose its capacity.
- Acid should be poured to water. Why is it so?  
When acid and water is mixed lot of heat is generated. Hence there is chances of splashing of the liquid. If water is poured to acid will splash causing injuries. In the other case splashing will be of water with concentration of acid, which will not hazardous as the other one.
- What types of lighting fittings are used in the battery room?  
Flame proof acid resistant
- Why ungrounded 250V DC system adopted in our system?  
The 250V DC system is feeding to some of the vital loads such as breaker control etc. Even if one ground has occurred then also these controls should be available. Continuous monitoring of ground current is employed to eliminate the by passing of logic due to double ground.
- Why battery capacity limits to 20 minute?  
Battery cost is more.  
It is better to restore class 3 faster by DG set then putting large battery.  
20 min, is enough to shutdown the unit safely.
- What are the main parts of lead acid battery?
  - a. Container
  - b. Lead dioxide positive plates
  - c. Lead negative plates
  - d. Post strap and seal assemble
  - e. Separators and retainers
  - f. Sulphuric acid electrolyte
  - g. Inter cell connector (lead plated copper)
- What are the different types of charging?  
(Normally always) Float charging – 2.15V per cell  
It maintains the battery fully charged condition during standby operation by delivering a small amount of current to cancel the effect of battery natural self-discharge.  
Equalizing charging (2.7V/cell) once in 3 months

Recharge a battery capacity through recovering all useable active materials in the cell plates.

Boost charging

Boost charging is a quick charging process, which is generally required, if the battery is drained to a large extent.

- What is the double sulphate reaction?  
$$\text{Pb O}_2 + \text{Pb} + 2\text{H}_2 \text{SO}_4 \leftrightarrow 2\text{PbSO}_4 + 2\text{H}_2\text{O}$$

During charging oxygen at positive plate and hydrogen at negative plate are releasing.
- What are the effects of over charging?  
Gassing  
Heating  
Loosening of plate active material
- What you mean by Drooping characteristics of charger?  
When the charger is connected to excess load of charger rating the charger should able to supply the load with out over loaded by maintaining the terminal voltage within limit without over load trip. This called a drooping output voltage characteristics.
- What are the effects of under charging?  
Sulphation  
Buckling of plates
- What are the effects of high temperature?  
Gassing of electrolyte and evaporation  
Service life is halved for every 8 deg increase above 25 deg.
- What are the effects of low temperature?  
Increased electrolyte viscosity.
- What type of thermometer is used for acid batteries?  
Alcohol type thermometer.
- What are the tests for battery?  
Conduct test – to check the capacity batteries  
Impedance test – to check the utilization of active materials.
- What are the functions of charger?
  1. For initial charging.
  2. For float charging.
  3. For battery equalizing charging.
  4. For battery boost charging.
  5. To supply normal DC loads.

- What is the rating of switchyard battery charger and batteries?  
Switchyard is having Float cum boost charger of 282 V DC maximum and 100 Amps rated charger of six-pulse full wave thyristerised controlled rectifier.  
Batteries are tubular 220 V DC. +ve plate is made up of low antimony lead selenium (Pb) and -ve plate is made up of paste plate type (O<sub>2</sub>). Container or tube is made up of polyester and glass fibre.
  1. Momentary load 160 A / minute.
  2. Continuous load 40 A / hour.
  3. Cell voltage 1.8 V DC and total number of cells are 106 in battery bank.
  4. Float voltage 2.16 V per cell to 2.18 V per cell.
  5. Maximum system voltage is  $106 * 2.18 = 242$  V DCBattery rated for 224 A for one minute or 80 A for 60 minutes.  
Specific gravity  $1110 \pm 5$  and specific gravity after 10 hrs discharge is  $1150 \pm 5$ .
- What are the protections provided in charger?
  1. Over load (49).
  2. Over voltage (59).
  3. Short-circuit (3250 Amps).
  4. Phase sequence and phase fail.
  5. di/dt and dv/dt protection.

## **CIRCUIT BREAKER**

- Give circuit breaker nameplate details of 6.6 kV, and 415 V.

|                     | 6.6 kV (SF6 circuit Breaker)      | 415 V (Air Circuit Breaker)   |
|---------------------|-----------------------------------|-------------------------------|
| Type                | HPA12/1240C(Tr./ PM)              | 812 (MCC/UPS)                 |
|                     | HPA12/2040C(Tr./ PM)              | 610 (Tie/PM/MCC)              |
|                     |                                   | 3037 (B/c, Incomer)           |
| Standard            | IEC 56                            |                               |
| Rated voltage       | 12 kV (6.6 kV)                    | 415 V                         |
| Insulation level    | 28 / 75 kV                        | 660 V                         |
| Rated current       | 1250A/2000A                       | 1600A/1000A/3750A             |
| Breaking current    | 40 kA                             | 50 kA (rms.)                  |
| Making current      | 100 kA                            | 105 kA (peak)                 |
| Short ckt withstand | 40 kA/sec                         | 50 kA/sec                     |
| Closing time        | 52 milli sec                      | 60 sec (III/IV) & 30 sec (II) |
| Opening time        | 75 milli sec                      | 35 sec (III/IV) & 40 sec (II) |
| SF6 pressure        | 2.3 - 2.8 bar (2.2 alarm) at 20°C |                               |
| Sliding contact     | Copper with silver of 10 microns  |                               |
|                     |                                   |                               |

- What are the difference between DCCB and ACCB?

### **DCCB**

Two poles seriesed for one side.

Breaker is adequately de-rated for use in dc circuits.

Only DINF, DIRS provided. DIT 5 will not work for dc.

In GFB, magnetic blowout coils used to increase the speed of rise of arc into the arc chutes for effective quenching.

### **ACCB**

The inherent current zero of sine wave helps arc quenching. For DCCB arc quenching is difficult, since current zero is not existing naturally.

- What are the indications used in 415V and 6.6 kV breakers panel?

|               | 415 V Breaker | 6.6 kV Breaker |
|---------------|---------------|----------------|
| Open          | Green         | Green          |
| Close         | Red           | Red            |
| Test          | White         |                |
| Service       | Blue          |                |
| Auto trip     | Yellow        | White          |
| Spring charge |               | Blue           |
| Gas pressure  |               | Yellow         |
| Voltage (RYB) |               | Red            |





- What are the advantages and disadvantages of 415V English Electric breaker?

**Advantages**

1. Auto reclosing shutters.
2. Proven wiping contacts.
3. Sturdy rugged mechanism.
4. Reliable aux. Switches contacts.
5. Slow closing facility independent of closing spring.

**Disadvantages**

Bulky, more space, spring charge motor 5A. , Spring charging time 14 sec 4 sec at timing, trip extends in test position also. No neutral bus bar link, we cannot finger contact resistance since fixed on bus side.

- Type of closing spring is compression type.(415V)
- Why parallel operations of classIII buses are not permitted?  
Fault on one side affects the other buses, switchgear fault level rating is exceeded.
- Why auto transfer is blocked for back up protection?  
Because Backup protection operates normally for bus faults. All main protections are generally operating for internal faults therefore there is no point in restoring the power supply through auto transfer when there is a bus fault existing.
- What decides the control transformer VA rating?  
Contactor coil VA rating.
- Can we use AC contactor in DC circuit?  
Yes, but with adequate de-rating.
- Can we use ac coils in dc circuit?  
Yes with economy resistor in series.
- Why shading rings provided in armature core of ac contactor. Why not for dc contactor?  
Because the force developed is not steady in ac therefore contacts will chatter but if shading ring is used force developed becomes steady due to splitting of phases of flux, therefore contacts becomes bounce free and humming sound reduces.
- Why copper contact are not used in contactor?  
Because corrosion rate increases. Poor surface property , large closing force required.

- Why pure silver is not used in contactor?  
Affected by sulphur, mechanical or arcing damages (adv. Lower voltage drop)

- What are the types of contactors?

| Type     | Contacts    | Rating | Use                            |
|----------|-------------|--------|--------------------------------|
| 3 TB 41  | 2 NO + 2 NC | 12 A   | 0 – 5.5 kW                     |
| 3 TA 22  | 2 NO + 2 NC | 30 A   | 7.5 – 11 kW                    |
| 3 TA 13  | 2 NO + 2 NC | 38 A   | 15 kW                          |
| 3 TA 24  | 4 NO + 2 NC | 70 A   | 18 – 38 kW                     |
| 3 TA 16  | 4 NO + 2 NC | 105 A  | 40 – 48 kW                     |
| 3 TA 28  | 4 NO + 2 NC | 170 A  | 55 – 80 kW                     |
| 3 TA 28  | 3 NO + 3 NC | 170 A  | 55 – 80 kW                     |
| 3 TB 56  | 4 NO + 2 NC | 400 A  | 93 kW for F/M supply PM.       |
| 3 TD 11  | 2 NO + 2 NC | 12 A   | 0 – 1.5 kW for valve motors.   |
| 3 T I 22 | 2 NO + 2 NC | 30 A   | 1.6 – 7.5 kW for valve motors. |

- What material used for contactor?  
Silver-nickel for <100A  
Silver-cadmium oxide for large currents.
- Why pick up voltage is more than drop out voltage?  
Initially air gap is more. Large force is required to overcome the high reluctance initially. After closing air gap is reduced. Hence drop voltage is reduced.
- Can we file the pitted contacts of contactor?  
No, use emery paper and etc.
- How the contact resistance can increase?  
Humidity + salty air, dust, poor contact pressure
- **Fusing current**- the current at which the fuse element melts depends upon the material, length and diameter.
- **Fusing factor**- fusing current /rated current (1.25 -1.75)
- **Prospective fault current** – first loop of fault current
- **Cut off current** - actual peak value of current reached due to interruption by fuse blowing.
- What is rated current and short circuit current?  
Rated current =  $VA / \sqrt{3} * V$  Amps.  
Short circuit current =  $VA * 100 / \%Z * \sqrt{3} * V$  Amps.
- What is the advantage of lower cut off current?

Less electromagnetic forces on contactor / CB's

- How two fuses in-series are discriminated?  
Total  $I^2t$  of minor fuse should be less than pre-arcing  $I^2t$  of major fuse.  
Major fuse should be greater than 1.5 times the minor fuse.

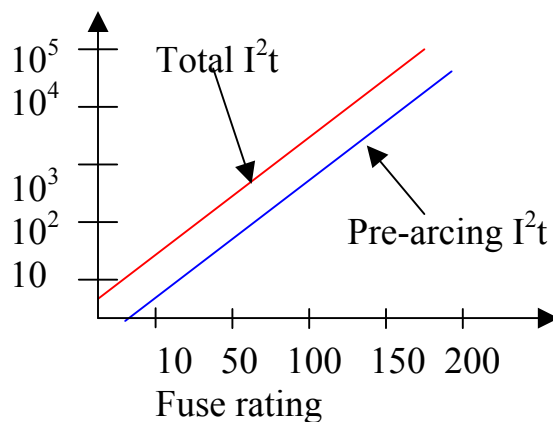
- Why OLR time set high for belt driven fans?  
Because acceleration time is high.
- What is the safety reason to keep the contactor / MCC remote from motor?  
Contactor = sparking equipment. Not suiting for hazardous location.
- Where wound type CT used and where not used?  
Used where low CT ratio req.  
Not used where high short ckt. Current exists.
- What is advantage of cast resin CT's?  
Can withstand bursting forces under short ckt, protect damages against external causes impervious to moisture.
- Why fuses with fusing factor more than 1.5 is not allowed in PVC cables?  
Because PVC cables have low thermal capacity than paper cables. Full loading of PVC only possible if it has close excess current protection (i.e.) Fusing Factor = 1.5

- What are the advantages of HRC fuses re-wirable fuses? What are the characteristics of HRC fuse?

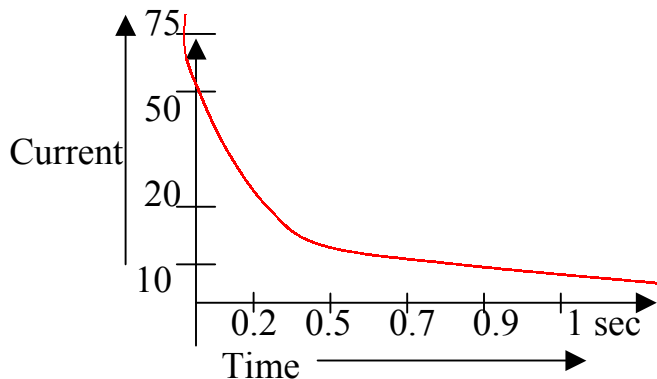
1. Consistent and stable characteristics for accuracy of discrimination. Capacity to break at high and low current. It is inverse time characteristics, as the current is high the time taken to break the circuit is less.
2. Arc quenching is reliable. Chemical action between quartz and arc gas gives high resistance to the arc. Quartz does not produce more gas after observing heat as its sand powder observes more heat of the arc.
3. Non deteriorating since it is sealed. No maintenance, Cheap and indication is available.

### Characteristics

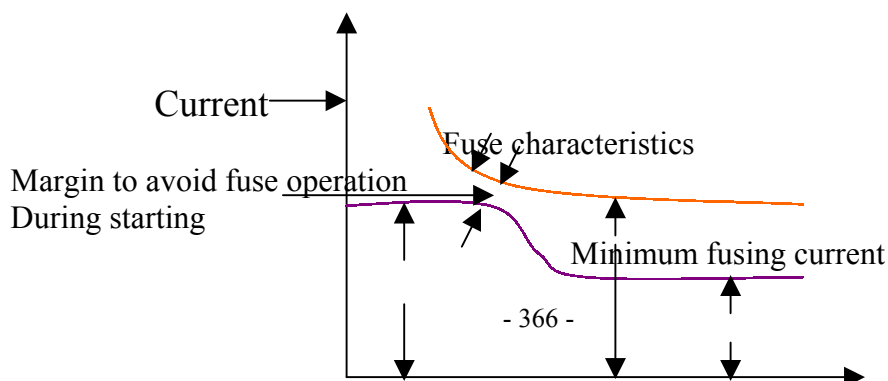
1.  $I^2t$  characteristics. This determines the energy that element can pass and to determine the cut off characteristics.



2. Inverse time characteristics, which is useful for selection of the fuse for motor.



Inverse time characteristics



Starting current

Running current

Time

Motor selection characteristics



- What is the advantage of CMM relay over normal Inv. O/C current relay?  
Inv. O/C relay under protects at low current and over protects at high currents.  
CMM: accounts for both +ve and –ve sequence currents i.e. Single phasing / unbalance supply conditions and gives three times more weightage for the –ve phase sequence current heating than + ve sequence current heating. i.e. Net rotor heating =  $I_1^2 + 3 I_2^2$ .  
Therefore CMM relay protection characteristic is closely matched to motor heating characteristic. So it is better than thermal overload relay also.
- What is the purpose of anti-pumping relay?  
When closing signal is continuously existing even after the closing of the breaker the anti-pumping relay will be picked up and it will not allow the breaker to close back in case of tripping of the breaker.
- Why breaker tripping is prohibited on very low pressure?  
The efficiency with which the arc quenching is taking place in the breaker depends on the air pressure. So if the air pressure is low effective arc quenching will not take place which will result in damage of CB. Hence the tripping of the breaker at very low air pressure is prevented.
- Why neutral breaker used in DG neutral grounding?  
In case of high earth fault currents it is therefore normal practice to install a circuit breaker in the neutral of the generator in order to reduce the total fault clearance time.
- What are the protections used in Class III & Class IV 415 V LV side?  
Class III 415 V LV side
  1. 51 (inverse over current)
  2. 50 (instantaneous over current)
  3. 27 (under voltage)
  4. 51N (earth fault)
  5. 64 (REF)  
Class IV 415 V LV side
  1. 51 RYB (inverse over current)
  2. 51N (earth fault)

- What are the protections used in 415 V Class II side?  
LV to UPS
  1. CTZM
  2. 50 (instantaneous over current)
  3. short circuit

UPS to PMCC S & T

1. 51 RYB (inverse over current)
2. 27 (under voltage)
3. 51N (earth fault)

From Class III to Class II tie

CTZM at Class III and 51, 51N at Class II.

- Define the followings.  
Insulation level – it is the combination of rated voltage, the corresponding impulse withstand voltage, which together characterize the insulation of the equipment as regards its ability to withstand the electrical stresses.

Rated short circuit breaking current – it is the highest RMS value of short circuit current which the circuit breaker is capable of breaking the circuit in safe.

Making current – it is the peak value of first loop of current of short circuit current which the circuit breaker is capable of making at the rated voltage.

Rated making current = 2.5 times rated breaking current.

Short time rating – it is the RMS value of current that the circuit breaker can carry in a fully closed position during a specified time.

Impulse withstand voltage – it is the amplitude of the standard voltage wave with the insulation of equipment can withstand.

Power frequency withstand voltage – it is RMS value of alternating voltage wave of power frequency (50 Hz) which the insulation of equipment should withstand.

- What is switchgear?  
Equipment which is used for switching, controlling and protecting an electrical circuit.

- Bus bar specifications of 6.6kV and 415 V.  
415V  
Aluminium 200 X 12mm  
2 nos. per phase, 1 no. for neutral  
Bus bar joints – silver plated to 5 micron thick (tightness 50 NM)  
6.6kV  
Copper  
Silver coated joints  
Insulation level – 27kV  
Fault level estimated – 27kA                      Designed – 40kA
- What is the type of arc extinction in switchgears?  
415V – resistance method (through arc splitter)  
6.6kV – single puffer principle
- How Arc quenching is done?  
When fault occurs depending on design element melts at one point and arc starts and a transient current is super imposed on prospective current. When the sum of two is zeroing the arc is quenching.
- What is lock out relay?  
It is the relay to prevent the closing of circuit breaker after tripping (protection) without attention of the operator.
- What is the significance of SF6 gas pressure in 6.6kV breakers?  
Density gauge  
Green – correct SF6 pressure (3 –3.5bar)  
Yellow – pressure for breaking system fault current (refilling should be done)  
Red – SF6 pressure less than 2 bar, which indicates leak in the system.
- What is the measure of atmospheric pressure and PSI?  
1 Atmospheric pressure =  $1.033 \text{ kg/cm}^2$ .  
1 PSI =  $0.07031 \text{ kg/cm}^2$ .
- What is the distribution of DC control supply in CL IV, III, II- 415V and 6.6 kV?  
Closing coil and Trip coil 2 supply from one source.  
Trip coil 1 supply from one source.  
Protections supply from one source.
- Why 86.1 and 86.2 relays are used?

All electrical protection is wired to 86.1 and under voltage protection is wired to 86.2 relay for automatic restoration in EMTR.

- What is the difference between lockout of 6.6 kV and 415 V CB's?  
Voltage levels.  
Manual / auto reset.  
Lockout relays of 415 V breakers are all Electro-magnetic type. There is no mechanical latch. But in 6.6 kV it is of mechanical latch type relays.
- If breaker contact resistance is more what action to be taken?  
In 6.6 kV breakers      1250 A breaker contact resistance is <100 μΩ.  
                                        2000 A breaker contact resistance is <50 μΩ.  
If contact resistance is found more than this value should be sent to the manufacturer for repair.
- What are the interlocks between 415 V and 6.6 kV switch gear?  
6.6 kV  
Breaker closed cannot rack in or out.  
Service lever cannot move while breaker closed.  
Breaker cannot be closed in in-between position.  
415 V  
Breaker door cannot be opened when breaker is in service.  
Breaker cannot be closed in in-between position.  
Breaker closed cannot be rack in or out.
- Where are the provision of GR-A and GR-B tie possibilities?  
Bus D1-D2 to E1-E2 (CL III 6.6 kV)  
Bus X to Bus Y         (CL III 415V)  
Bus S to Bus T         (CL II 415 V)
- What are the properties of SF<sub>6</sub> gas?  
This is inert gas. Odorless, non-toxic, colourless, stable, non-inflammable and density is more hence high dielectric strength. The special property of this gas is Electro negativity. This gas attracts electrons to form –ve ions and –ve ion are heavier than electrons and move slow in conduction, so that resistance in medium increases and get arc get extinguishes.



## CABLES

- What are the purposes of cable trays?
  - a. Avoid sagging of cables
  - b. Give mechanical support
- What are the disadvantages of paper insulation?
  - a. Absorbs moisture.
  - b. Cable termination/sealing problems.
- What are the advantages of XLPE?
  - a. Easy routing at heights
  - b. Easy maintenance
  - c. Large current (90 °C)
  - d. No sheath (no fatigue)
  - e. No paper tape wrapping technique
  - f. High dielectric strength
  - g. Very little deformation even at high temp,
  - h. More rated current, overload, short ckt capacity
  - i. Low tan delta and hence suits long routes
  - j. Very light
  - k. Good mechanical properties.
- What is the specified cable life?  
50 years.
- How armours /sheaths grounded?
  - 1 core cables -- sheaths/shields/armours grounded at one end only, other end insulated to prevent the circulating current through sheaths.
  - 3 core cables -- grounded at both ends but not including core balance CT's, since even small induced current causes 50N operation.
- Why armouring done?  
For mechanical strength, protect against damage by impact of an object.
- How the required conductor size can be reduced by use of HRC fuses?  
HRC fuse limits the peak amplitude of fault current. HRC fuse melts at prospective current but not allows circuit to pass their high rupturing capacity that is it's kA.

- What are the types of cables used in 6.6 kV and 415 V system voltages?  
In **6.6 kV** system AC (unearthed) grade having stranded aluminium conductors cables are used. Their insulation's are as follows.
  1. XLPE – Crossed linked polyethylene insulation.
  2. FRLS PVC – Fire retardant low smoke insulation with PVC inner and outer insulation. In RB copper conductor stranded cables are used.
  3. FS – fire survival insulation.
  4. HR PVC – heat resistant insulation.

In **415 V** system 1100 V grade copper or aluminium stranded cables are used. Their insulations are HR PVC and FS type.

- At what temperature cables are rated?

Normally cables are rated for 40°C

|                | Maximum temp in °C | Short time temp in °C |
|----------------|--------------------|-----------------------|
| PVC            | 70                 | 160                   |
| HRPVC          | 85                 | 160                   |
| Fire survival  | 90                 | 250                   |
| Silicon rubber | 90                 | 250                   |
| XLPE cable     | 90                 | 250                   |

- Why 1.1 kV grade cables used for 415V?  
To take care of the both earthed / unearthed systems.
- While carrying out cable joints, why should we ensure the continuity of 1) metallised paper for PILC, 2) sheath and armour.  
Continuity of metallised paper ensures less voltage gradient, hence preventing puncture of insulation.  
Continuity of sheath / armour ensures that grounding is maintained, so no over voltage is induced, and easy to detect earthfault in cables.
- Why bimetallic washers provided in aluminium copper transition joints?  
To avoid galvanic corrosion failure.
- What is the type cable used in radiation areas?  
Mineral insulated (MI) cables.





## **EMTR AND AUTO TRANSFER**

- What is meant by EMTR?  
In case of normal supply failure to CL-III & CL-II the loads will be fed by the alternative/standby sources. This changeover of supply is called Emergency Transfer.
- How EMTR is initiated?  
EMTR is initiated on sensing the CL-III & CL-II bus under voltage.
- What are the routes of EMTR?  
CL-III bus under voltage. The DG's will start. All the breakers connected to the affected bus will trip. DG breaker will close on dead bus. Loads will be restored one by one.  
CL-II bus under voltage. The tie breaker of the affected bus will close.
- What does load-shedding mean?  
When there is only one source to feed the two buses, the total loads can not be fed by this single source. Hence some of the less important load will not be allowed to start or it will be tripped if it is running.
- What does total load-shedding mean?  
Even after the load shedding the is continue to deliver more than the rated power sensed by overpower relay or running with under frequency sensed by the under frequency relay the total load shedding will take place. In case of auxiliary transformer is feeding the total load shedding will take place after 4 minutes.
- What does auto transfer mean?  
If one of the sources is tripped on main protection its breaker will be tripped and the tie-breaker will close. This transfer of supply from one source to other source is called auto transfer. To restore the class IV whenever the UT or SUT is lost Auto transfer is provided.
- Why auto transfer is prevented if the backup protection is operated?  
The back up protection is supposed to operate in case of a bus fault. Hence the auto transfer is prevented.
- What are the types Auto transfer scheme?
  1. Fast transfer scheme to close the tie-breaker in less than 200 milli seconds. This limits transient current and voltage dip in the bus and does quick acceleration of the motors.

2. Slow transfer after 200 milli seconds.

- What are the conditions for Auto transfer scheme?

Backup protections are not allowed to initiate the Auto transfer. Because under voltage may exist in the bus. Similarly protection in LV of the transformers are not initiating the Auto transfer scheme. There are three metrics used in Auto transfer scheme and 2/3 logic is adopted.

#### **Conditions**

1. Fault generator (86BG or 86A1).
  2. Fault in UT.
  3. Fault in GT.
  4. Fault in 220 kV bus (SUT).
  5. Fault in SUT (86M).
- What are the uses of EMTR scheme?
    1. To restore class III when class IV supply fails.
    2. To extend supply to class II when UPS fails.
    3. In one DG condition to load restoration.
    4. Sub sequent restoration of large motor loads.
  - What are the sequences of motor load restoration in EMTR?
 

|                        |           |
|------------------------|-----------|
| 1. AHPPW –1001         | - 4 Sec.  |
| 2. APWC – 1003         | - 8 Sec.  |
| 3. APWC – 1004         | - 12 Sec. |
| 4. AHPPW –1002         | - 16 Sec. |
| 5. PPP – 1001          | - 20 Sec. |
| 6. MOD – 1002          | - 24 Sec. |
| 7. MOD – 1001          | - 28 Sec. |
| 8. Air Comp – 1002     | - 32 Sec. |
| 9. ABFP – 1006         | - 36 Sec. |
| 10. 7343 Exst Fan 1003 | - 40 Sec. |
| 11. ECCS PM 1001       | - 44 Sec. |
| 12. ECCS PM 1002       | - 48 Sec. |
  - Why synchronizing scheme has been adopted? What are interlocks provided?  
To check running and incoming buses, which are going to be interconnected are in synchronism with each other.

#### **Interlocks**

1. Synch selector.
2. Only one breaker can operate at a time.
3. Master synch relay contact should available (bypass will bypass this synch contact).

Bypass facility is provided to close the breaker on dead bus only.

- What are the settings provided in synchronizing scheme (SKE Relay)?  
Voltage –  $V1 - V2 = 10\%$   
Frequency –  $t = 0.05 \text{ Sec (2.5 Hz)}$   
% Slip – 0.45  
Phase angle difference -  $20^\circ$ .

- What are the major losses in nuclear power generating system?

Condenser - 500 MW.  
 Moderator - 40 MW.  
 C/V and E/S system - 3.7 MW.

- Give the specification of DG and NGR of DG.

#### **DG specification**

Type HSPTL 12/653 synchronous generator.  
 KVA 2815  
 Volts 6600 V  
 Amps 246 A  
 Phase 3  
 Frequency 50 Hz  
 Insulation Class-F  
 PF 0.8  
 Duty S1  
 IC 01  
 IP 23  
 RPM 1000  
 Exciter 110 V, 3.2 A (Brush – less of permanent magnet, electronic automatic voltage regulator)  
 Ambient temp 50 °C

#### **NGR specification**

Resistance at 20°C 95.3Ω  
 Voltage 6.6 kV/ $\sqrt{3}$   
 Insulation class 7.2 kV  
 Transient current 40 A / second.  
 Continuous rating 10 Amps.

- What is the operational requirement of DG's?  
 1. Whenever class IV fails DG sets (2 + 1 standby) are started by EMTR and capable of restoring class III loads within 30 Seconds. One example is given below.

| Event                   | Minutes | Seconds | Milli seconds | Difference |
|-------------------------|---------|---------|---------------|------------|
| Class IV fail           | 00      | 00      | 280           | 00:00:280  |
| EMTR initiate           | 00      | 01      | 303           | 00:01:023  |
| DG start (1, 2, 3)      | 00      | 01      | 336           | 00:00:033  |
| Voltage, Speed reached  | 00      | 07      | 257           | 00:05:921  |
| CB 351, 361, 370 Closed | 00      | 07      | 491           | 00:00:234  |

Restoration will be done in 07 seconds and 491 milli seconds. After this to build up power and frequency it takes about 1 minute 26 seconds and 852 milli seconds. Then load restoration starts as per EMTR scheme.

2. DG's are capable of paralleling with 6.6 kV class IV supplies.
3. DG's are capable of paralleling with each other.

- What are the design criteria's of DG's?
  1. 4000 starts and 4000 hrs run at full load for lifetime.
  2. Operation at 45°C and high atmospheric condition.
  3. Designed to run in earthquake and seismic condition.
  4. Designed to start as per EMTR scheme and take load as per EMTR and load shedding scheme in one-DG condition without drop in voltage or frequency 25% and 5% respectively.
  5. Designed for run in high speed and to build up voltage and speed within 10 seconds.
  6. Designed to start and loading with external row water for cooling for 3 minutes.
  7. Designed to start at normal and load condition temperature.
  8. Designed to run at no load for 4 hrs in a 4 months with affecting the load and over load.
  9. Designed to supply power in one-DG condition.
  10. Continuous supply is 2250 kW and can run at 2475 kW for 2 hrs in 24 hrs at 6.6 kV and 0.8 PF.
  11. Designed to start and stop at 48 V DC supply and stop at 220 V DC in the case of 48 V DC is not available.
  12. DG – 3 is physically separated for control and installed at adjacent unit. Because in case of unit is not avail then for cooling water is available in other unit.
  13. Monorail of 3 Ton is provided.
  14. Provisions are made for filtered air and ventilation and combustion.
  15. Co<sub>2</sub> fire fighting system is provided for smoothening effect in case of fire.
  16. Active process water from class III is provided.
- What are the auxiliaries required for DG?
  1. Starting air system.

Components are compressor, air dryer, air receiver, solenoid valve for start control, pneumatic starting air valve, air distributor and injection valve at each cylinder.

This system operates at high pressure and also provided with soft start of 8-bar pressure in testing of system periodically.
  2. Lub oil system.

This is closed loop of having oil sump of capacity of 7 days at full load. This also supplies oil to bearing lubrication, crankshaft, piston, and wiper.

This closed loop Circuit includes pre-lubricating circuit and normal lubricating circuit. Pre- lubricating circuit is controlled by PLC, but at first commissioning and overhauling pre-lub start immediately.
  3. Water cooling system.



This is provided with closed loop fresh water for remove heat from lubricating oil system, charge air cooler, engine components (cylinder lines, cylinder head etc). Fresh water chemistry is controlled to avoid organic growth and corrosion. This water is heated for normal operation to avoid thermal shock. This water is cooled by active process water. One tank is provided to transfer fresh water to the system. Before transferring fresh water chemical addition should be done.

4. Fuel oil system.

The engine driven fuel oil pump is flooded with fuel oil from the day tank by gravity. Low-pressure fuel from fuel pump is supplied to individual injection pump is injected to individual cylinders through injectors.

5. Combustion air and exhaust gas system.

The engine is supplied by compressed combustion air with the help of exhaust gas driver Turbo – charger. Each bank cylinder is provided with a Turbo – charger. Turbo – charger is provided with filters. The exhaust is passes through silencer.

6. Speed governing system.

Governer is hydraulic mechanical type. The governer is linked to the fuel racks. The maximum work output of the UG – 8 governer is 8 lb – ft over the full 42° travel. For full load 30° is sufficient and remaining for overloading.

Governer comprises

- a. Speed droop setting.
- b. Oil sight glass.
- c. Load limiter
- d. Compensation pointer and adjuster.
- e. Local speed adjuster.

7. Two numbers of ventillation fans are provided in each DG building. One starts at respective DG breaker close and other at  $>45^{\circ}\text{C}$ . DG room is provided with 7 numbers of smoke detectors (ionized type) and 7 numbers of flame detectors (photoelectric type).

8. Separate DG's are having separate MCC for their auxiliaries power supply. For DG – 1 auxiliaries MCC P1. For DG – 2 auxiliaries MCC Q1 and for DG – 3 MCC DG – 3 is provided.

9. Phase winding is provided with two RTD's for hotspot measurement and bearing provided with one RTD each.

10. LCP is provided one each for each DG.

- When DG's start is not possible?

1. DG trip.
  2. Turning gear engaged.
  3. DG set stop push button pressed.
- What are stages of DG starting?
    1. At start signal compressed air through solenoid valve passes over piston and rotates the shaft.
    2. At speed >60-rpm ignition starts.
    3. Closing of excitation starts at >800-rpm.
    4. At speed of > 900-rpm rated speed and rated voltage signal starts.
    5. Closing of over speed is at >1150-rpm.

- What are the protections provided for DG?
    1. Differential protection (87).
    2. Over speed of engine.
    3. Reverse power protection (in LOCA condition time delay).
    4. Low lubricating oil pressure.
    5. Cooling water temperature high.
    6. 6.6 kV switchgear protections.
    7. Excitation failure.
    8. Emergency stops push button.
- In LOCA condition 4 – 8 protections are not permitted to operate.

### Electronics

- What is Diode?  
Diode is a two-layer semiconductor device, conducts only positive cycles when applied to anode.
- What is Thyristor?  
Thyristor is a four or more layer semiconductor device & having 3 or more junctions. It is also called Silicon Controlled Rectifiers (SCR). A healthy SCR must block in both the directions at least  $1\text{M}\Omega$  resistance, a fused SCR will conduct in both directions.
- What is material used in making semiconductor?  
Silicon & Germanium are the raw materials used for making semiconductor. Semiconductors are located between conductors & insulators in the resistivity spectrum & allow current to flow only under certain conditions.
- What is material used in making non-linear resistor & purpose of it in field discharge resistor?  
Silicon carbide materials used for making non-linear resistor. The purpose of this resistor is to avoid surge voltage when field breaker opens. These resistors are connected in parallel to the main field winding (Rotor).
- How over voltage is produced in Field breaker?  
Over voltages appear if synchronous generators and motors fall out of step inducing an AC voltage in the field system. Depending on the type of construction of the machine and the slip this voltage can become un-permissibly high, for this purpose over voltage protectors are provided in the field breaker cubicle.
- What is firing angle?  
The angle in the AC cycle at which the thyristor starts conducting at the application of positive voltage to gate is known as the firing angle ( $\alpha$ )
- What is Inverter operation?  
When firing angle  $\alpha = 90^\circ$  the positive & negative voltages areas are equal. With a higher than  $90^\circ$  the negative areas are greater so the total voltage becomes negative. This condition is termed as 'Inverter Operation'.
- What is the purpose of RC network across thyristor?  
RC network across each thyristor protects against Hole Storage Effect.
- Why reactors are provided in Thyristor bridges?

Reactors are provided to limit the rate of rise of current ( $di/dt$ ) in the device, thereby avoiding possible damage to the device. They also effect a proper sharing of load among thyristor bridges when connected in parallel.

- What is purpose of connecting thyristor bridges in parallel?  
Thyristor bridges are connected in parallel to improve current rating.
- What is purpose of Load angle limiter?  
Load angle limiter, it either limits the angle between grid load center and the rotor axis or generator terminal & rotor axis.
- What is purpose of Rotor angle limiter?  
It limits generator voltage & rotor voltage.
- What is purpose of Rotor current limiter?  
It limits overloading of rotor.
- What is purpose of Stator current limiter?  
It limits the stator current.
- What is purpose of Slip stabilization?  
It avoids oscillation of the AC machine (Rotor oscillations).
- What is purpose of reactive power (VAR)?  
It is an energy required to built up magnetic field to drive the power.
- What is the advantage of Static Excitation?  
Fast response time, high reliability, interchangeability of parts during operation, less wear & tear due to static devices & less maintenance.
- What is the advantage of field forcing in the rotor?  
Field forcing acts for 10 seconds to maintain the generator terminal voltage during fault condition so as to operated the protection relays.
- When the negative sequence reactance arises?  
Negative sequence arises whenever there is any unbalance present in the system. Their effect is to set up a field rotating in opposite direction to the main field.
- When the Zero sequence reactance arises?  
If a machine is operating with an earthed neutral, a system earth fault will give rise to zero sequence current in the machine.

### **Basic Electricity**

- What is Current?

The flow of electrons in a circuit is called current, it is measured in Amperes (I).

- What is Voltage?

Voltage is the difference in potential (charge) between two points or voltage is the amount of driving force or pressure applied to a circuit, it is measured in Volts (V).

- What is Resistance?

The resistance of a circuit is the circuit's opposition to the movement of electrons. A resistor restricts or limits the amount of current flowing in a electrical circuit, it is measured in Ohm ( $\Omega$ ).

*Series Resistor:* When resistors are connected in series they have one point in common. The total resistance is equal to the sum of the individual resistors.

$$R_{\text{tot}} = R_1 + R_2 + R_3$$

The current in a series circuit is the same in each component of the circuit because the current must flow through each resistor in series to get to the next resistor.

$$I_{\text{tot}} = I_1 = I_2 = I_3$$

The applied voltage divides across each component in a circuit in proportion to the resistance of the component.  $V_{\text{tot}} = V_1 + V_2 + V_3$

*Parallel Resistor:* When resistors are connected in parallel, they have two points in common. The total resistance of parallel resistors is equal to the reciprocal of the sum of the reciprocal of the individual resistors.  $R_{\text{tot}}$  of a parallel circuit is called the equivalent resistance,

$$R_{\text{eq}} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

- Why color-coding is necessary for resistor?

A wide variety of resistors are physically large enough to have their resistance value printed on them. However, carbon composition resistors are too small for this method of identification so a color coding system is used. Four bands are printed on one end of the resistor and are read from the band closest to the end of the resistor toward the center. Each color represents a numerical value as indicated below.

|          |           |           |              |               |             |
|----------|-----------|-----------|--------------|---------------|-------------|
| 0- Black | 3- Orange | 6- Blue   | 9- White     | ±5% - Gold    | } Tolerance |
| 1- Brown | 4- Yellow | 7- Violet | 0.1- Gold    | ±10% - Silver |             |
| 2- Red   | 5- Green  | 8- Grey   | 0.01- Silver |               |             |

Suppose the color bands of a resistor are yellow, violet, red and gold. The resistance value is determined as follows:

$$4 \quad 7 \quad 00 = 4700\Omega$$

Yellow = 4

Violet = 7

Red = 2 (two zeros)

Gold = ±5%

4700+5% = 4935 } The actual resistance should be between 4467 and 4935 ohms.

4700-5% = 4465 }

Occasionally a fifth band is used to indicate the failure rate of the resistor:

Yellow 0.001% per 1000 hours

Orange 0.01% per 1000 hours

Red 0.1% per 1000 hours

Brown 1.0% per 1000 hours

- What does Ohm's Law states?

In a closed electrical circuit, current is directly proportional to voltage and inversely proportional to resistance at constant temperature.

$I = V/R$ . Where  $I$ = Current,  $V$ = Voltage &  $R$ = Resistance

- What does Kirchhoff's voltage law states?

Kirchhoff's voltage law states that " the algebraic sum of potential rises and drops around a closed loop is zero."  $\sum V = 0$

- What does Kirchhoff's current law states?

Kirchhoff's current law states that " the algebraic sum of current entering and leaving a node is zero." (A node is a junction of two or more branches.)

- What is a Capacitor?

When two conductors are placed side by side, separated by a nonconductive material, and connected across a battery, free electrons drift in the direction of the



driving voltage is called capacitor. Its unit is farad, normally in micro farad ( $\mu\text{f}$ ) or Pico farad (pf).

- What is Inductor?

Inductors use the ability of electrical current to create a magnetic field. If a voltage is applied to a coil of wire, the current flowing in the coil will cause a magnetic field to develop. The more times the wire is coiled and the more current there is in the coil, the greater the strength of the magnetic field. Its unit is Henry, normally in milli Henry (mH).

- What is Inductance?

The property of a coil that opposes a change in the current flow is called inductance. The inductance of a coil depends on four factors:

- 1) The number of turns (windings) in the coil. Inductance is proportional to the square of the number of turns in the coil.
- 2) The diameter of the coil. The larger the diameter of the coil, the higher the inductance.
- 3) The permeability (ability to become magnetized) of the core material.
- 4) The length of the coil. The shorter the coil, the higher the inductance.

- What is Power?

Power is a rate of doing work, or works done per unit in time. The unit for measuring power is the Watt (W). Power in watts is equal to the product of the applied voltage and the current flowing. Stated algebraically,  $P = I E$

- What is Alternating Current?

Continually changing amount and direction of the current and voltage is called alternating current (AC). The components of an ac circuit causes a time period to be introduced between current and voltage; that is, current and voltage are out of phase.

**Few definitions and symbols used in alternating current**

- 1) Amplitude or peak value: The maximum value reached by a waveform.
- 2) Capacitive reactance ( $X_C$ ): measured in ohms, is the opposition to a change in current flow provided by a capacitor. Capacitive reactance causes current to lead voltage by  $90^\circ$ :  $X_C = 1/2\pi f C$ .
- 3) Cycle: The portion of a waveform contained in one period of time.
- 4) Effective value: The value of voltage that occurs at  $45^\circ$  (0.7071 times the maximum value).
- 5) Frequency: The number of cycles per second is called frequency and measured in Hertz (Hz).
- 6) Impedance ( $Z$ ): The opposition to current flow in an ac circuit. It is a combination of resistance, Inductance and capacitance.
- 7) Inductive Reactance ( $X_L$ ): Inductive reactance, measured in ohms, is the opposition to a change in current flow produced by a coil of wire. Inductive reactance causes current to lag voltage by  $90^\circ$ :  $X_L = 1/2\pi f L$ .
- 8) Instantaneous value: The magnitude of a waveform at any instant of time.
- 9) Period (T): The time interval between successive repetitions of a periodic waveform.
- 10) Periodic waveform: A waveform that continually repeats itself after the same time interval.
- 11) Resistance: the opposition of a circuit to the movement of electrons. Resistance in an ac circuit acts the same as resistance in dc circuit.

### **Measuring Instruments**

- **What is Voltmeter?**  
It is an instrument to measure voltage. It is always connected in parallel to the power supply.
- **What is Ammeter?**  
It is an instrument to measure the current flowing in a circuit. It is always connected in series with the load.
- **What is Megger?**  
The megohmmeter, commonly called a megger for short, is used to measure very high resistance values. It is primarily used to test the insulation of conductors. To measure high resistance values, a high voltage is applied, either by the use of a hand-cranked generator or electronic power supply.
- **What is Clamp-On Ammeter?**  
Clamp-on ammeter is used to check the current in a circuit, without being physically connected in a circuit. They are convenient to use in the field since the circuit does not have to be opened to take a current reading.
- **What is Infrared or Thermal scanner?**  
Infrared or thermal scanners are used to measure temperature without contact with the equipment. They produce an image of the component showing temperature variations, this is effective in spotting worn or loose connections and components in industrial circuits.
- **What is Phase sequence indicator?**  
Phase sequence indicator used to indicate the 3-phase direction- comes in two styles; Lights and meters. In the lighted variety, a sequence of light goes on for the phase sequence being read, while the meter indicates which phase direction it is reading.
- **What is Rotation tester?**  
This device is used during the installation of a motor to determine the direction of the motor once it is installed. The shaft is mechanically rotated in the desired direction and the meter indicates if that is the direction in which the motor will rotate.

### **DC Machines**

*Conversion of one form of energy into another enables us to use natural power sources as well as manufactured power sources to produce our electrical power supply. Although electricity can be produced by friction, pressure, heat, light, chemical action and magnetism, the most common method used by large power producers is magnetism.*

- What is Electric Generator?  
Electric generators are called a dynamo that converts mechanical energy into electrical energy. A dynamo consists of two basic parts- the stationary part and the rotating part.
- How electromotive force is created in a generator?  
When a conductor cuts the magnetic lines of forces, an Electro motive force (emf) is generated.  
The magnitude of the generated voltage is directly proportional to the rate of change at which a conductor cuts the magnetic lines of force.
- What is DC motor?  
An electric motor converts electrical energy in to mechanical energy.
- How many types of DC motors are there?  
*DC shunt motor*: shunt motor speed varies slightly from no load to full load.  
*DC series motor*: series motor speed varies greatly as load changes.  
*DC compound motor*: the compound motor contains both a shunt field and a series field and therefore has characteristics between the shunt and the series motors. This motor has the good starting torque characteristics provided by the series field, while the shunt field provides for a relatively constant speed.

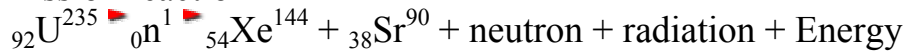
### **Maintenance & Troubleshooting**

- Troubleshooting is a field of repair work that usually tests how well the student has learned the lessons. The principles involved in control functions, components and circuit analysis, along with the basic laws of electricity.
- Your best tool when troubleshooting is your ability to think. Don't jump to conclusions. Have confidence in your ability. Learn how the equipment in your area is supposed to operate both electrically and mechanically.
- Observe all plant rules and regulations. Electricity can be dangerous. In addition to the hazards of electrical shock and electrocution, burns from an electrical flash can be devastating. Be careful when opening the circuit. The inductive kick that can occur when a circuit opens produces a voltage that is many times the voltage applied to the system.
- No matter how complex or expensive an electrical control system is, the components of the system begin to deteriorate as soon as they are installed and failure of some components in the system will ultimately result.
- Blown fuses, overload contacts, open contacts, short circuits, burned out coils and grounds are responsible for most electrical circuit failures.
- Troubleshooting can be generalized in 3 steps:
  - 1) Determine the symptoms; that is, find out how it acts. (When equipment is operating properly, you should find out how it is supposed to function.)
  - 2) Decide by logical reasoning what might be wrong. (Try to isolate the problem to a section of the control.)
  - 3) Determine what has to be done to correct the problem.
- If we are troubleshooting an existing circuit, one that has been in service and operated properly, we can eliminate the possibility of fault installations or design.
- The first step- determine the symptoms- can best be accomplished by working with the machine operator and following the machine through its sequence to the point of failure.
- Remember that no matter how complex, control circuits are made up of only two things. Contacts that open and close a circuit and coils that operate the contacts, keeping in mind the control voltage.
- Probably the single most important rule in troubleshooting is to remember to change only one thing at a time.
- Remember the operator knows the machine operation and can be an asset to you in your troubleshooting. Question the operator but don't challenge his operating ability.

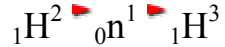
- Anyone attempting to troubleshoot without a drawing and a meter is wasting the time.
- Instead of random checking the circuit; start from the source to the machine or from the machine to the source.
- Finally take time to think.

## Radiation Protection

Fission reaction



Tritium formation



1 Seivert = 100 Rem

Annual Dose Limit (ADL) = 20 mSev or 2 Rem for Employees.

Annual Dose Limit (ADL) = 15 mSev or 1.5 Rem for Contractor.

Annual Dose Limit (ADL) = 1 mSev or 100 mRem for Public.

5 Years = 100 mSev or 10 Rem

DAC (Derived Air concentration)

>10 DAC use tritium bottles

10-15 DAC use airline

>50 DAC use ventilated plastic suite (VP suite)

1 DAC for 1 hour = 0.01 mSev or 1 mRem.

- Why no entry for Moderator room & Pump room during operating condition?  
Due to the presence of  $\text{N}^{16}$  &  $\text{O}^{17}$ , which are high gamma emitter, their field is around 7 mev.
- What are the gases discharged to the stack?  
Argon-41, Tritium, fission products, noble gases & Iodine particulates.



- What are the emergencies provided in the plant?

*Plant Emergency:* Excessive release of radioactive material or high radiation fields in a section of the plant

*Site Emergency:* Uncontrolled release of radioactive material or high radiation fields within the site boundary

*Off- Site Emergency:* High release of radioactive material from the plant resulting in significantly increased radiation fields and/or contamination levels extending to areas outside the site

*Emergency Planning Zones (EPZ):* Emergency planning zone, defined around the plant up to 16 km, provides a basic geographic frame work for decision making on implementing measures as part of a graded response in the event of an emergency. The area around the Kaiga generating station is divided into the following Zones up to 16 km radius.

*Exclusion Zone:* The exclusion Zone extends up to a distance of 1.6 km around the central plant zone of 0.7 km where no public habitation is permitted. This zone is physically isolated from out side areas by plant fencing and is under the control of Kaiga Generating Station.

*Sterilised Zone:* Sterilised zone is an area where no new growth of population is permitted. Natural growth is however allowed in this Zone. This are extends up to a radius of 5 km from the central plant Zone. This Zone is defined to restrict the population to an easily transportable number in case of an emergency.

*Primary Zone:* The primary Zone extends up to 8 km from central part Zone where protective measures like evacuation and sheltering are required against possible plume exposures during an Emergency.

*Secondary Zone:* The secondary Zone extends up to 16 km from central plant Zone protective measures like sheltering control on food stuff are required against possible exposure from ingestion of radioactivity.

## **CLASSIFICATION OF EMERGENCIES**

Emergencies are classified on the basis of the nature and severity of the incident. The effect of the emergency may be restricted either to a small area of the plant or a few individuals or it may pose damage to the installation staff. Emergencies of more severe nature could result in unacceptably enhanced release of radioactive materials or toxic/noxious substance from the plant of resulting in hazard in the surrounding public domain. Accordingly the emergencies are classified into:

1. Plant emergency
2. Site emergency
3. Off-site emergency

### **Plant Emergency**

This type of emergency is classified in to

- a) Personal emergency
- b) Emergency Alert
- c) plant emergency

*Personal Emergency:* This involves accidents or incidents in any of the plant areas, which call for emergency treatment of personal. The situation may result from high radiation exposure or significant contamination or abnormal intake of radioactivity by personal. The examples of personal emergencies are listed in Annexure-I.

*Emergency Alert/Emergency Standby:* This involves abnormal conditions, which have a potential to proliferate in to a more serious situation but still provide time for pre-cautionary and constructive steps to prevent an emergency situation or migrate its consequences. The examples of emergency Alert are listed in Annexure-II.

*Plant emergency* This involves excessive release of radioactive materials or high radiation fields in a section of the plant requiring operator action and/or automatic operation of the safety system. Although positive isolation or restriction on occupancy of the affected areas might be enforced, evacuation of personal might be required if it is suspected that the doses to personal or likely to exceed the intervention levels. The examples of plant emergency conditions or listed in Annexure-III.

### **Site Emergency**

This class of emergency arises due to situation, which seriously affect plant operation involving high radiation fields in accessible areas and release of radioactive materials extending beyond the plant up to the site environment. The protective measures such as incorporation of stable Iodine, sheltering and evacuation of personal from plant areas other than control room to areas designated to be habitable under the site emergency conditions and evacuation of non-essential persons from the site may be considered. The examples of site-emergency condition are listed in Annexure –IV.

### **Off-site Emergency**

An Off site emergency situation results when the release of radioactive materials from the plant is of a magnitude necessitating protective action to be taken for members of the public in the neighborhood of the plant.

**EMERGENCY DECLARATION AND NOTIFICATIONS:**

Declaration of Emergencies shall be made by the Duty SCE / PED based on the information from the plant or as per the advice from Kaiga emergency Committee (KGEC).

*Declaration of Emergency:* Siren will be sounded as described below for declaring emergency. Following the Siren, there should be an announcement.

*Siren:* Short intermittent siren 5 seconds on, 5 seconds off for a period of two minutes.

*Emergency Announcement:*

The announcement shall be made as follows;

"ATTENTION ALL PERSONNEL - THERE IS PLANT EMERGENCY"

THE INCIDENT AREA IS .....

THE ASSEMBLY AREA IS .....

THE EMERGENCY CONTROL CENTRE IS.....

PERSONS PRESENT AT ..... SHOULD AVOID GOING TO .....

This announcement shall be repeated thrice in English, Hindi and Kannada.

*Evacuation:* Evacuation if necessary will be made by announcement on Public Address (PA) system.

*Termination of Emergency:* A continuous Siren is sounded for 2 minutes. Following the emergency Siren, there shall be an announcement in English, Hindi and Kannada on public address system terminating the emergency.

*Notification Codes:*

The messages for notification of start/termination of on site and off-site emergencies are indicated as follows. These should be disseminated to various agencies. The codes for notification of commencement or termination of various types of emergencies are:

a) External radiation exposure (mSv)    DAC-hr (HTO)    DAC-hr(I-131)

DAC-hr (I-131) -----( $\leq 1$ )

(For meeting iodine thyroid dose limit of 50 mSv)

The explanatory notes for these guidelines are given in Annexure-IX.

*Countermeasures during a radiation emergency:* Following countermeasures have been identified for control of exposures during a radiological emergency within the plant site areas and in the public domain.

1. Sheltering
2. Administration of Stable Iodine
3. Evacuation.
4. Relocation.
5. Control of Access.
6. Control of Food and Water
7. Decontamination of Affected Areas and Buildings.

DOMAIN:

Domain 1 = 0.1 mSv/hr

Domain 2 = 0.01 mSv/hr

Domain 3 = less than 0.01 mSv/hr

***Stochastic and Deterministic effects.***

*Stochastic effects:* Stochastic effects are those for which the probability of an effect occurring, rather than its severity, is regarded as a function of dose, without threshold. Example: Cancer.

*Deterministic effects:* Deterministic effects are those for which the severity of the effect varies with the dose, and for which a threshold may, therefore, occur. Examples Cataract, permanent or temporary sterility.

*Practices:* Any human activity, which increases the overall exposure to radiation, is a "Practice" such as operation of nuclear power stations.

*Intervention:* Any human action intended to reduce or avert exposures to sources which are not part of controlled practices or which are out of control as a consequence of an accident is "Intervention".

*Objectives of Radiation Protection:* Prevent deterministic effects and to limit the stochastic effects to levels deemed to be acceptable.

***Principles of Radiation Protection:******Practices:***

- Justification: No practice shall be adopted unless its introduction produces a sufficient benefit to the exposed individual or to the society to offset the radiation harm that it might cause.
- Optimisation: All exposures shall be kept As Low As Reasonably Achievable (ALARA) economic and social factors being taken into consideration.
- Dose limitations: Individual exposures are limited by dose limits since the dose above the dose limits are unacceptable

***Intervention:*** The general principles of radiological protection for intervention are:

- The reduction in dose should be sufficient to justify the harm and the costs to the individual and the society due to the intervention.
- The benefit of the reduction in dose less the cost of intervention should be As Large As Reasonably Achievable.
- Dose limits do not apply in case of intervention. However there will be some projected dose levels above which intervention will be justified because of serious deterministic effects.

***Dose limits:*** Occupational Workers

- For *stochastic effects*: The dose limit for uniform irradiation of the whole body shall be 20 mSv (2 Rem) averaged over 5 years (January 1,1999 to December 31,2003) and shall not exceed 30 mSv (3 Rem) in a single year.
- The average whole body dose for the occupational workers in the station should normally not exceed 5 mSv (500 Rem).
- For deterministic effects, the dose limit shall be 500 mSv (50 Rem) in a year to Bone surface, Skin and for the lens of the eye, for which the limit shall be 150 mSv (15 Rem) in a year.

The whole body exposure level should Remain less 10 mSv (1 Rem) in any month and 15 mSv (1.5 Rem) in any calendar quarter.

In case of intakes of radioactive material into the body, the total amount of activity taken into the body in a calendar year shall not exceed one ALI (Annual Limit on Intake).

Incase of exposure resulting from both external radiation and intake of radionuclides in the body it shall be ensured that the sum of effective dose resulting from all such exposures does not exceed the annual dose limits.

$$\text{Whole body dose } I_i \text{ -- } + \Sigma \text{ -- } < 1$$

$$0.02 \text{ Sv } (ALI)_i$$

Where  $I_i$  is the intake of the  $i^{\text{th}}$  radio-nuclide and  $(ALI)_i$  the ALI value for the  $i^{\text{th}}$  radio-nuclide.

*Planned Exposure:* Situation may occur in-frequently during normal operations when it may be necessary to permit a few workers to receive dose in excess of the annual whole body dose limit. In such circumstances, Station director may permit exposure such that dose does not exceed 30 mSv in a single year and 20 mSv averaged over 5 years.

*External Exposure Control:* Any external whole body exposure that exceeds 5 mSv (0.5 Rem) in any month is referred to as significant dose.

*Internal Exposure Control*

- a. Proper ventilation of work areas and use of the recommended protective equipment would avoid intake of radionuclides in the body.
- b. In any case of actual or suspected high intakes HPU should be contacted for advice and appropriate action.

*KGS-Operating Manual on Radiation Protection Procedures*

For assessment of internal exposure due to tritium, bioassay of urine will be taken as the standard reference. For assessment of internal exposure by radionuclides other than tritium bioassay and/ or whole body counting whichever is applicable will be taken as standard reference. For control of intake of tritium the following procedures shall be followed:

*Permissible Contamination levels*

Air borne Contamination the levels of air borne contamination in working areas at the station should be maintained below the Derived Air Concentration (DAC) values  
 $DAC (Bq/m^3) = ALI Bq/2400 m^3$

*Investigation of Doses*

Investigation levels Whole body dose: Committee (SDIC) shall investigate these exposures

Dose Reference Levels for Investigation

| Tissue/Organ Investigation Levels mSv (Rem) |          |           |          |
|---------------------------------------------|----------|-----------|----------|
|                                             | Monthly  | Quarterly | Yearly   |
| Whole body                                  | 10 (1)   | 15 (1.5)  | 20 (2)   |
| Skin                                        | 100 (10) | 300 (30)  | 500 (50) |
| Lens of Eyes                                | 30 (3)   | 80 (8)    | 150 (15) |



*The functions of SDIC:*

- a. To investigate fully the causes of the doses above the investigation levels and to prepare a factual report.
  - b. To suggest Remedial measures to prevent recurrence of such doses.
  - c. To suggest further action in respect of work to be allocated to the exposed person.
  - d. To recommend Remedial measure and medical follow up wherever necessary.
- Exposure exceeding any of the limits stipulated below shall be regarded as potentially serious:

*Whole body dose:* 100 mSv (10 Rem)

*Exposure to Eye Lens:* 300 mSv (30 Rem)

Such cases shall be referred to Head, Medical Group, BARC and Chairman, SARCOP immediately

Head, Medical Group, BARC shall initiate appropriate medical investigation

Medical report shall be submitted to Chairman, SARCOP, within a week. Chairman, SARCOP shall constitute a special committee for investigation of such exposures.

*Tritium half life:* Radiological = 12.3 years, Biological = 7 days, tritium effective =  
 $(TR * TB) / (TR + TB)$   
 $(12.3 * 365 * 7) / (12.3 + 365 + 7) = 7 \text{ Days}$

*REVERSE SQUARE LAW:* Dose at a rate from the point of source is inversely proportional to the square of the distance. I is inversely proportional to  $L / d^2$

*Technical specification Values:* Fission products

Noble gases 14.8 TBq / day, Tritium = 13 TBq/day, Ar 41 = 2.04 TBq / day,

I-131 = 185 MBq/day, Particulate = 1480 MBq / day

Liquids: Tritium = 1.295 TBq/day

*RADIOACTIVE TRANSPORT INDEX:* 1 meter from the source shield. Declaration of radioactive material = 70 kiloBq / kg

## **Maintenance Performance Planning**

### *1. Essential sequence of maintenance Jobs execution.*

Identify maintenance jobs, asses safety, radiological precautions, plan the work, do the pre-job briefing, take the safety and ALARA measures, carry out the maintenance, test and normalise equipment or system, update records and history cards, review maintenance performance and devise future strategy, achieve excellence in maintenance through dedicated team work.

### *2. Maintenance performance indicator based on equipment & work control*

Maintenance performance indicator (MPI) is the measure of performance of each aspects of maintenance. These are established as convenient measures to evaluate current performance levels against standard as well as an index to compare with past performance.

MPI base on equipment performance (EMPI)

- a) Equivalent availability % (should be as high as possible)

$$\frac{\text{Equipment operating time} \times 100}{\text{Equipment operating time} + \text{down time}}$$

- b) Mean time between failures (MTBF) should be as high as possible

$$\frac{\text{Number of operating hours}}{\text{Number of failures/breakdowns}}$$

- c) Meantime to repair (MTTR) as low as possible

$$\frac{\text{Sum of repair time}}{\text{Number of breakdowns}}$$

- d) Number of plant outage caused due to equipment failure. (Objective should be zero)

- e) Number of respective failures during reporting period. (as low as possible)

- f) Number of breakdowns during reporting period (As low as possible)

### *3. Maintenance Performance indicator based on work control*

- a. Work control indicator (WCI) should be near to unity

$$\frac{\text{No. of DR received from control room per month}}{\text{No. of PM jobs planned}}$$

### *4. Maintenance performance indicator based on maintenance man hours*

- 1) Man hours spent on breakdown maintenance

- 2) Man hours spent on PM including implementation of ECN/FCN's etc.

- 3) % man hours spent on breakdown maintenance

$$\text{Man hours spent on} = \frac{\text{Breakdown maintenance}}{\text{Total maintenance man hour available}} \times 100$$

- 4) % of man hours spent on PM

$$= \frac{\text{Man hours spent on PM}}{\text{Total maintenance man hour available}} \times 100$$

Total maintenance man hour available

- What is FME explaining with the examples?

Foreign material is defined as material that is not part of a system or component as designed. This includes dirt, debris, broken or missing parts, slag, tools rags, liquids/chemicals, lapping compounds, grinding particles and any other item that would affect the intended operation of a system or component

All personnel shall assume responsibility for preventing the introduction of foreign material into systems. This will minimize damage or harmful effects. Such as corrosion, fuel damage, component malfunction, or failure, changes in chemistry. Reduced heat transfer, increased radiation levels, changes in system flow characteristic and improper contact operation.

*Specific actions includes the following*

Work packages will be planned using field walk downs to determine specific FME recommendations

If temporary dams are installed which will not be readily visible upon system closure, verification of removal shall be included in the checklist.

- What is the importance of communications?

Effective, open communication is essential for safe and efficient performance of plant maintenance. Expressing concerns describing assignments, discussing problems, are few aspects of maintenance of communication. Clear and unambiguous communication is an integral part of procedure compliance and safe work practice. The following additional communication practices will be followed.

- a. Repeat back is used to ensure accurate communication, especially when portable radios, headsets, or telephones are being used.
- b. Upon completion of a task, technicians shall report job completions to their supervisors and seek additional assignments.
- c. To confirm to the principle of solving problems at the lowest possible level, potential grievance issues are to be discussed with the first line supervisor.
- d. Plant approved terminology, equipment identification and abbreviations are to be used at all times.
- e. 2-way communication is required at times!
- f. Listen
- g. Understand
- h. Then reply or repeat message.

- Importance of self checking peer verification

- a. *STAR Principle*

- S- Stop pause before performing a task,

- T- Think Understand exactly what is to be done before taking any action.

- A- Act Touch the component without actuating it. Then do it.

- R- Review, verifies that the actual responses is the expected response.

- b. *Self-checking* is a self-verification step or action before it is performed. This behavior is developed through constant checking to ensure the intended action is correctly and positively performed on the right equipment. Consistently applied this will minimize error by forming a barrier against complacency and over confidence. All are responsible for conducting self-checking prior to manipulating a component or devices, or altering equipment configuration. For examples relays, positioning switches, breaker or valves, lifting/landing wires, connecting test equipment, removing or installing fuses.

- c. Any deficiency found in the field like labels, nameplate missing/tampered should be intimated to the supervisor.

- d. Do it right the first time.

- e. Peer verification is achieved through the use of inspection points, these include dual verification, independent verification, supervisory verification and quality verification. Peer verification leads to a broader concept of checking other.

- f. Questioning attitude should develop for continuously learning.

*The distinction between predictive and periodic maintenance is presented below.*

- a. Use predictive maintenance results to trend and monitor equipment performance so that needed corrective or preventive maintenance can be performed before equipment failure.
- b. Predictive maintenance actions are determined by the data required to monitor equipment condition.

Examples are as follows:

*Vibration analysis* (includes spectral analysis and bearing temperature monitoring) and lubrication oil and grease analysis are used to monitor rotating equipment.

*Infrared surveys* (thermography) are performed on heat producing equipment such as motors, circuit breakers, batteries, load centers, bus ducts, transformers and insulated areas to monitor for high resistance or insulation breakdown.

*Oil analyses* are performed on lubrication for rotating equipment to identify degrading equipment and chemical breakdown of lubricants.

*Motor operated valves* are diagnostically tested and analysed. Tests determine parameters such as run current, valve stem thrust and torque switch and limit switch actuation points.

- c. Periodic maintenance is time based action taken on equipment to prevent breakdown and involves servicing such as lubrication, filter changes, cleaning, testing, adjustments, calibration and inspection. Periodic maintenance can also be initiated because of the results of predictive maintenance, vendor recommendation, or experience. Examples are as follows:
  - a. Scheduled valve re-packing to avoid leakage based on previous experience.
  - b. Replacement of bearings or pump realignment as indicated from vibration analysis and/or lubricating oil analysis
  - c. Major or minor overhauls based on experience or vendor recommendations.
  - d. Maintenance on equipment belonging to a redundant safety system if so allowed by the Technical Specifications

- d. Preventive Maintenance Programme Effectiveness

Continually review the preventive maintenance programme for effectiveness, and change if necessary based on changes in plant design, operating conditions, regulatory commitments and as found conditions. In addition, unexpected equipment failures should result in a critical self-assessment to determine why the previous maintenance activities were insufficient to maintain equipment reliability. The primary objectives of the programme are to reduce future component failures, optimize preventive maintenance tasks and use of resources, identify programme scope and satisfy regulatory and utility concerns. Emphasize obtaining accurate feedback on preventive maintenance tasks. Enhancement, provide additional guidance on methods to determine preventive maintenance effectiveness.



- What are the advantages and disadvantages of planned maintenance?

Advantages of Planned Maintenance.

1. As the name reflects maintenance jobs planned properly ie. manpower, tools, tackles, required for maintenance is well planned and readily available or reserved for planned job
2. Procedures for doing the job is well known before doing the job and job can be performed as per procedure/checklist.
3. It saves the time and unplanned outages of equipment.
4. Common facilities/tools/tackles/ in the section in the section can be made available at the right time as job and requirements for that are already well planned.
5. Overtime to employees can be limited.
6. Job can be done systematically, accurately as quality job can be expected.

Disadvantages of Unplanned maintenance.

1. Unplanned job won't have any expectations when to start, when to stop.
2. Man power/tools tackles were available/not available at the right time is not ensured.
3. Job may have to do in hurry which can lead to mistaken or job can be done leisurely (no sufficient work front for the available manpower.) so wastage of man machine tools etc.
4. In NPP we cannot accept unplanned jobs, as all works are safety related/important.

- What is pre-job briefing and post job briefing?

*Pre-job briefing:* Unit no, DR/WP/, USI/system/load, Job description, Eqpt history, Scope of Job, Any special tool or equipment required, Safety/Alarm, Procedures, expectation for the job, tech specifications requirements, communication, FME requirements, environmental concepts, any abnormal conditions.

*Post job briefing:* Details of work done, difficulties faced, deficiency found, parts replaced, experience to be communicated, review modification, review procedure, any suggestions, drawing updating, updating of history card, completion of checklist, any testing/logic checks required, clearance for surrendering permit.



- What are the activities by which performance of the station will be judged?  
Activities of station by which performance is judged by public
  - a. Capacity factor.
  - b. Availability factor.
  - c. Radiation release (gas and liquid effluents).
  - d. Thermal release.
  - e. Man-rem.
  - f. Development programs.
  - g. Public awareness.
  - h. Usefulness of the plant product to the public.
  - i. Employment and other facilities provided to the local public.
  - j. The Basic amenities provided to the employees.
  - k. The standard of living of the employees.
  - l. The profit earned by the Plant.
  - m. The quality and cleanliness in and around the Plant.