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(MANOJ KUMAR)

SPECIAL THANKS TO MANOJ KUMAR FOR THE BEST NOTES FOR ELECTRICAL

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FUNCTION - 5

EECEOL

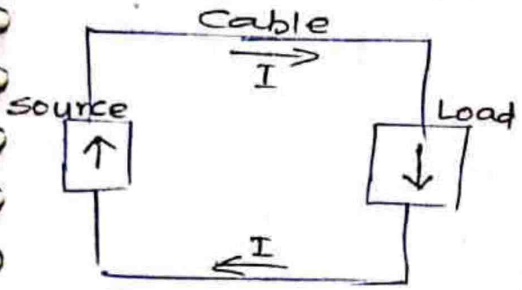
Electrical Electronics and Control Engineering at Operational Level.

Procedure:-

1→ Take printout of this pdf.
2→ Go through it properly (minimum 3-4 times)
3→ Try to answer questions of your respective mind.
4. I have left some pages blank intentionally, whenever you get new question, add it on the blank pages and study
5. Ask your friends to ask question from you.
6. If you like notes, then please donate using UPI on carbidee@ybl (MANOJ KUMAR) contact on telegram '@carbidee'

Basics

Circuit:- It is path taken by electric current, At load current is required or energy is consumed or work is done



→ current flows from higher potential to lower potential so for current to flow there must be a potential difference

→ For the load current is from +ve to -ve terminal but for energy source in the form of cell, battery or generator, current is from -ve to +ve terminal

- The electrical pressure generated by energy source is termed as electromotive force (e.m.f) & symbol is E. emf is measured as voltage (V.)

- Circuit laws:-

1. In a circuit current strength $\propto$ voltage applied across its ends.

I (current) → A (Amperes)

Resistance (R) is opposition to flow of current

Unit → ohm → Represented by Ω (omega)

2. $I \propto \frac{V}{R}$

Ohm's Law :- $I = \frac{V}{R}$

- KIRCHHOFF'S LAWS:-

1. VOLTAGE LAW:- The sum of potential or voltage drops taken round a circuit must be equal to Applied potential difference

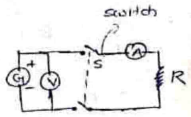
i.e $V_1 + V_2 + \cdots = V$

2. Current Law:- The current flowing away from a junction point in a circuit must be equal to current flowing into that point i.e $I_1 + I_2 + \cdots = I$

- Conductance (G) :- It is reciprocal of Resistance (R)

i.e $G \propto \frac{1}{R}$ Unit of conductance → Siemens (S)

Ammeter :- Used for measuring current
- Should have very low resistance
- connected in series with load
- Negligible voltage drop across it

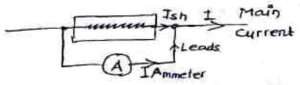


Voltmeter :- Measures voltage or Potential diff.
- should have high resistance (finite res)
- ~~Can be~~ Are connected in parallel to load

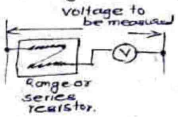
• Range extension of Ammeter and Voltmeter :-

Shunt :- Shunt is specially constructed resistor of low resistance.

If we want to measure a current greater than the capacity of ammeter, shunt is used with ammeter in the parallel connection
Through ammeter finite fraction of main current will flow & rest current will flow through shunt.
shunt is calibrated with ammeter & must be used with it always.



- To measure higher voltage than that of capacity of voltmeter series or range resistor must be used.
This range resistor drop excess voltage & dissipates certain amount of heat
- This Range resistor is connected in series with voltmeter.



• Current (I) :- The flow of charge particles or the rate of flow of charge in a conducting medium is called electric current. The charge particles could be -ve (e^-) or +ve (proton)

Just like a river current, which is the continuous flow of water molecules, an electric current is the continuous flow of charge particles. The amount of charge flowing through a certain point in a conducting medium in a specific time is called electric current.
current is denoted by 'I'.

$$I = \frac{Q \text{ (charge)}}{t \text{ (Time)}}$$ SI unit = Ampere (A)

Ampere :- One ampere is the amount of current where one coulomb of charge flows through a certain point in a conducting medium in a time of one second. Or a conductor carrying one ampere of charge is said to have a charge flow of one coulomb per second.

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• Voltage:- (V):- In electric circuit voltage is force or pressure that is responsible for pushing the charge in a closed loop conductor. The flowing of charge is called current. The voltage is the electric potential between two points; the greater the voltage, the greater will be the current flow through that point (i.e V∝I)
Denoted by 'V' SI unit :- Volts.

Volt:- It is the potential difference between two points that allows a current of 1 ampere through it and dissipates 1 watt of power between these points.

OR

It is potential difference which moves one joule of energy per coulomb charge between two points.

Power Factor (P.f) :-

Note:- Power factor is only related to AC circuits i.e there is no power factor (P.f) in DC circuits in DC circuits due to zero frequency and phase angle difference (ϕ) between current and voltage.

3 definitions for Power factor:-

1) The cosine of angle between current and voltage is called Power factor.

$P = VI\cos\theta$

OR $\cos\theta = P/VI$

OR $\cos\theta = kW/kVA$

OR $\cos\theta = \frac{\text{True Power}}{\text{Apparent Power}}$

Here
P = Power in Watt
V = Voltage in Volts
I = Current in Amperes
kW = Real Power in kWatts
VA = Apparent Power in Volt-Ampere or kVA
$\cos\theta$ = Power factor

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2) The ratio between Resistance and Impedance in AC circuit is known as Power factor.

$\cos\theta = \frac{R}{Z}$

Here R = Resistance in ohms (Ω)
Z = Impedance in ohms (Ω)

Impedance (Z) :- It is total Resistance offered by the AC circuit.

3) The Ratio between Active power and Apparent Power in volt-amperes is called power factor.

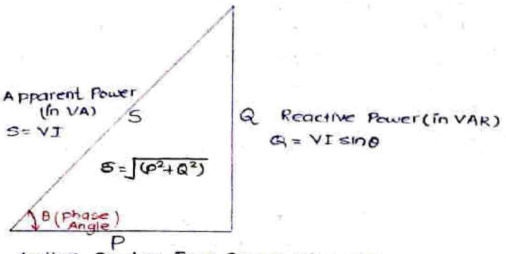
$\cos\theta = \frac{\text{Active power}}{\text{Apparent Power}}$

OR $\cos\theta = P/S$

OR $\cos\theta = \frac{kW}{kVA}$

Here
kW = P = Real Power in kilo-Watts
kVA = S = Apparent Power in kilo-Volt-Amps.
$\cos\theta$ = Power factor.

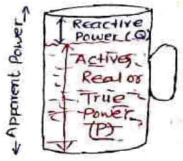
- Power factor Triangle :-



All formulas :-

- $P = VI\cos\theta$
- $\cos\theta = \frac{P}{VI}$
- $\cos\theta = \frac{kW}{kVA}$
- $\cos\theta = \frac{\text{True Power}}{\text{Apparent Power}}$
- $\cos\theta = \frac{R}{Z}$
- $\cos\theta$ = Power Factor = $\frac{kW}{kVA}$
- $\cos\theta = \frac{\text{Active Power}}{\text{Reactive Power}}$

Water-Glass Analogy



- Active Power (P) :- Active power is also known as Real power OR True power OR Watt-full power OR Useful power OR Actual power.
  It is denoted by 'P' & measured in Watts (W)
  - Actual power is the actual power which is really transferred to load such as transformer, induction motors, generators etc & dissipates in the circuit.
  - This power is actually consumed or utilised in AC circuit.
  - It is actual outcomes of the electrical system which runs the electrical circuits or load.

- Reactive Power 'Q' :- This power is also known as Use-less Power OR Watt less Power.
  - The power that continuously bounce back and forth between source and load is known as reactive power 'Q'.
  - This power is just absorbed and returned in load due to its reactive properties.
  - Reactive power is that energy which is first stored and then released in the form of magnetic field or electrostatic field in case of inductor and capacitor respectively.
  - Reactive power is ($Q = VI\sin\theta$) positive for inductive loads and negative for capacitive loads.
  - Unit of Reactive power is Volt-Ampere reactive i.e VAR & 1 VAR = 1V x 1A

- Apparent Power (S):-
- The total power in AC circuit both dissipated and absorbed / returned is called as apparent power.

OR

- The combination of reactive power and true power is called apparent power.

OR

If the phase angle (θ) difference blw current and voltage are ignored then poduct of voltage and current is RP. i.e Reactive power is product of voltage and current without phase angle.

- Unit of S is VA i.e $1VA = 1V \times 1A$

Note:- When the circuit is pure resistive, then apparent power is equal to real or true power, but in inductive or capacitive ~~power~~ circuit (When Reactances exists) then apparent power is greater than Real or true power.

- Causes of Low Power Factor:- carbidee@ybl

1. Harmonic Current:- The presence of harmonic current reduces the power factor in system.
2. Improper Winding/Wiring:- Due to improper winding/wiring or electrical accidents, an imbalance in the 3-phase power occurs which causes low power factor.
3. Inductive load:- Most of industrial loads consist of induction motors. Such machines draws magnetizing current and set up a magnetic field for its proper working and hence work at a low power factor.
   The current drawn by inductive loads is lagging and results in poor power factor.
4. Electrical discharge lamps: (High intensity discharge lighting) Arc lamps operate at very low power factor.
5. Variation in the Power System Loading:- The load demand in the modern power system is not constant throughout the day. The demand is high during morning and evening hours (generally) and light during rest of day. When the system is loaded lightly, the voltage increases, increasing the magnetization current demand of machine. This causes a poor power factor in the system.

→ Harmonic current → It is sinusoidal wave form

• Disadvantage of low power factor :-

∵ $P = VI\cos\theta \Rightarrow I \propto \frac{1}{\cos\theta}$ i.e current is inversely proportional to power factor. So when power factor increases, current decreases and vice versa.

So, in case of low power factor, current will be increased which will lead to following disadvantages.

1. Copper Loss or Large Line Losses:-

∵ Line Losses $\propto I^2$ ⇒ larger the current, greater the line losses.

2. Large kVA rating & size of electrical equipment :-

∵ $\cos\theta = \frac{kW}{kVA} \Rightarrow \cos\theta \propto \frac{1}{kVA}$ ⇒ Lower the power factor, the larger the kVA rating of machine & if the larger the kVA rating of machine, the larger the size of machine & if the larger the size of machine the larger the cost of machine.

3. Greater conductor size and cost :-

∵ Voltage drop = V = IZ

- In case of low power factor, current will be increased thus to transmit this high current, we need the large size of conductor. Also the cost of a large size of conductor will be increased.

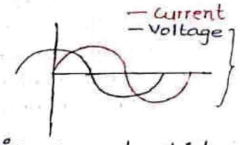
4. Low efficiency :- In case of low power factor, there would be large voltage drop and large line losses and this will cause the system or equipment efficiency (η) too low. For instance, due to low power factor, there would be large line losses; therefore alternator needs high excitation thus generation efficiency as well as transformer's efficiency would be low. Same is the case of for lower motor's efficiency in case of low power factor.

• Methods to improove power factor :-

1. Use of static capacitor :- Generally power system loads are inductive loads that take lagging current which decreases the system power factor.

For power factor improvement purpose, static capacitors are connected in parallel with those devices which work on low power factor.

{ Inductive loads are those loads in which current and voltage are out of phase with each other by 90°



• These static capacitors provides leading current which neutralize (totally or partially) the lagging inductive component of load current (i.e leading component neutralize or eliminate the lagging component of load current) thus power factor of the load circuit is improved.

2. Synchronous Condenser :-

When a synchronous motor operates a No-load and over-exited then it is called synchronous condenser. Whenever a synchronous motor is over-exited then it provide leading current and works like capacitor.

When a synchronous condenser is connected across supply voltage (in parallel) then it draws leading current and partially eliminates the re-active component & so power factor is improved.

Generally synchronous condenser is used to improve power factor in large industries.

3. Phase Advancer:-

Phase advancer is a simple AC exciter which is connected on the main shaft of the motor and operates with the motor's rotor circuit for power factor improvement. Phase advancer is used to improve power factor in industries.

As the stator windings of induction motor takes lagging current go out of phase with voltage, therefore the power factor of induction motor is low. If the exiting ampere-turns are excited by external AC source, then there would be no effect of exciting current on stator windings. So power factor is improved.

Note:- Improving power factor can maximize current carrying capacity, improve voltage to equipment, reduce power losses and lower electricity bills.

• EMF (Electromotive Force):-

Electromotive force is the energy supply to the charge by a battery cell. In other words, emf produces and maintains voltage inside an active cell and supplies energy in joules to each unit of coulomb charge.

Denoted by 'ℰ' SI unit → Volt.

• EMF is the maximum potential difference between two points of battery when no current is flowing from the source in case of open circuit.

• EMF is the cause & voltage or Potential difference is effect.

$$\mathcal{E} = \frac{W}{Q}$$

W = Work (J)

Q = charge (C)

• Difference b/w EMF & Voltage:-

• The name EMF at first sight implies that it is force that causes current to flow. But it is not correct because it is not a force but energy supplied to charge by some active device such as battery.

• EMF maintains potential difference or voltage while voltage causes current to flow.

• When we say that EMF of a device (eg. a cell) is 2V, it means that device supplies energy of 2 Joules of each coulomb of charge. ~~When we~~

When we say that potential difference between point A & B of a circuit (suppose point A is at higher potential) is 2V, it means that each coulomb of charge will give up an energy of ~~2V~~ 2 joules on moving from point A to B.

Faraday's Law:-

According to Faraday's law, when a conductor is placed in a varying magnetic field, an emf is induced in conductor.

This magnetic field can be due to permanent magnet or an electromagnet.

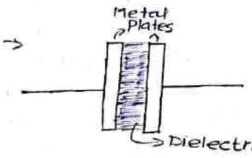
- If magnetic field is produced by AC current, it will produce varying magnetic field.
- And if magnetic field is produced by DC current, it will produce static magnetic field.

Thus in order to produce an emf, there should be relative motion b/w either conductor wrt magnetic field
or magnetic field wrt conductor.

- **Capacitor:-**

A capacitor is a two terminal passive electronic component that stores charge in an electric field between its metal plates. It is made up of two metal plates (electrodes) separated by an insulator known as dielectric.

Capacitor →



A dielectric acts as to increase the capacitors charge capacity.
A dielectric can be glass, ceramic, plastic film, air, vacuum, mica etc.

Capacitance:- Capacitance is the ability of capacitor to store charge in its metal plates (electrodes). It's unit is Farad 'F'.

Farad:- One farad is the amount of capacitance when a charge of one-coulomb causes the potential difference of one volt across its terminals.

Note:- The capacitance is always positive & it can't be -ve.

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Applications of capacitor:-

- Smoothing power supply's output
- For power factor correction
- For frequency filters, high pass, low pass filters.
- Coupling & decoupling of signals
- In Motor starters
- Snubber (Surge absorber & Noise filter)
- Oscillators.

- A capacitor is a passive two terminal electrical component which stores electrical energy temporarily in electric

• AC Vs DC

Advantages of AC (Alternating Current)

1. The generation of AC is cheaper than D.C
2. A.C machines are simple, robust and do not require much attention for their repairs & maintenance during their use.
3. Wide range of voltages are obtained by using transformer.
4. The magnitude of current can be reduced by using an inductance or a conductor without much loss of energy.
5. AC can easily be converted into DC using rectifiers
6. When A.C is supplied at higher voltages in long distance transmission, the line losses are small compared to a D.C transmission.

Disadvantages of AC

1. Peak value of A.C is high & it is dangerous to use so better insulation is required.
2. It attracts person who touches it unlike D.C which gives a repelling shocks.
3. An A.C is transmitted from surface of conductor & hence need several strands of thin wires insulated from each other.

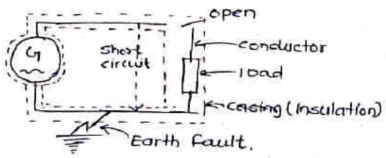
• Overload :- An electrical overload is the condition where the load takes more current then normal or rated current.
Overload is the overcurrent flow in the circuit which causes overheating in the connected device hence, overload is a type of overcurrent
• Value of overload current is 125% of rated current.

Overload Protection:-
Overload Protection is actually a protection against overheat due to flow of overcurrent in the circuit for specific time.
Slow blow fuses & overcurrent relays are used against overload protection whereas thermal magnetic circuit breaker are used for both overcurrent & overload protection. The 'magnetic' element provides protection against overcurrent & 'thermal' element protects the circuit from overload.

Generally overload protection circuit activated when 120%-160% greater current starts to flow in the circuit than the rated current by power supply.

• Earth Fault:-

Earth fault is a fault blw live conductor & earth (here ship's hull). So earth fault is due to a break in the insulation, allowing the conductor to touch the hull or an earthed metal enclosure.



Generally earth fault occurs within electrical equipment. It is generally due to an insulation failure or loose wiring which results in a live conductor to coming into contact with the metal enclosure of equipment.

To avoid danger of electric shock & fire from earth faults, metal enclosures & other non-current carrying metal parts of electrical equipment must be earthed.

The 'earthing' conductor connects the metal enclosure to the earth (ship's hull) and prevents such metal parts from attaining a dangerous voltage with respect to the earth in the event of an earth fault occuring.

- Significance of Earth Faults:-

If an earth fault occurs on the insulated pole of an 'earthed distribution system' it would be equivalent to a 'short circuit' fault across the load via the ship's hull.

The resulting large earth fault current will immediately 'blow' the fuse in line conductor & the equipment will be isolated from the supply & considered as safe but loss of equipment can create problem if it is 'essential' like steering gear. The large fault current can also cause arcing and ultimate damage at fault location.

So an earthed distribution system requires only one earth fault on the line conductor to cause an earth fault current to flow.

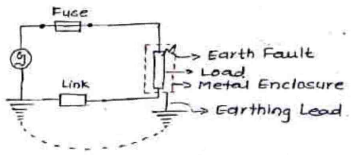


Fig:- Significance of earth Faults in an Earthed distribution system.

An earth fault occuring on the line of an 'insulated distribution system' will not cause any protective gear to operate and the system would continue to function normally & the equipment still operates, it doesn't stops.

The earth single earth fault doesn't provide a complete circuit so no earth fault current will flow.

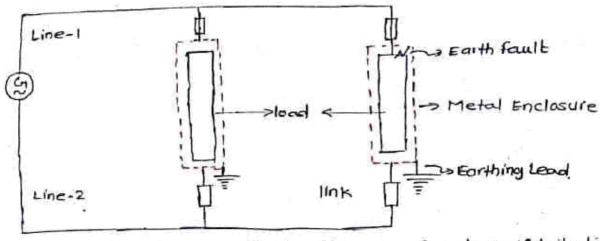


Fig:- Single earth fault in an isolated distribution System.

If an earth fault developed on another line, then two earth faults together would be equivalent to a short circuit fault (via ship's hull) & resulting large current will operate protection devices and cause disconnection of essential services creating a risk to the safety of the ship.

An insulated distribution system requires two earth faults on two different lines to cause an earth fault current to flow. so an insulated system is therefore more effective than an earthed system in maintaining continuity of supply of equipment. Hence it is adopted for most marine electrical systems.

Note:- Double-pole switches with fuses in both lines are necessary in an insulated single-phase circuit.

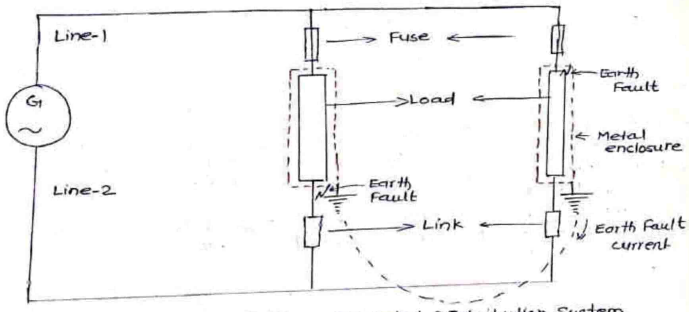


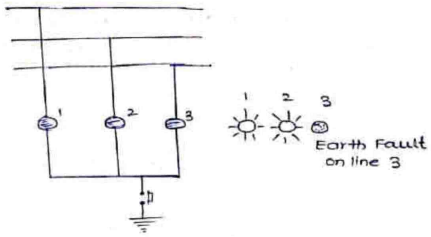
Fig:- Double earth Fault in an Isolated Distribution System.

• High voltage systems (3.3 kV & above) on board a ship are normally earthed. Such systems are normally earthed via a resisto connecting the generator neutral to earth point.

Note:- Tankers have only insulated distribution system. This is to reduce the danger from earth fault currents circulating in the hull in hazardous zones, which may cause an explosion of the inflammable cargo.

Finding Earth Fault:-

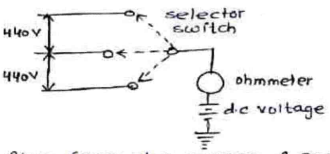
1. Earth Fault lamps:-



- If the system is healthy (i.e no earth fault) then the lamps glow equally with equal half brilliance.
- If the earth fault occurs on one line, then the lamp connected to that line is dim or extingwished (doesn't glow) & other lamps glow brighter.

→ They are simple & inexpensive but they are not sensitive & fails to indicate the presence of a high impedance earth fault.

2. Earth Resistance meters:-



This system connects a small d.c voltage between earth & each of the lines of the system in turn, if there is a path back to the voltage source through an earth fault a current will flow from d.c source. A meter is included in the current path to measure the size of current flow, this together with the voltage of the source will give a reading of the system insulation resistance

With this type of instrument, the earth fault current can be ~~limm~~ limited to 1mA whereas with earth lamps it is about 60 mA, this makes it suitable for tankers.

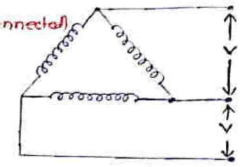
• Earth Neutral System	• Insulated Neutral System
1. Used for HV system (above 1000 V)	1. Used for low voltage system (upto 1000V)
2. It will trip with 1 earth fault	2. It will not trip with 1 earth fault
3. Essential services are affected with 1 earth fault.	3. Essential services are continued even after 1 earth fault.
4. Fault finding is easy as quick isolation is possible.	4. Fault finding is difficult.
5. More Maintenance	5. Less maintenance
6. More space required.	6. Less space required.
7. Here neutral is connected to earth by a neutral earth resistor.	7. Here neutral is not connected to earth.

- Difference between electrical & electronics :-

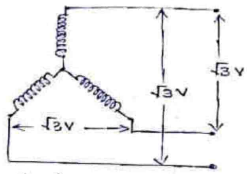
Electrical	Electronics
1. Electrical technology deals with the generation, distribution, storage & conversion of electrical energy etc.	1. Electronics technology deals with designing, amplifying and switching electrical energy with the help of different electronics equipment.
2. In the electrical circuit, electrical energy consists of flow of electron.	2. In the electronics circuit, the energy consists of flow of electron & holes.
3. Electrical devices produce voltage & current.	3. Electronics devices controls the voltage & current.
4. Electrical devices works on Alternating current (AC). Ac may be single phase or three phase. Range of AC is 'V' to 'kV'.	4. Electronics devices works on Direct current (DC). Range of DC is 'mV' to 'V'
	Donate (using UPI) carbidee@ybl (Manoj Kumar)
5. In electrical circuit, conductors are used. copper (Cu) & Aluminium (Al) are best conductors.	5. Only semiconductor is used in electronic circuit. eg:- Silicon (Si), Germanium (Ge)
6. In the electrical circuit, the role is to monitor or control high electrical power.	6. Electronics circuit monitors or controls low power.
7. Electrical devices can't make a decision, eg:- electrical bulb	7. Electronics device can make a decision, eg:- Mobile phone.
8. Occupy large size and require more space.	8. Occupy small size.
9. Electrical energy is converted into other forms i.e heat, motion or light.	9. It doesn't convert electrical energy into other forms
10. eg:- Transformer, Alternator motor, Fuse, Generator etc.	10. eg:- Diode, Transistor, Thyristor, micro-controller.

- 3-phase 3 wire system

(Delta-connected)



(Star connected)



Three-phase system are used extensively.

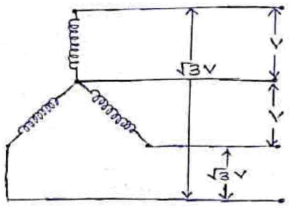
A 3-phase 3-wire system includes all phases i.e R, Y & B. it can be connected in Delta as well as star.

The voltage between the lines is 'V' in case of delta-connection & √3 V in case of a star-connection where 'V' is the voltage of each phase.

3 wire phase-3 wire system is used for three phase loads only eg- 3 phase motors.

As there is no return path for out-of-balance current, in case of unbalanced star loads, the load will get unequal voltages in its phase. In case of extreme unbalance, phase voltage across a load may become almost equal to line voltage which is dangerous.

- 3-phase- 4 Wire System.



The neutral or 4th wire is taken from star point (of star connection). If V is the voltage of each winding, the line voltage is $\sqrt{3}$ V. Usually phase voltage i.e voltage between any outer and the neutral for a symmetrical system is 230 V so that the voltage between any two lines or outers is $\sqrt{3} \times 230 = 400$ V

Single-phase lighting loads, accomodation spaces etc, or single phase motor which run on 230 V are connected between the neutral and any one of line wires.

These loads are connected symmetrically so that the line wires are loaded equally. Hence the resultant current in the neutral wire is zero or atleast minimum. The three-phase induction motors requiring higher voltages of 400 V or so are put across lines directly.

3-phase-4 wire system can feed both balanced three phase loads as well as unbalanced three loads and single phase loads.

The neutral point wire provides a path for out-of-balance current. Therefore eventhough currents are unbalanced, phase voltages are balanced.

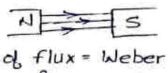
Maxwell's law:-

Time varying magnetic field will create time varying electric field & vice-versa. (Time varying electric field means AC).

Magnitude of induced emf is directly proportional to
1. No. of turns in conductor (N_T)
2. Rate of change of flux through conductor ($\frac{d\phi}{dt}$)

i.e $E_{induced} \propto N_T \times \frac{d\phi}{dt}$

eg:-



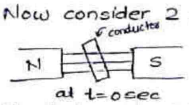
Here 3 magnetic line of force so flux = 3

Unit of flux = Weber

1 Wb = 10^8 Maxwell

{ 1 maxwell = 1 gauss × cm^2
i.e 1 maxwell is that total flux across a surface of one square centimetre perpendicular to a magnetic field of strength one gauss)

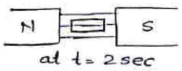
Now consider 2 permanent magnets & a conductor blw them:-



at t=0 sec
(conductor not moving)

Initial flux = 3 lines

Here No emf generated due to no movement in conductor



at t = 2 sec
(conductor Rotates)

Final Flux = 1 line

So $\frac{d\phi}{dt} = \frac{\text{Final flux - Initial flux}}{\text{Final time - Initial time}} = \frac{1-3}{2-0} = \frac{-2}{2} = -1$

So to increase $\frac{d\phi}{dt}$ increase either

i) magnetic lines of flux

ii) Speed of rotation of conductor

• Lentz law:-

According to Lenz law, direction of induced emf is such that it opposes the cause that produces it.

$\because E_{induced} \propto N_T \times \frac{d\phi}{dt}$ → cause

So Always $E_{induced} = -N \times \frac{d\phi}{dt}$

• Lorentz law:-

A current carrying conductor when placed in a magnetic field experiences a force.

This force is Lorentz force. & magnitude of this force is given by

$F_L = i\,(\vec{l} \times \vec{B})$

i = current

$\vec{l}$ = length of conductor

$\vec{B}$ = magnetic field

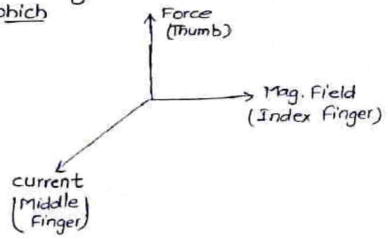
So $F_L = B.i.l.\sin\theta$

Here B = flux density

$B = \frac{\phi}{A}$ in W/m^2 or tesla

Note:- • The direction of Lorentz force (F_L) can be determined by Flemings left hand Rule.

A.T. which



• Flemings left hand rule is for motors.

Battery Questions

1. Lead Acid Battery Maintenance or Battery Maintenance
2. Emergency Battery Maintenance
3. Tickel charging - all details, why done, how done
4. Working of lead-acid Battery
5. Primary & Secondary Battery/cell
6. Why we add water to lead acid battery
7. How to indent battery for ship
8. Diff. blw Lead-Acid & Ni-Cd batteries
9. Trickel charging, charging circuit of battery,
10. How do you measure specific gravity of electrolyte
11. How hydrometer works, its diagram, material of hydrometer
12. What is material of liquid inside cylinder of hydrometer.
13. How to take transitional batteries on load
14. Battery charged indication & colour of charged plates
15. Sulfonication in lead acid Batteries
16. 10 difference blw primary & secondary cell.
17. Battery charging voltage for 24 V battery.
18. Where battery is used onboard & its charging system
19. Diagram of Trickle charging system.
20. Battery Room safeties
21. Advantage of lead acid batteries over alkaline batteries
22. Internal Resistance in battery.
23. Battery check onboard
24. Cadmium battery explosive proof light.

Cell & Batteries

Static electricity:- It is electricity at a high potential & exhibits itself as a stationary charge.
eg:- Rubbing nylon cloth on hairs straightens them.

Battery:- An electric battery is a device consisting of two or more electrochemical cells that convert stored chemical energy into electrical energy. Each cell has a +ve terminal (cathode) & a -ve terminal (anode). The terminal marked +ve (cathode) is at a higher electrical potential energy than the negative terminal (anode)
+ve terminal (cathode) is the source of electrons when connected to external circuit and delivers energy to an external device.

Two types:- i) Primary
ii) Secondary

Primary Battery / Cell :-

Primary (Single-use or Disposable) batteries are used once and discarded. These can be used once only. In these batteries chemical action destroys one of the electrodes, generally the -ve. Primary cell can't be recharged.

eg- Dry cell, zinc-chlorine cell, metal air cell

It is ideal for simple application where an inexpensive and non-critical source of electricity is needed.

- In dry cell, electrolyte is not dry, liquid, it is moist-paste.

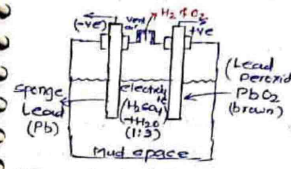
- Secondary Battery / cell :-

Secondary (Rechargable) Battery can be discharged and recharged multiple times. The original composition of the electrodes can be restored by reverse current (i.e charging is done by supplying external current in opposite dir^{n}) In these batteries, the electrodes & electrolyte can be restored to their original position/condition by recharging the cell.

eg:-

Primary Battery	Secondary Battery
1. Lower initial cost	1. Higher Initial cost
2. No maintenance required	2. Regular maintenance Required
3. No charging	3. Periodic charging Required
4. lighter & smaller so suited for portable application	4. Less suited for portable use (except lithium-ion latest technology)
5. Longer service per charge & good charge retention.	5. Less charge retention.
6. Not for emergency backup, hybrid battery, high cost military application	6. Ideally suited
7. Non-Rechargable	7. Rechargable.

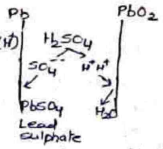
- Lead Acid cell/Battery :-



Each cell of Lead acid Battery contains two set of plates, immersed in electrolyte. Those connected to the positive terminal of a charged cell are of Lead peroxide, & those connected to -ve terminal are of Lead.

The electrolyte in which the plates are immersed is a dilute solution of sulphuric acid in distilled water.

Discharge action :-



During discharge, the hydrogen ions (H^+) removes oxygen from the lead peroxide (PbO_2) of the +ve plates and combines with it to form water (H_2O)

Loss of oxygen from Lead peroxide reduces it to grey lead (Pb). The water formed by the action dilutes the electrolyte. so th as the cell discharges, the specific gravity (relative density) decreases.

At the -ve side of cell, sulphate ions (SO_4^{--}) combines with the pure lead of -ve plate to form a layer of white lead sulphate ($PbSO_4$). The lead sulphate layer increases during discharge and finally covers the active material of plate.

Positive plate Reaction

$$PbO_2 + HSO_4^- + 3H^+ + 2e^- \longrightarrow PbSO_4 + 2H_2O$$

Negative plate Reaction

$$Pb + HSO_4^- \longrightarrow PbSO_4 + H^+ + 2e^-$$

Total Reaction

$$Pb + PbO_2 + 2H_2SO_4 \longrightarrow 2PbSO_4 + 2H_2O$$

Gas emission:- Towards the end of charging & during discharge, the current flowing into the cell causes a breakdown or electrolysis of water in the electrolyte, shown by bubbles at the surface. Both hydrogen & oxygen are evolved & released through vent caps into battery compartment. There is an explosion risk if hydrogen is allowed to accumulate (flammable range is 4% to 74% of hydrogen in air). So good ventilation is required to remove gas & precaution against naked light or sparks in enclosed battery comp. compartment is required.

Topping up: (जैसे पानी डालते हैं battery में)
Batteries suffers water loss due to both gassing & evaporation with continuous drop in liquid level.
These is no loss of sulphuric acid from electrolyte (unless spillage). Regular checks are made to ensure that liquid level is above the top of plates and distilled water is added as necessary (i.e topping is done).
Overfilling will cause the electrolyte to bubble out of the vent.
~~Overfilling will cause the electrolyte to bubble~~
• High consumption of distilled water would suggest overcharging.

Electrolyte :- Sulphuric Acid (H_2SO_4) is used as electrolyte for lead-acid batteries. In concentrated form, H_2SO_4 is non-conductor of electricity so distilled water is mixed in H_2SO_4 (concentrated) so H_2SO_4 breakes into Hydrogen (H^+) & sulphate (SO^{--}) so that it conduct current.
→ Water should not be added to H_2SO_4 because it will because it will produce heat & violent reaction.
instead acid (H_2SO_4) is very slowly added to pure water while stirring.
→ Acid-resisting paint must be used in battery room deck.

Q:- Why can't we store AC in batteries instead of DC?

Ans:- We can't store AC in batteries because AC changes their polarity up to 50 (when frequency = 50 Hz) or 60 (when frequency = 60 Hz) times in a second. Therefore the battery terminals keep changing i.e Positive (+ve) becomes Negative(-ve) and vice-versa, but the battery can't change their terminals with the same speed so AC can't be stored in batteries.

Moreover, when we connect a battery with AC supply, then it will charge during positive half cycle and discharge during negative half cycle, because the positive(+ve) half cycle canceles the negative (-ve) half cycle so the average voltage or current in a complete cycle is zero, so we can't store AC in batteries.

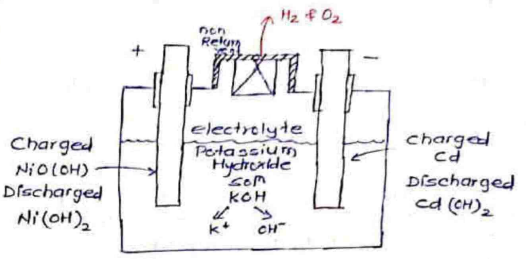
Q:- How to order lifeboat battery:-

1. CCA (Cold-cranking Amps) & MCA (Marine cranking Amps) rating
2. Ah rating
3. Voltage rating
4. Type of battery
5. Maintenance free or flooded type
6. Battery life
7. Size & dimensions

Note:- • CCA → (Cold-cranking Amps) :- Generally, it is used to determine a battery's capacity to start an engine in cold temperatures. The amount of amps a lead-acid battery can deliver F for 30 sec, while still keep terminal voltage equivalent to 0° higher than 1.2 volts per cell.

• MCA (Marine cranking Amps):- The amount of amps a lead-Acid battery can deliver at 32 degree F in 30 sec.

• Nickel-Cadmium Battery/Cell:-



Material for positive plate :- Nickel Hydrate [$NiO(OH)$]
" " negative " :- cadmium (Cd)
electrolyte :- Potassium hydroxide (KOH) + distilled water (with addition of lithium)

The ions produced in the formation of potassium hydroxide solution (K^+ & OH^-) acts as current carrier and takes part in an ion transfer.

Discharging:-
During discharging Nickel Hydrate [$NiO(OH)$] is converted to Nickel Hydroxide $Ni(OH)_2$
Similarly OH^- (Hydroxyl ions) converts cadmium to cadmium hydroxide of -ve plate.
OH^- moves one plate to another and doesn't affect the electrolyte so no generation of water like in lithium-ion batteries so the specific gravity of electrolyte doesn't change in case of Nickel-cadmium batteries.

Charging:- During charging, positive of charging supply is connected to the positive of cell & negative to the negative terminal. Flow of current from the charging source reverses the discharge action.

In charged Condition		In discharged condition	
+ve plate	-ve plate	+ve plate	-ve plate
$2NiO(OH)$	Cd	$2Ni(OH)_2$	$Cd(OH)_2$
Hydrated oxide of Nickel	Cadmium	Nickel Hydroxide	cadmium Hydroxide

- Vent caps are non-return valves because gases (H_2 & O_2) can be released but atmospheric air can't enter inside. if it enters inside battery, battery may explode.
- Vent caps are non-return valves because gases (H_2 & O_2) can be released but contact by electrolyte with atmosphere is prevented. &
Electrolyte absorbs carbon di oxide (CO_2) from the atmosphere & damages the battery because of formation of potassium carbonate. so vent caps must be kept close.

Topping up:- Same as of ~~Lithium-ion~~ Lead-Acid batteries.

Electrolyte:- Potassium Hydroxide soln - strongly Alkaline and properties are similar to caustic soda (sodium hydroxide).

Characterstics:-
Specific gravity:- 1.210 (doesn't change in Nickel cadmium batteries)
But over a period of time renewal is necessary at about specific gravity of 1.170.

- Battery Room Ventilation
- Hydrogen (H_2) is lighter than air so proper ventilation should be there.
- If exhaust fan is required than exhaust fan blades must be non-sparking
- Motor of exhaust fan must be away/outside from the ventilation passage with seals to prevent entry of gas in its casing.
- Exhaust fan must be independent of other ventilation systems.
- All outlet vent ducts must be of corrosion-resistant material or protected by suitable paint.
- Ventilation inlets should be below battery level

- Battery Room safeties:-
- Use of naked light & smoking should be restricted in battery room.
- Metal jugs should not be used as distilled water containers.
- Emergency switchboards should not be ~~used~~ placed near battery space
- Flameproof lights must be used.
- Ideal temp range 15°c to 25°c
- Battery life is shortened by temperature above 50°c
- Battery capacity is reduced by low temperatures.
- Proper ventilation should be there so that gases developing during charging escapes from battery Room,
- Ventilation duct should be above accomodation level and should be aft of engine room blower.
- exhaust fan starting switch should be located outside room
- Intrinsically safe instrument & tools should be used inside
- Battery should be placed on wooden blocks.

→ Acid-Resistant paint should be used inside battery room.

• Battery Room inspection:-/ Battery Maintenance:-

- Battery installation & its charging circuit should be checked.
- Battery room environment (Dry & well insulation required)
- Battery top should be clean & dry
- Terminal nuts should be tight (Apply petrolium jelly - as it prevents corrosion)
- Electrolyte level should be checked (maintain sp-gravity, use of hydrometer)
- charging equipment (check for dirt, overheating, loose connections). Avoid excessive rapid charging.
- Notice of No smoking should be kept.
- Flame proof light & fittings should be checked.
- Battery Room temp. range (15°-25°c)

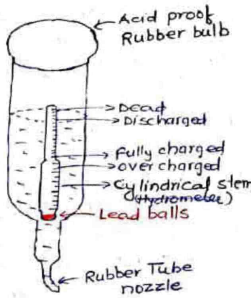
• Trickle charge/Float charge:- Batteries gets discharged if not used due to local action/environment. So once the battery is fully charged, it is put on trickle charge. In this type of charging, very small amount of current is supplied to just make up for the loss of charge [generally 50 to 100 mA per 100 amp-hr battery capacity]

Hydrometer:-

Hydrometer is an instrument used to measure the specific gravity of liquid/electrolyte

Rubber tube nozzle is put inside the electrolyte & Rubber bulb is pressed & released. Electrolyte moves up & down stem floats up & down.

In stable position, specific gravity can be measured.



Emergency Generator:-

SOLAS chapter 2-1 Regulation 42 for passanger ships & Regulation 43 for cargo ships

A self contained emergency generator shall be provided. The power rating of emergency generator is based on the size of ship.

Location:- 1. It shall be located above uppermost continuous deck outside engine room.
2. It should be readily accesible from open deck.
3. It should be located Aft of collission bulkhead
4. Emergency generator, switchboard, Emergency lighting switchboard & transformer units, all shall be located in the same compartment.

Regulations:-
1. Flash point of fuel should not be less than 43°C.
2. should be started automatically after failure of main source of power supply within 45 seconds and at its rated load.
3. It shall be started at 0°C or it shall have heating arrangements
4. It should be able to start in 22.5° List & 10° Trim.
5. It should have atleast two independepent source of starting. Both of them should be provided atleast three consecutive starts

Emergency Electrical Power:-

An emergency electrical power service must be provided onboard in the event of main power failure. The emergency power source can be an emergency generator, batteries or both, whichever is used, it must be self contained & independent of engine room power supply.

Common requirements for emergency generators & batteries (extracted from SOLAS 2021)
1. They should normally be located above water line
2. They should not be located forward of the collision bulkhead
3. They should be located in a compartment that is outside and away from the engine room.
4. The compartment should be accessible from open deck
5. The system should be capable of operating with a list of upto 22.5° & a trim of upto 10°

Additional requirements for emergency batteries:-
1. Emergency batteries should not be located in the same space as the emergency switchboard.
2. They must carry emergency load throughout the discharge period without being recharged or without its voltage changing by more than 12%.

Additional requirements for emergency generators:-
1. Emergency generators must have their own prime movers, fuel supply tanks (fuel closed flash point should not be less than 43°C), starting equipment should be capable of three starts (with atleast two methods) & switchboards.
2. The generator must start automatically upon failure of the main supply, connect to the emergency switchboard and supply the emergency circuits, this must all take within 45 seconds.

- Supplies from the Emergency switchboard:-

1. Emergency lighting
2. Navigation lights
3. Navigational aids, gyro
4. Radios
5. Internal communication equipment required in an emergency situation
6. Water tight doors
7. Life boat launching equipment
8. 1 steering motor
9. Emergency battery charging
10. Emergency bilge pump
11. 1 Fire pump
12. Automatic sprinkler pump if fitted
13. Fire detection & Fire alarm system & the fire door holding & release system
14. One air compressor
15. Winches
16. E/R supply & exhaust fan to restart generator
17. L.O priming pump for generator
18. Boiler control pan

Note:- It is normally not possible to parallel the main generators & the emergency generators & there are interlocks to prevent this from happening.

- Battery Testing:-

1 Lead Acid Battery Testing:- Lead acid batteries can be tested by Hydrometer. It gives the value of specific gravity of electrolyte. At fully charged condition (1.27-1.285) and at fully discharged it is 1.1. Also when it gets fully discharged then voltage also falls down to 1.3V which also gives the indication of discharging. But high value of voltage can misguide for fully charged condition. Specific gravity of lead acid batteries are at ambient temperature of 15°C, add 0.007 for every 10°C above 15°C & subtract for 10°C below 15°C.

Note:- Above specific gravities are at 15°C

2. Alkaline Battery Testing:- In alkaline batteries, specific gravity doesn't fall on discharging so specific gravity can't be measured using hydrometer.

- Specific gravity doesn't fall on discharging. It is full only due to the lifetime use of battery so if specific gravity of alkaline batteries falls over a period of use then it means that either the electrolyte has to be charged or the battery.
- Charging and discharging can be decided by voltage. If the voltage becomes below 1.1 volt then it means that battery is discharged. It is the only indication of alkaline batteries. Battery is considered to be fully charged when its voltage remains constant at 1.6 - 1.8.

• How to know if battery is fully charged.

1) Voltage:- When a battery gets full charged, its voltage becomes constant. The voltage remains at 1.6 - 1.8 Voltage on open-circuit, charged 2.2V per cell or higher

2. Specific Gravity:- The specific gravity of electrolyte decrease during discharging due to formation of water. And during charging it increases due to absorption of water.

A fully charged battery have specific gravity of 1.280-1.300 & a discharged battery have 1.11 - 1.14.

Specific gravity can ~~can~~ be measured using hydrometer.

S.No.	Charged state	Specific gravity somewhere
1	Full charge	1.280-1.300 (1.20-1.27)
2	0.75 charge	1.230-1.280
3	0.50 charge	1.200-1.230
4	0.25 charge	1.170-1.200
5	Discharged	1.110-1.140 (1.17-1.18)

3. Grassing:- When a battery is fully charged, it ~~rea~~ releases hydrogen from negative terminal & oxygen from positive terminal. At this ~~thi~~ time, charging of battery should be stopped.

4. Colour Plate:- In fully charged condition, the colour of positive plate becomes dark brown and negative plate becomes grey. (slate grey)

The efficiency of battery at this condition is maximum.

Ways to increase specific gravity:-

i) By adding battery acid to the battery

ii) By charging

Q:- Why motor can't run on star only?

Ans. ∵ $T_{star} = \frac{1}{3} T_{delta}$ (i.e T_{delta} is 3 times of T_{star})

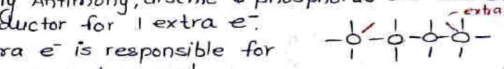
so if motor is made to run on star only it will not develope rated torque so if it is operated at full load, there will be overheating of windings and motor may get burn.

- DOL starter
- Types of Fuses
- What is diode & Function of it (5 points atleast)
- f^n of starter & choke in tubelight
- Zener diode and its full explanation. How it is different from simple diode.
- SCR, terminal names, Uses?
- Complete explanation of Thermistor
- What is condenser
- Explain Thyristor
- Diode Testing
- Fuse and its function
- Zener protection
- Why we use starters for starting a motor. Explain all 4 starters
- What is multimeter. What all parameters it measures. What happens inside it when we change selector switch
- Explain Megger with diagram
- Clampmeter use
- How voltmeter and ammeter used in circuit
- Capacitor is used in ac circuit but not in DC. Why?
- Diff. b/w diode & Zener diode (10 points)

ELECTRONIC EQUIPMENT

- Conductivity depends on no. of free electrons
- Conductivity of metals(conductors) decreases with increase in temperature.
- Conductivity of semi-conductor material increases with increase in temperature.
- Semiconductor materials have more no. of free e^- than insulators but less no. of free e^- than conductors.
  eg- Silicon, Germanium
- Conductivity of semi-conductors can be increased by DOPING.

- N-Type Semi-conductors:-
  > Five valence e^- impurity is added to pure semi-conductors instead of 4 valence e^-.
  Generally Antimony, arsenic & phosphorus are added to pure semiconductor for 1 extra e^-.
  the extra e^- is responsible for the movement of current.



- P-type semiconductor:-
  P-type semiconductor are obtained by adding impurities like aluminium, borium or indium.
  These adds removes negative electrons so leaving gaps or positive holes which transmits charge.

Semi-Conductors
(Si, Ge) have 4 valence e^-

- Intensive
  Pure Semi-conductor
  No. of e^- = No. of holes
- Extensive
  Impure Semiconductor
  - P-type
    obtained when trivalent impurities are added to pure germanium crystal eg:- B, Al
    Also known as 'Acceptor'
  - N-type
    obtained when pentavalent impurities are added to pure semiconductor
    eg:- As, P, Sb
    Also known as 'Donor'.

Thermistor:- Thermal + Resistor

- Thermistor is a special type of resistor whose resistance changes with the change in temperature

Two Types

- NTC (Negative Temperature Coefficient):- If Resistance decrease with increase in temperature, known as NTC.
- PTC (Positive Temp. Coeff.):- If Resistance increase with increase in temp, are known as PTC

- Thermistor have a Negative Temp. Coeff. (NTC) of resistance
- 1°C rise in temp → 5% decrease in resistance.

Use

1. Digital thermometers
2. Precision temp. measurements, control & compensation

- Thermistors are highly sensitive but have a non-linear characterstics of resistance versus temperature.

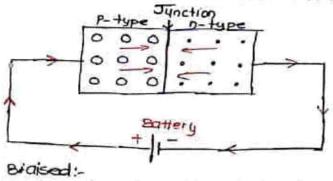
- Semi-conductor junction rectifier (two-layer device)

A semi-conductor junction rectifier is a wafer of silicon, germanium or other semiconductor material which are doped by impurities, or other materials having similar effects, so one part is p-type & other type is n-type.

A Battery connected in circuit will cause positive holes in the p-section to be attracted towards its negative terminal. and vice versa.

Forward Biased

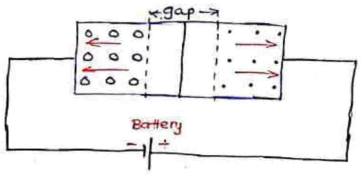
When +ve terminal of battery is connected to p-type and -ve terminal of battery is connected to n-type, positive charges are attracted to -ve terminal & -ve charge (e^-) are attracted to +ve terminal of battery and a junction is formed and hence current flows.



Current flows in Forward Baised

Reversed Biased:-

But when +ve terminal of battery is connected to n-type and -ve terminal of battery is connected to p-type, still positive charges are attracted to -ve terminal & -ve charge are attracted to +ve terminal of battery but this time a gap is formed and hence no or current flows through circuit.

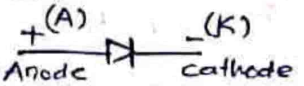


No current flows in Reversed Baised

Knee Voltage:- The voltage at which Junction breakes and current starts flowing through semi-conductor is known as knee voltage.

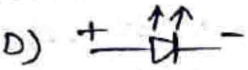
Knee Voltage for Germanium = 0.3 V
Silicon = 0.7 V

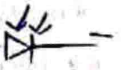
Diode:- Diode is an electrical device which allows current to move in one direction only. i.e it has low (ideally zero) resistance to current in one direction & high (ideally infinite) resistance in other direction.

eg:- • Semiconductor diode 

• Vacuum Tube diode 

• Zener Diode

• Light Emitting Diode (LED) 

• Photo Diode 

Use of diode:-
- As Rectiffer,
- signal limiters
- Voltage Regulators
- Switches
- signal modulators
- signal mixers

Zener Diode:- Basically diodes are used for the purpose of rectifying waveform and can be used within power supplies or within radial detectors (unidirection current property)

Types:-

Donate
carbidee @ ybl

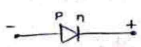
1. Light emitting Diode (LED):-

It is one of the most popular type of diodes and when it permits the transfers of electric current blw the electrodes, light is produced.

In when the diode is switched on or forward baised, the e^- recombines with the holes and release energy in the form of light (electro-luminescence). The colour of light depends on the energy gap of semiconductor.

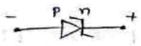
- Zener Diode :- A zener diode is a diode which allows current to flow in the forward direction in the same manner as an ideal diode, but also permits it to flow in the reverse direction when the voltage is above a certain value known as the 'Breakdown Voltage', or 'Zener knee voltage' or 'Zener Voltage' or 'Avalanche Point' or 'Peak Inverse Voltage'.
It is a properly doped crystal diode with sharp breakdown voltage is known as zener diode
It is always reverse connected when forward biased.
Properties are similar to ordinary diode. Zener diode do not burnt out just because it has entered the breakdown region as long as the external supply connected to the diode limits the faults current less than the burnt out value.

p-n jn diode (Rev. Bia.)

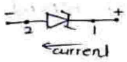


When a simple p-n jn diode is Reverse biased and if voltage is more than Breakdown voltage, it gets heated up and gets destroyed/burnt.

Zener diode (Rev. Bia)

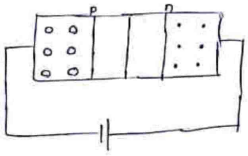


When zener diode is reverse biased, and if voltage is more than Breakdown voltage it doesn't burnt.

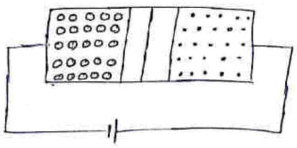


In zener diode, when it is reverse biased potential difference blw two points (Here 1 & 2) doesn't cross a certain level
- It is heavily doped.

simple P-n jn diode



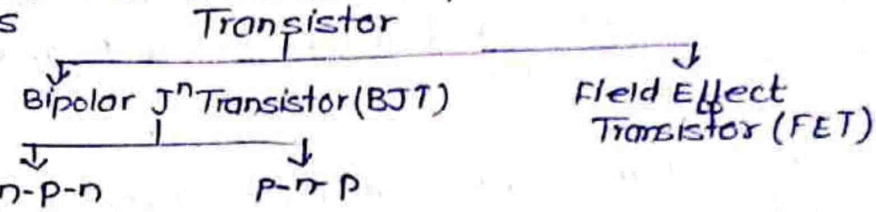
Zener diode



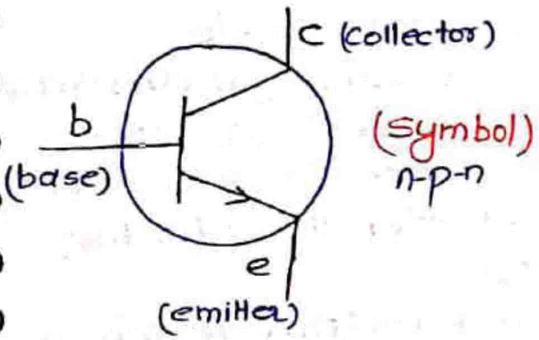
Since zener diode is heavily doped, in Reverse biased, it can flow current (since barrier region is small) and it doesn't get burnt whereas in a simple p-n jn diode barrier region is much more (∵ it is not heavily doped) it gets heated up and burnt.

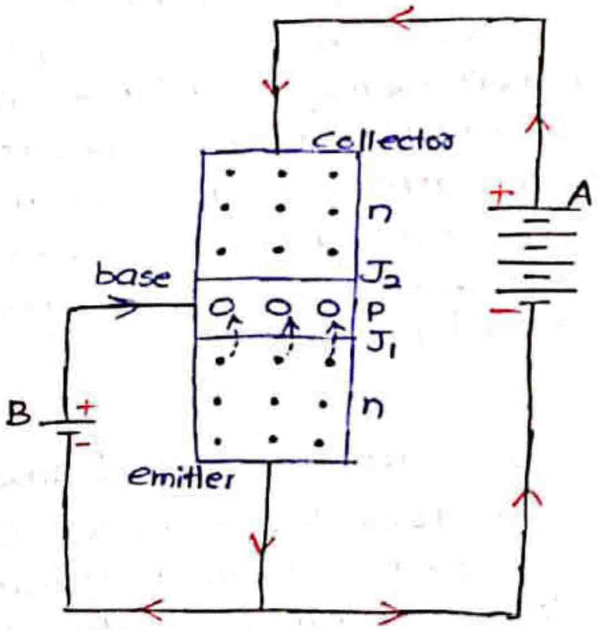
Transistors:- Rectifiers and zener diodes are two layers semi-conductor devices.

- Transistor have 3 layers which are arranged as either npn or pnp.
- Methods used to make transistors are similar to those for the manufacture of diodes.
- The operation is based on principle that Application of voltage will make -ve current carriers move in one direction and positive current carrier in other direction.
- Transistor is a semiconductor device used to amplify and switch electronic signal and electronic power.
- Transistor is of two types



- Operation of npn transistors:-





Construction & Working:- Battery 'A' is connected to ends which are collector & emitter. Another battery 'B' is connected to the middle (base) section and has a common connection with the emitter with battery 'A'.

- Emitter:- One section which supplies charge carriers is called emitter. To do so emitter is always forward biased when compared to base.
- Base:- The middle section of transistor, which forms the two PN-junctions between emitter & collector, is called the base. The base-emitter jⁿ is always forward biased which allows a low resistance for the emitter circuit. The base-collector junction is reversed biased which provides a high resistance in the collector circuit.

Collector:- The section other than emitter which collects the charges is called the collector. The collector is always reverse biased.

- Emitter-base Terminal:- There is a diode in between the emitter-base terminals so those two terminals should function as a normal diode & conduct in only one direction.
- Collector-base Terminal:- There is a diode similar to the emitter-base terminal. These terminals again should act as the terminals of a normal diode & conduct in only one direction.
- Emitter-Collector Terminals:- The emitter-collector terminals are not connected internally & hence will not conduct in either direction

- The transistor is in OFF state if the voltages at base & emitter are same. As the base voltage increases above the emitter voltage, the device shifts to its ~~one~~ ON state.

In ON state, there is sufficient voltage difference with base terminal being the higher one, there is a flow of electrons generated from collector to the emitter which in turn causes a current to flow from emitter to collector.

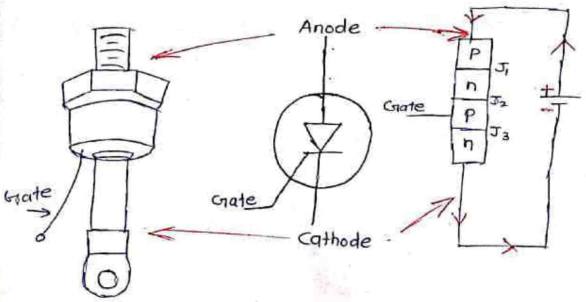
~~In this transistor, based on the working~~
Here input terminal is base terminal & output terminal is collector-emitter region.

Note:- Transistor = Transfer + Resistance
A transistor transfers the resistance from one end to the other. A transistor has high resistance in the input section while low resistance in the output section.

Note:- • Diodes have atletwo alternate layers of p-n.
- Transistor have 3 layers
- SCR (silicon Controlled Rectifier) have 4 layers
- Triacs have mare than 4 layers.

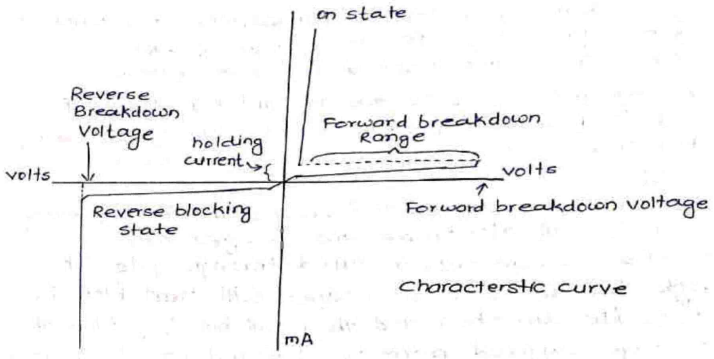
• Thyristor:- — A thyristor is a 4-layer device with alternating P-type & N-type semiconductors (P-N-P-N)
The primary f^n of thyristor is to control electric power and current by acting as a switch.
- Cost of maintenance is low, operate under right conditions, remain functional in the long term without developing a fault.
- Thyristor are solid state switches (with four layers of P-N layers) which are turned ~~on~~ ON oby by application of low-level signal voltage through a trigger connection known as Gate electrode.

• Silicon Controlled Rectifiers (SCRs)
(Have 3 Junctions)



The low level signal (trigger) voltage is applied at the third lead which is gate electrode.

Working of SCR:-
An SCR in circuit will resist current flow in working direction, apart from leakage because the middle junction is np or reverse biased.
Leakage is somewhat greater than with a simple diode because the pn junctions on either side of the centre one are sources of extra minority carriers when forward biased.

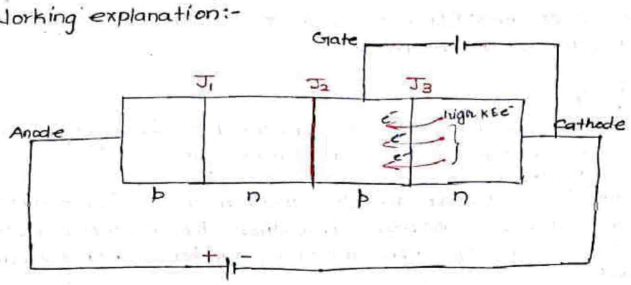


If applied voltage is increased, more minority carriers are emitted from the outer junction and leakage increases more than in a diode

Junction J_1 acts as forward biased
J_2 " " Reversed "
J_3 " " Forward "

Latching current:- It is minimum current which is required to ON the SCR.

- Working explanation:-



Case i) When SCR is forward Biased (when +ve terminal of Battery is connected to p-layer of SCR) and Gate is also supplied with a low voltage:-

- As we know J_1 & J_3 are forward biased and if SCR is forward biased J_1 and J_3 will break easily but since J_2 is reversed biased it will not break easily.

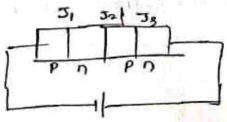
To break it we need to increase the battery voltage when J_2 will also break and SCR gets ON.

or else we can supply curred through gate. The high K.E e^- is last n-layer will start flow in opposite direction and they will hit J_2. More the voltage supplied more no. of e^- will hit J_2 & more easily it will break.

Case:-2 SCR is reverse biased: ~~Reversed bia~~.

Voltage at which J_2 breakes in forward biased is known as breakdown voltage

in Reversed biased, there will be two Junction (J_1 & J_3) to breake so reverse breakdown voltage will be more.



- SCR will remain switched ON unless current falls below a certain holding value.
- During normal operation SCR is turned ON by gate signal much lower than the breakdown voltage. Working voltage would be anywhere blw the range of breakdown voltage.

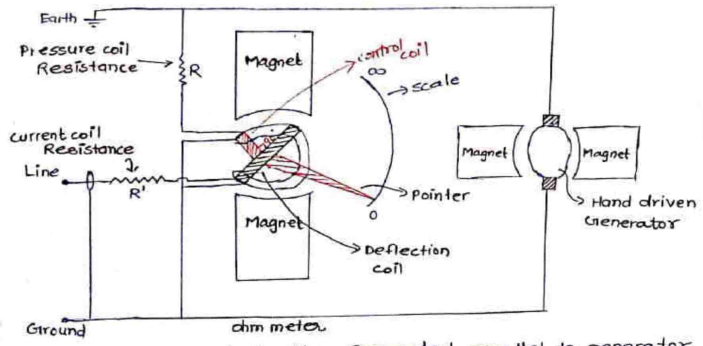
Applications:-

- As a latching switch in an alarm circuit.
- Used for conversion of A.C to D.C, but by varying the trigger turning part of the wave can be blocked and part let through
- Used in mainly D.C power supplies
- Triacs are two directional switches, designed for use in A.C application and able to switched to pass current in either direction.

Megger:- Megger is portable insulation tester. It is used to measure very high resistance of order of MΩ

- It measures the resistance of insulation.
- It works on the principle of comparison i.e the resistance of the insulation is compared high, the pointer of moving coil deflects towards infinity and if it is low, then the pointer indicates zero resistance. The accuracy of Megger is high as compared to other instruments.

Donate carbidee@ybl



- Deflection & control coil :- Connected parallel to generator, mounted at right angle to each other, maintain polarity in such a way to produce torque in opposite directions.
- Permanent Magnets:- Produce magnetic field to deflect pointer with North-South pole magnet
- Pointer:- One end of pointer connected with coil, another end deflects on scale from infinity to zero.
- Scale:- A scale is provided in megger from range 0 to ∞ to enable us to read value
- DC generator or Battery connection:- Testing voltage is produced by hand operated DC generator for manual operated Megger. Battery is provided for automatic type Megger for same purpose.
- Pressure coil Resistance and Current coil Resistance:- Protects instrument from any damage because of low resistance external electrical resistance under test.

Working:-
- Voltage for testing produced by hand operated megger by rotation of crank in case of hand operated type, a battery is used for electronic tester.
- Deflection coil or current coil connected in series and allows flowing the electric current taken by the circuit being tested.
- The control coil is also known as pressure coil, is connected across the circuit
- Current limiting resistor connected in series with control and deflecting coil to protect damage in case of very low resistance in external circuit.
- As the voltage increases in external circuit, the deflection of pointer increases and deflection of pointer decreases with increase of current.
- Hence resultant torque is directly proportional to voltage and inversely proportional to current.
- When electric circuit being tested is open, torque due to voltage coil will be maximum and pointer shows '∞' means no shorting throughout circuit and has maximum resistance within the circuit under test.
- If there is short circuit, pointer shows 'zero' which means 'NO' resistance within circuit being tested.
- Work philosophy is based on ohm-meter or ratio-meter. The deflection torque is produced with megger tester due to magnetic field produced by voltage and current, like ohm's law
- The torque of megger varies in a ratio with V/I (ohm's law:- V = IR or R = V/I).
- Electrical resistance to be measured is connected across the generator and in series with deflection coil.
- Produced torque shall be in opposite direction if current is supplied to coil.
- High Resistance :- No current- No current shall flow through deflecting coil, if resistance is very high i.e infinity position of pointer.
- Small Resistance = High Current:- If circuit measures small resistance allows a high electric current to pass through the deflecting coil i.e produced torque make the pointer to set at 'zero'.
- Intermediate Resistance = Varied Current:- If measured resistance is intermediate, produced torque align or set pointer between range of '0' to '∞'.

- checking correct Operation:- Shorten (touch) the probes together and switch to MΩ mode, the pointer should indicate approximately '0'
- Megger is used to measure insulation resistance and other high resistance value. It is also used for ground, continuity and short circuit testing of electric power system. The chief advantage of the megger over an ohm meter is its capacity to measure resistance with a high potential or breakdown voltage.

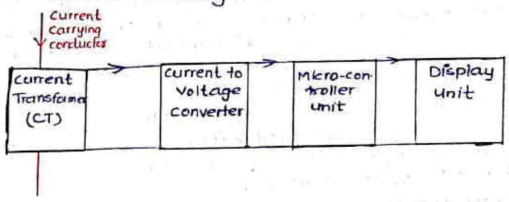
- Clamp meter :-

Clamp-on ammeter or simply 'clamp-meter' is an instrument used to measure the current flowing through a conductor. An AC clamp meter basically consists of a current transformer (CT) in its jaws (a bar CT usually). Utilizing the current transformer (CT) principle, the reading will be displayed.

Working of AC clamp meter :-

When the instrument is 'clamped' on a conductor, the conductor itself acts as primary & the magnetic flux due to current flowing through the conductor cuts the secondary of current transformer (CT)

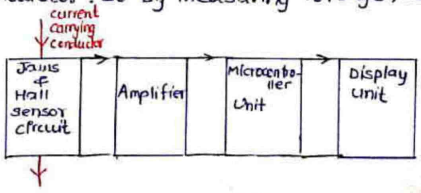
The current in the secondary of the CT is converted to the voltage using a current to voltage converter. This signal is fed to an analogue to digital converter. A micro-controller is usually employed & it will drive the display circuit for current reading



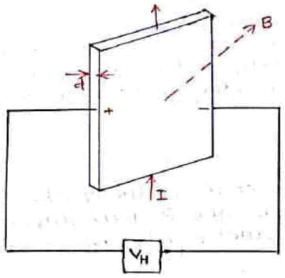
- Working of DC clamp meter :-

Unlike AC, current transformers can't be used for measuring direct current (DC). So Hall effect sensor is used for this purpose. The Hall element used responds to the magnetic flux due to direct current in the conductor which produces voltage across element.

The developed voltage is proportional to the current in the conductor. so by measuring voltage, current can be determined



• Hall effect & Hall sensor:-



The Hall effect is the production of potential difference across an electrical conductor, transverse to current in conductor and a magnetic field perpendicular to the current.

A hall effect sensor is a transducer that produces a voltage when kept under the influence of magnetic field. The charge carriers experience a force called Lorentz force. Due to this force, the charges gets ~~disturbed~~ distributed on the surface of material leaving equal & opposite charges on the opposite surface which constitutes a potential difference that exists as long as magnetic field is steady.

In a DC clamp meter Hall Effect sensor is used as magnetometer. The voltage so developed is proportional to magnetic field & hence to the current.

Even though a clamp meter is mainly used for measuring current, these instruments are added with feature to measure voltage, resistance, frequency etc.

• Static electricity:- Static electricity is an imbalance of electric charges within or on the surface of material. The charge remains until it is able to move away be means of an electric current or electrical discharge.

The static electric charge is created whenever two surface contact and separate, and atleast one of the surfaces has a high resistance to electric current.

It is a stationary electric charge that is built up on a material.

• Cause of static electricity:-

Material are made up of atoms that are normally electrically neutral because they contain equal no. of +ve charges (protons) and -ve charge (e^-). The phenomenon of static electricity require a separation of positive and negative charges. When two dissimilar material are in contact, e^- may move from one material to other, which leaves an excess of +ve charge on one material and an equal -ve charge on the other. When the materials are separated, they retain this charge imbalance.

• Static electricity is generated by friction that occurs b/w different materials during relative motion. Electrostatic charge can then accumulate in materials which are poor conductors of electricity or which are good conductors but are insulated.

• If two such bodies with static electricity accumulated are brought close together, and if the difference of potential is great enough, the accumulated charge will jump b/w them.

- Static electricity may occur on tankers because of :-

• An electrostatic charge is generated in the liquid as it flows turbulently through the loading pipeline into the ships tank.

• During cold operation

• Don't disconnect hoses before they are pulled out of tank.

• Jumpers are attached to flanges to maintain conductivity.

• When a non-bonded projecting object, or something introduced into the tank, can become a potential electrode or spark promoters, collecting the charge from the liquid. When close enough to an earth, the spark promoters instantaneously releases its energy/charge in a spark through the atmosphere of tank.
Such a spark have enough energy to ignite a flammable vapour.

• Precaution to eliminate static electricity:-

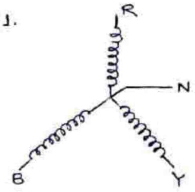
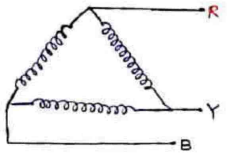
1. Safe pumping rate (Faster the liquid flows, higher is the electrostatic charge)
2. Presence of water.
3. Gas bubbling up through the filled tank.
4. Unearthed conductors - avoiding the presence of unearthed conductor in ships tanks is of fundamental importance to prevent sparks because they provide the electrode from which a spark can jump.
5. Projections and probes in tanks:-
Tanks are sometimes equipped with sounding pipe which extend down from underdeck towards the liquid surface. other example of projections and probes are high level alarms, spraying nozzle and fixed tank washing machine.
If the liquid being loaded is at a high surface voltage, an incendive brush discharge to an unbonded projection may take place. The need to avoid to such a situation will have been taken into account during the design of fixed projection inside cargo tank. and all requirements for safety as to materials of construction, earthing, insulation and static electricity generation will have been checked while the ship was being built.
6. Gauging & sampling of tanks.
7. steaming- steam issuing/releasing from a nozzle will generate a mist of charged water droplets. (carry out inerting)

8. Bonding and Earthing:-
A spark can't jump b/w two conductors which are either electrically bonded together or both earthed, because they are kept at same voltage.
Effective bonding is achieved by connecting a metal cable b/w objects. The cable is sometimes permanently fixed to one conductor and bolted or clamped to other. Bonding & earthing cables should be inspected periodically and their resistance should be checked with meter.

9. Washing of Tanks:-
During tank washing, a charged mist is produced and is present all over the space. such mist remains/exists for few hours after washing end. If an unearthed conductor is lowered into the charged mist, it becomes charged to a voltage which may be high enough for a spark to jump to some part of the tank structure.
The limitation on water flow rate per nozzle, per machine and per tank is established/fixed by extensive research & should not be exceeded. If the water contain cleaning additives or is recycled or the washing medium is other than clean water, water washing should be conducted in non-flammable atmosphere i.e the tank should be made inert. The practical aspect of tank washing is therefore important to observe.

10. Never use polyprene ropes as they accumulate charge.
- It is accumulation of electric charge on the surface of a material, usually an insulator or non-conductor of the electricity through physical contact & separation.
→ Charge separation:- When a dissimilar metal comes in contact, electrostatic charge occurs at interface.
→ Charge Accumulation:- The period of time for which charge is retained is known as relaxation time. The lower the conductivity, the more will be relaxation time.
→ Charge dissipation:- Electrostatic discharge occurs when electrostatic field becomes too strong & electric resistance of insulated material breaks suddenly & their extreme local heeling.

• Comparision of star (Y) & Delta (Δ) connections:-

Star Connection (Y)	Delta Connection (Δ)
1.  In star connection, the starting or finishing ends (similar ends) of three coils are connected together to form the neutral point. A common wire is taken out from the neutral point which is called Neutral.	1.  In DELTA connection, the opposite ends of three coils are connected together. In other words, the end of each coil is connected with the starting point of another coil & three wires are taken out from the coil joints.
2. There is neutral or star point	2. No neutral point.
3. Three phase four wire system is derived from star connections (3-Φ, 4-wires systems). We may also derive 3 phase 3 wire system from star connection.	3. Three phase three wire system is derived from delta connections i.e 3 phase 4 wire system is not possible in delta connection.
4. line current is equal to the phase current i.e $I_L = I_{ph}$	4. Line current is $\sqrt{3}$ times of phase current i.e $I_L = \sqrt{3}\, I_{ph}$
5. Line voltage is $\sqrt{3}$ times of phase voltage i.e $V_L = \sqrt{3}\, V_{ph}$	5. Line voltage is equal to the phase voltage i.e $V_L = V_{ph}$
6. In star connection, the total power of three phase could be found by $P = \sqrt{3}\, V \times I$	6. In delta connection, the total power of three phase could be found by $P = 3 \times V \times (1/\sqrt{3})$

Star Connection (Y)	Delta connection (Δ)
7. The speed of star connected motors are slow as they receive $1/\sqrt{3}$ voltage	7. The speed of delta connected motors are high because each phase gets total of line voltage
8. In star connection, smooth starting and operation with nominal power, normal operation without overheating can be achieved.	8. In delta connection, motor receives highest power output
9. In star connection, phase voltage is low as $1/\sqrt{3}$ of the line voltage. Therefore it needs a low no. of turns hence saving the copper.	9. In delta connection, phase voltage is equal to the line voltage, hence it needs more no. of turns which increase the total cost.
10. Low insulation required as phase voltage is low as compared to Delta.	10. High insulation is required as phase voltage is equal to line voltage.
11. Star connected is a common & general system which is used in power transmission	11. Delta connection is a typical system used in distribution system & industries.

• Difference between Earthing & Grounding:-

There is no difference between Earthing & Grounding but these are the same terms used for Earthing or Grounding.

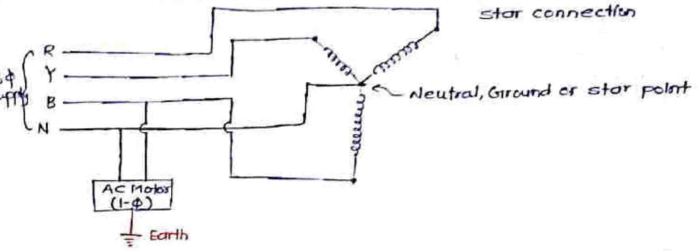
Grounding is the commonly word used for earthing in the North American standards like IEEE, NEC, ANSI & UL etc while Earthing is used in European, Common wealth countries & Britain standards like IS & IEC etc.

So Earthing & Grounding are synonyms i.e both are similar words used for the same thing.

• Bonding:-

The word bonding is used for joining two wires (as well as conductors, pipes or appliances) together. Bonding is known as connecting the metallic parts of different machines which is not considered to be carrying electric current during normal operation of the machines to bring them at the same level of electric potential.

• Neutral, Ground & Earth



Neutral:- Neutral is return path for an AC circuit which is supposed to carry current in normal condition. This current may be because of many reasons but primarily because of phase current imbalance.

There may be other reasons too but the magnitude of this current is in fraction of phase current & in few case it can be even double of phase current. So Neutral wire is always assumed to be charged (in active circuit). This neutral wire is given to ground (by grounding) to make the second terminal of neutral wire at zero potential.

Earth or Ground:-

Earth or ground is for safety concerns against leakage or residual currents on the system via least resistant path. While phase & neutral is connected to the main power wiring, earth may be connected to body of equipment or to any system which in normal condition doesn't carry current but in case of some insulation failure, is supposed to carry some minor current.

This current is not directly coming from live or phase wire, but is from secondary links which was not in touch with live system in normal condition. This ~~condition~~ current is usually much lesser than main line current or phase current & mostly is in order of mA. But this leakage current is good enough to kill someone or may risk fire. Such current are being provided a low resistance path & sent to earth via earth wire.

- Because of difference in application we never mix grounding of neutral & earth. However both are made grounded (but process may be different). If both will be mixed then the earth wire which is not supposed to carry any current in normal condition, may have some charges across & it will become hazardous.

ALTERNATOR (OR A.C. Generator)

→ Rules & Regulations:-

1. The main source of electrical power shall consist atleast two generating sets.
2. The capacity of these generating sets shall be such that in the event of any one generating set being stopped, it will still be possible to supply those services necessary to provide normal operational conditions of propulsion and safety.
3. In addition, the generating sets shall be such that as to ensure that with any one generator or its primary source of power out of operation, the remaining sets shall be capable of providing the electrical services necessary to start the main propulsion plant from a dead ship condition.
4. The main electric lighting system, which shall provide illumination throughout those parts of the ship normally accessible to and used by passengers or crew shall be supplied from the main source of electrical power.

• Generator Specifications :-

Frequency = 60 Hz
Poles = 8 poles
Phase = 3 ϕ
Rated voltage = 450 V
Rated current = 962 V
Output rating = 750 kVA

Basics:-

AC generator or Alternator works on the same principle as that of D.C generators.

In D.C generator, armature rotates and field system is stationary whereas in alternators, armature is stationary and field system rotates.

Donate
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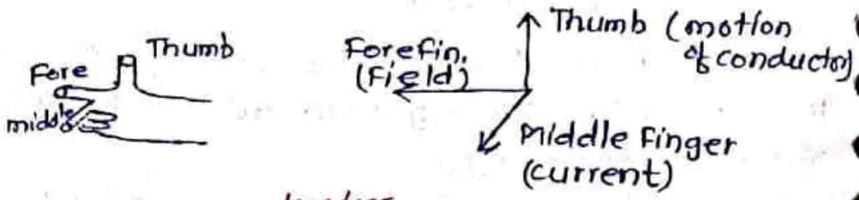
Difference b/w alternator & Generator:-

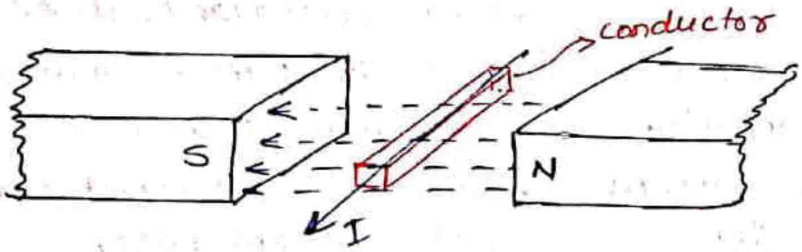
Alternator	Generator
• A machine that converts mechanical energy into AC electrical energy.	• A machine that converts mechanical energy into AC or DC.
• Can generate AC only	• Can generate both AC & DC.
• Rotating part is magnetic field	• Rotating part is armature.
• Stationar part is armature.	• Stationary part is magnetic field
• Generated output current is taken from stator	• Generated output current is taken from rotor.
• Doesn't need polarization after install.	• Needs polarization after install.
• Have wide range of RPM	• Have low range of RPM.
• Generated voltage varies depending on load	• Generated voltage is constant irrespective of load.

Generator Principle:-

Generator works on Faraday's Law of electromagnetic induction which says,

- Whenever a conductor is placed inside magnetic field and if conductor cuts magnetic field, voltage and current gets generated.
- Direction of current can be given by Fleming's Right Rule which says if thumb shows motion and forefinger shows dirn of magnetic field then middle finger will show dirn of current.





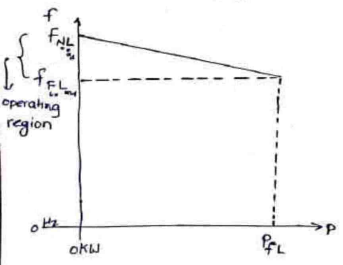
- Magnitude of induced voltage depends on the strength of magnetic field, rate of cutting and length of conductor.

- Droop setting in Alternator & its importance:-

Droop:- Droop is a method of controlling the reactive power of an alternator as the load increases. This is used in synchronizing applications, where multiple generators are in parallel. With all units set up to droop by the same percentage, the reactive load will be shared equally b/w them, because if one take more reactive load, the droop will work to counter this effect.

Range of droop setting is 0% to 5%.

- Droop is drop in frequency of machine as load increases. When we draw more power from alternator, the rotor decelerates & the speed reduces. Then speed governor tries to gain the original speed but unable to do so. So speed & frequency reduces ($f = \frac{PoN}{120}$)



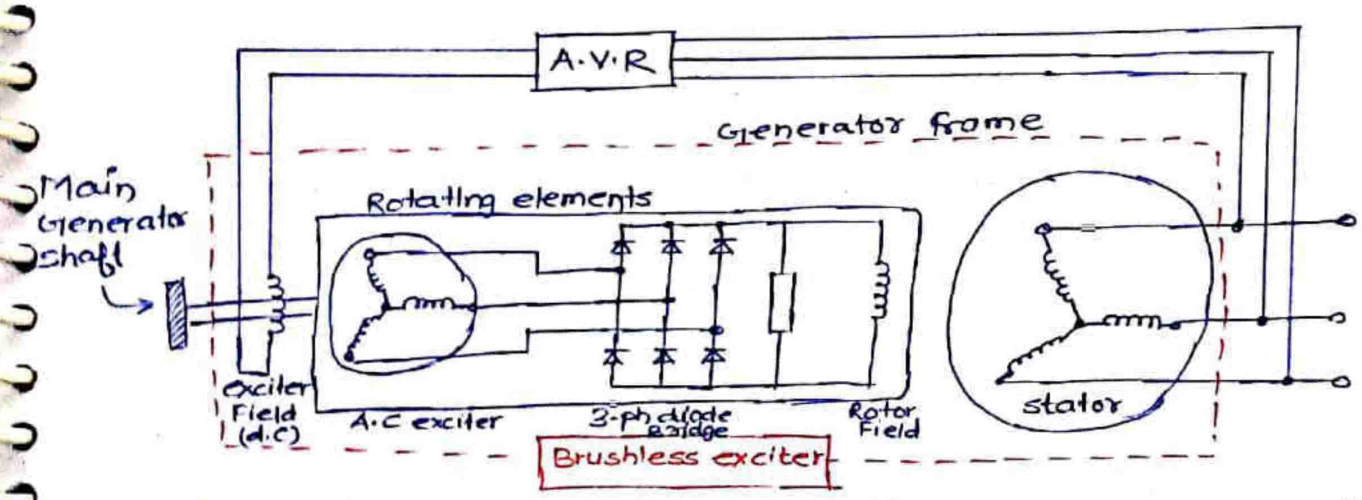
$$\text{droop} = \frac{f_{NL} - f_{FL}}{f_{FL}} \times 100\%$$

0 droop ⇒ isochronous mode

Excitation:- Excitation system is defined as the system which is used for production of flux by passing current in the field winding.
The main requirement of an excitation system is reliability under all conditions of service, a simplicity of contron, ease of maintenance.

Types

1. Brushless excitation:-



This is rotational method of excitation. The brushless exciter is a small a.c generator attached to the end of main generator shaft. The stator of the brushless exciter corries the magnetic field and the rotor carries the conductors which will have a voltage induced in them.
The stator of exciter consists of electromagnets whose d.c supply is provided by an A.V.R
As the prime mover turns, it turns the conductors on the exciter rotor in the magnetic field produced by stator, This induces a voltage in the rotor conductors. This is a.c voltage. The induced voltage is passed through diode rectifiers & converted into d.c, the diodes are mounted on shaft and are referred as rotating diodes.

The rectified d.c voltage from the brushless exciter rotor is next passed to the field windings of the main generator where it will produce the magnetic field required by the main generator.

• Static excitation:-

DOL started induction motors takes 6-8 times the normal full load current as they are started. A large motor therefore puts a heavy current demand on a.c system, causing the applied voltage to dip, where recovery from the dip is low. This result in a momentary dimming of lights and similar effects on other components / equipments. There is a limit to the size of motor that can be started direct online, but the ability of alternators to recover from large starting currents has been enhanced by the development of static excitation systems.

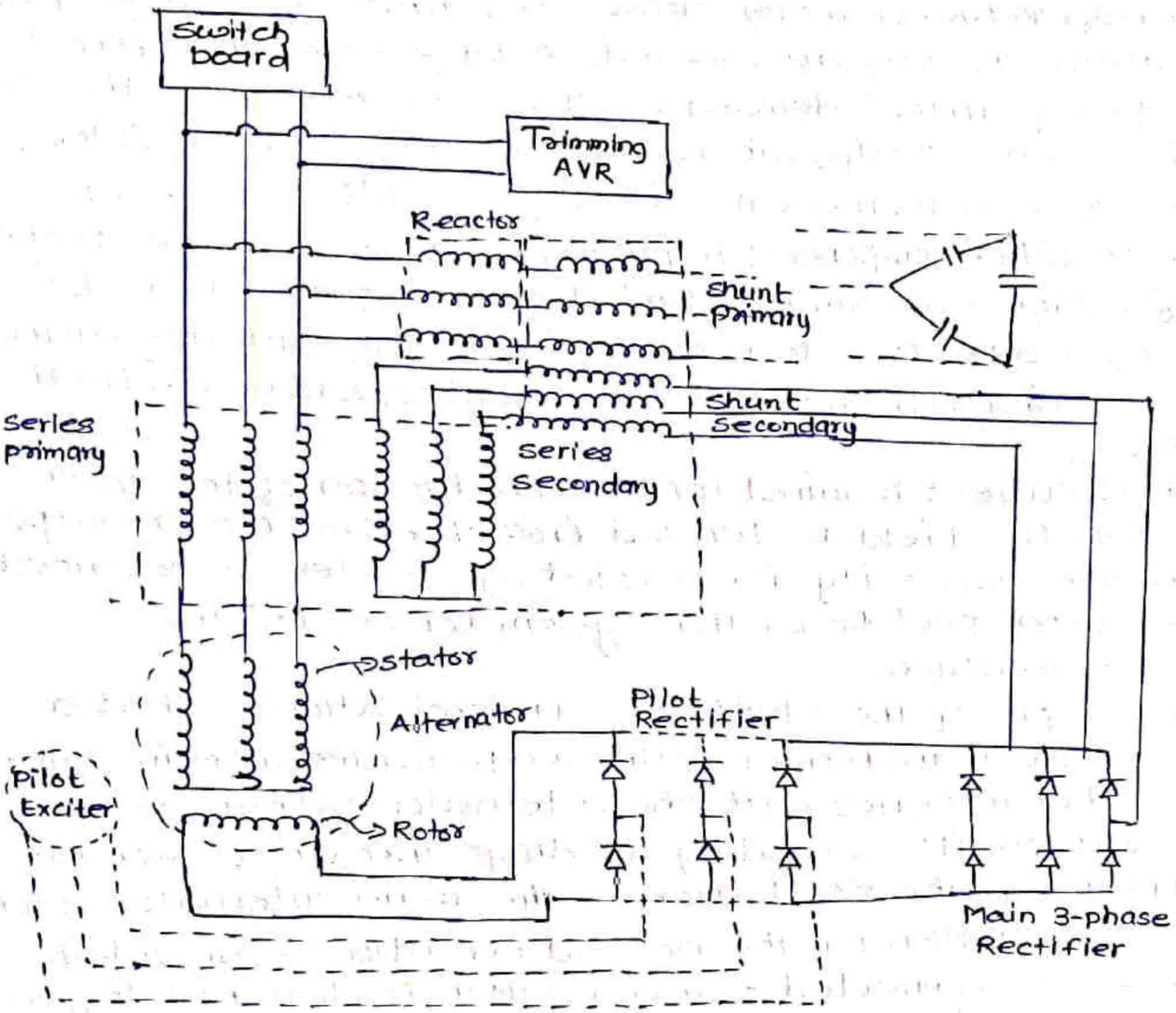
The direct current required for the production of the rotor pole magnetic field is derived from the alternator output without the necessity for a rotating exciter as described for the carbon-pile / d.c exciter system for or for the brushless machine.

The principle of the static or self-excitation is that a three-phase transformer with two primaries, one in shunt & the other in series with the alternator output, feed current from its secondary windings through a 3-phase rectifier for the excitation of the main alternator rotor.

Excitation for the no-load condition is provided by the shunt connected primary, which is designed to give sufficient main rotor field current for normal alternator voltage at no load. The reactor coils create an inductive effects so that the current in the shunt winding lags the main output voltage by 90°. Build up of voltage is assisted by capacitors, which promotes the resonance condition with the reactors or by means of a pilot exciter.

The load current in the series primary coils contributes to the additional input to the excitation system to maintain voltage as the load increases. Variations in load current directly alter excitation & rotor field strength to keep the voltage approximately right.

Fig:- Static excitation system



Both shunt & series inputs are added vectorially in the transformer. Diodes in the 3-phase rectifier change the alternating current into direct current, which is then smoothened & fed to the alternator rotor through slip rings. Voltage control within close limits is achieved by trimming with a static AVR to counteract small deviations due to internal effects & wandering from ideal load / voltage line. The AVR may be of static type. change in coil current brought about the AVR alter the transformer's output enough to trim the voltage.

- Why Alternator/Generator Rated in kVA, not in kW.

- The power ($\sqrt{3} V_L I_L \cos\theta$) delivered by alternator and generator for the same value of current depends upon power factor (p.f = $\cos\theta$) of the load.
But the alternator conductors are calculated for a definite current and the insulation at magnetic system are designed for a definite voltage independent of power factor (p.f = $\cos\theta$) of the load. For this reason apparent power measured in kVA is regarded as the rated power of the alternator.

- The main factors manufacturers consider while designing electrical devices and appliances which provide electric power like transformer, UPS, alternator & generators etc are load & power factor. As they don't know exactly what is power factor & which kind of load will be connected to the device & appliances.
So they simply design & rate the electrical device according to its maximum current output that the conductors can safely carry while they consider unity power factor (In case of pure resistive load)

- If we connect inductive or capacitive load (when p.f is not atleast unity) the output would differ than as there are losses occurs due to low power factor.
- For this reason, kVA is an apparent power which doesn't take into account the p.f instead of kW (Real power)

Here

kW = kVA x $\cos\theta$

kVA = kW / $\cos\theta$

• Parallel operation of Alternators :-

Synchronizing :- The operation of connecting an alternator in parallel with another alternator or with common bus-bar is known as synchronizing.

• It is never advisable to connect a stationary alternator to live bus-bars because stator induced emf being zero, a short-circuit will result.

Conditions for parallel operations :-

1. The terminal voltage (effective) of the incoming alternator must be same as bus-bar voltage & it is indicated by voltmeter.
2. Speed of incoming alternator must be such that its frequency ($= \frac{PN}{120}$) equals bus-bar frequency. It is indicated by synchronizing lamps
3. The phase of alternator voltage must be identical with the phase of bus-bar voltage. It means that the switch must be closed at (or very near) the instant the two voltages have correct phase relationship.

Note:- Condition (1) is indicated by voltmeter, (2) & (3) are indicated by synchronizing lamps or synchronoscope.

4. The e.m.f of incoming machine must be in phase with the busbar voltage.

Why paralleling / synchronizing Required:-

- To share a total load that exceeds the capacity of a single machine / generator.
- changeover of main and standby generator units require paralleling for smooth transition without blackout situation.

- It is not advisable nor possible to run a main generator in parallel with emergency generator or shore supply (for simplicity & security). circuit breaker interlocks are provided to prevent it.

Parallel running is achieved in two stages:-
i) Synchronising ii) Load sharing

→ Both can be carried out automatically but manual control is still common & is a backup to automatic.

→ The generator already 'on the bars' is called running machine and the generator to be brought into service is the incoming machine.

- In practice, it is difficult to adjust the speed of the incoming machine so that pointer of synchroscope is stationary at 12 o'clock. Such a condition is not essential and a more practical proposition is to have the pointer rotating slowly in the 'fast' direction and to close the paralleling switch it about 11 o'clock. Due to time lag of the operating mechanism and human response, actual synchronising will thus take place close to 12 o'clock position and the machine running fast will be slowed lightly and take a small proportion of load. If synchronised when running slow, the incoming machine would take a motoring current which may operate its reverse-power relay and 'trip' the circuit-breaker of the machine already on the 'bars' due to overloading.

- The likely consequences of attempting to the close the incomer's breaker when the generators are not in synchronism are, at the instant of closing the breaker, the voltage phase difference cause a large circulating current blw the machines, which results in a large magnetic force to 'pull' the generators into synchronism. This means rapid acceleration of one rotor and deceleration of the other. The large force may physically damage the generators and their prime movers, which may include deformation of stator windings, movement between the stator core and frame, failure of the rotor diodes in brushless machines, twisted rotor shafts, localised crushing of shaft-end keyways and broken couplings. The large circulating current may also trip each generator. The ultimate result is a blackout, danger and embarrasement.

• Manual Synchronising:-

- Synchroscope:- Synchroscope in a small motor with coil on two poles connected to the 2 phases of the incoming machine. The armature winding of rotor is supplied from two phases of main bus bar. The circuit incorporate a resistance & an inductance coil in parallel. Inductance has the effect of delaying current through it by 90° relative to the current in the resistance. Dual current are fed to the armature via slip rings to produce magnetic field.

The polarity of poles will alternate N/s by alternating phases in the incoming m/c. Rotating field will react with the poles by turning the rotor by clockwise or anticlockwise.

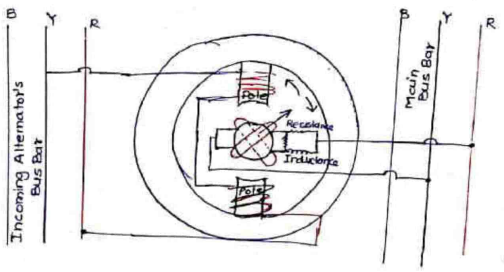
Clockwise- Incoming m/c is too fast (compared to busbar freq)

Anticlockwise- Incoming m/c is slow. (compared to bus bar freq)

→ Normal procedure of synchronizing is to adjust the incoming m/c speed slightly fast; synchroscope pointer turning clockwise, breaker is closed

Two coils

1. Resistive → current is in phase with voltage.
2. Inductive → current is lagging voltage by 90°



TRANSFORMER

Manual Synchronising:-

i> Using Synchroscope:-

In order to achieve smooth synchronising, the incoming m/c must be brought upto an appropriate speed in order to obtain approximately the same frequency or within 0.2% of the bus-bar frequency. Incoming generator's voltage is now 'trimmed' so as to be equal to within 5% of busbar voltage. This may not be possible if the load is fluctuating. Fine tuning of speed can now be observed on synchroscope or synch synchronising lamps; the incomer being adjusted so that the synchroscope pointer rotates slowly clockwise (in the 'fast' direction) at about 4 sec/revolution or counter-clockwise.

The circuit breaker should be made as pointer approaches 12 o'clock. Making the breaker b/w '5 to and 5 past' the 12 o'clock position of the synchroscope is satisfactors as long as pointer's rotation is fairly slow. It is normal to synchronise with the incoming m/c slightly fast. This prevents the incoming machine's reverse power trip protection relay from operating

The indication available to show the optimum synchronised condition is that the incoming generator ammeter will show very little 'kick' when correctly synchronised.

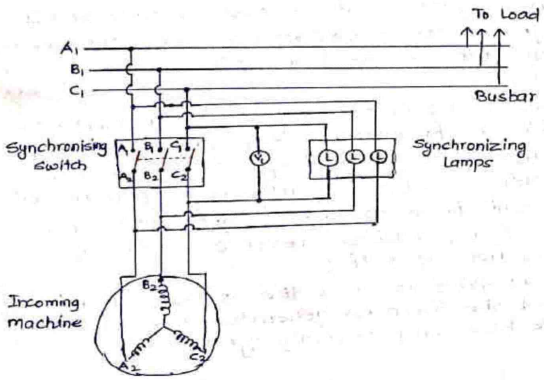
Q:- Why synchroscope switch is closed at 11'o clock, why not 12'o clock

- When the synchroscope needle is approaching 12'o clock, the 'slip' (differential) between the sine waves is approaching minimum (slip is zero when the synchroscope is at 12'o clock) & the voltage differential between the phase is minimal (it's zero when the synchroscope is at 12'o clock). Due to time taken to close the synchroscope switch, it is generally done at 11'o clock. Due to small delay to close, by doing at 11'o clock, we are achieving closing close to 12'o clock.

ii) Synchronising Lamps (or Lamp Method)

The lamp method of synchronising makes use of filament lamps, so connected across the contacts of the paralleling switch that the intensity of illumination varies continuously. The correct synchronised position may be shown by one of the following methods :-

i) 'Lamps dark' method (2 lamps)
ii) 'Lamps bright' method (2 lamps)
iii) 'Sequence' method (3 lamps)



A set of three synchronizing lamps can be used to check the conditions for paralleling or synchronization of the incoming machine with the other machine. A dark lamp method along with a voltmeter is used for synchronizing.

The prime mover of incoming machine is started & brought nearer to its rated speed. A field current of the incoming machine is adjusted in such a way so that it becomes equal to bus voltage. The flicker of the three lamps occurs at a rate that is equal to the difference in the frequencies of the incoming machine & the bus. All the lamps will glow & off at the same time if the phases are properly connected. If this condition doesn't satisfy, then the phase sequence is not connected properly.

- Thus, in order to connect the machine in correct phase sequence two leads of the line of the incoming machine should be interchanged. The frequency of the incoming machine is adjusted until the lamp flicker at a slow rate. The flicker rate should be less than one dark period per second. After finally adjusting the incoming voltage, the synchronizing switch is closed in the middle of their dark period.

Advantage of Dark lamp Method:-

- The method is cheaper
- The correct phase sequence is easily determined

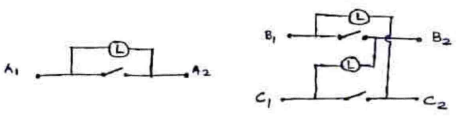
- Disadvantage of Dark lamp Method :-
- The lamp becomes dark at about half of its rated voltage. Hence it is possible that the synchronizing switch might off even when there is a phase difference b/w the machine.
- The filament of the lamp might burn out.
- The flicker of the lamps doesn't indicate which lamp has the higher frequency.

- Three bright lamp method (Sequence Method)

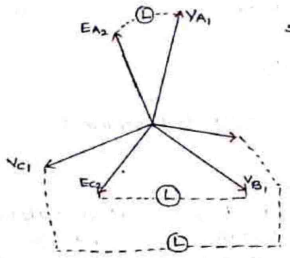
In this method, the lamps are connected across the phases such that A_1 is connected to B_2, B_1 is connected to C_2 & C_1 is connected to A_2. If all the three lamps get bright & dark together, this means the phase sequence is correct. The correct instant of closing the synchronizing switch is in the middle of bright period.

- Two bright one dark lamp method :-

In this method, one lamp is connected between corresponding phase while the two others are cross-connected between the other two phases as shown in fig.



- Here A_1 is connected to A_2, B_1 to C_2 & C_1 to B_2. The prime mover of the incoming machine is started & brought upto its rated speed. The excitation of the incoming machine is adjusted in such a way that the incoming machine induces the voltage E_{A_1}, E_{B_2}, E_{C_3} which is equal to the Busbar voltages V_{A_1}, V_B, & V_{C_1}



The correct moment to close the switch is obtained at the instant when the straight connected lamp is dark & connected cross lamps are equally bright. If the phase sequence is incorrect, no such instant will take place, and all the lamps will be dark simultaneously.

The direction of rotation of the incoming machine is changed by interchanging the two lines of the machine. Since the dark range of the lamp extends to a considerable voltage range, a voltmeter V_1 is connected across the straight lamp. The synchronizing switch is closed when the voltmeter reading is zero.

Thus the incoming machine is now floating on the busbar & is ready to take load as generator. If the prime mover is disconnected, it behaves as motor

iii) Using Voltmeter:-

Adjust the generator speed until the voltmeter very slowly fluctuates from zero to maximum. close the breaker when the voltmeter indication passes through zero.

Q:- We can use single but large size generator for all load. Why we need more than 1 generator?

- We need more than one generator so that we can carry out scheduled maintenance on other generator.
- If only one generator we use & if that stops working, we didn't have any reliability of another power source.
- If we have only low loads, power factor become low. If power factor become low then efficiency will reduce & more fuel will be used. & useful power production will be less.

So more than 1 (multiple) generators are required because of

1. Increased reliability & redundancy
2. Low cost for power generation
3. Expandability & flexibility
4. Decreased low load operation.

• AVR (Automatic Voltage Regulator)

Under constant excitation conditions, we know that a generator's terminal voltage drops with increasing load, to control this drop we must vary the excitation current which is supplied to the machine.

An A.V.R senses a generator's terminal voltage & output current and uses these values to adjust the excitation to the generator. A simple A.V.R system will only sense terminal voltage but if better regulation is required both terminal voltage and output current need to be used to determine the level of excitation required.

An A.V.R can be incorporated in system in one of following two ways :-

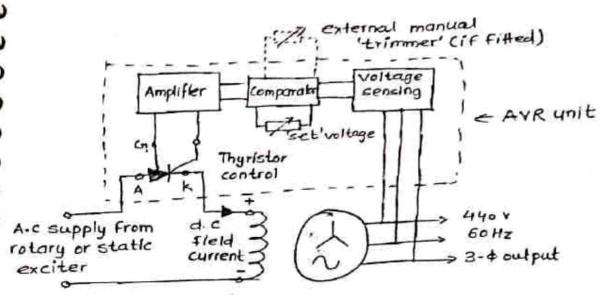
i) Excitation supply : this supplies the whole of the required excitation current under normal operating conditions.

ii) Compounding control : The generator is compounded to supply excessive excitation which the A.V.R adjust to the correst level.

Components :-

1. A voltage comporision circuit for the detection of any variance between generated and required voltage.
2. An amplifier and conditioning circuit which converts the signal from the voltage comparator circuit into a suitable control signal.
3. A control element which varies the excitation current.
4. Other non essential elements which only improve basic performance.

• Circuit Diagram (AVR)



Working principle :-

The generator output voltage is sensed in the sensing element, this element produces a low voltage output which is proportional to the generator output

The low voltage output from the sensing unit is compared to a set value representing normal terminal voltage in the reference bridge. The reference bridge will generate an error signal which is proportional to the difference between the generator output and its required output.

The error signal may well be amplified to create enough signal strength for the rest of the circuit.

The amplified error signal will be used in a firing circuit, the firing circuit will use the size of the error signal to determine at which position in the cycle the thyristors, which applies the excitation field, should be turned on. If the generator output voltage has dropped then the position of firing for the thyristors needs to be brought closer to the start of the a.c cycle

The final component in the generator field supply circuit, this circuit may be directly supplying the power to the generator field through slip rings or it may supply the power to a brushless exciter field which will in turn supply the main field. The power for the field is drawn from an A.C source, this power is rectified from a.c to d.c via a thyristor rectifier i.e a controlled bridge. The firing circuit controls the point at which thyristors turn on & therefore they control the power passing to the field.

• Alternator Maintenance & checks:-

1. Ensure that Alternator prime mover is shut down & locked off before you begin the maintenance. Also make sure that generator breaker is OFF & generator must be kept on mannual mode in ECR.
2. Switch off space heaters & isolate
3. All wiring of alternator should be checked for damaging of insulation & tightness of terminal.
4. Inspect & clean the rotor and stator windings using a drycloth & if possible then with low pressure dry air. An industrial vacuum cleaner may be used to remove dirt from windings.
5. Air gap should be checked by 1- 1.5 mm
6. Terminal box cover gaskets to be checked.
7. Cable gland to be checked for integrity.
8. Check sliprings & brushes
9. Space heaters to be checked for proper operation.
10. check cooling air inlet & exhaust opening for dust ~~free~~ They should not be blocked & should be free from dirt & dust.
11. The oily deposits can be removed by washing the windings with special slow or fast drying degreasant liquids.
12. Rotor slip rings must be checked for uniform (even) wear and that the carbon brushes have free movement in their boxes.
13. AVR to be checked & cleaned off oil & dust
14. All connections in terminal box to be tightened properly.
15. Foundation bolts of alternator to be checked for tightness.
16. After maintenance, do not take on load, only observe noise, temp, vibrations & voltage generated.

• Reasons for Alternator not developing any voltage:-

1. Loss of Residual Magnetism
2. Failure of Diodes
3. Malfunction of slip rings & Brushes
4. Faulty AVR
5. Loss of excitation.

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(Manoj Kumar)

• Alternating producing voltage but not Rated voltage:-

1. Prime mover's RPM is less
2. Loss of Residual Magnetism
3. Faulty AVR
4. Air gap is too high between stator & Rotor windings.
5. short circuit in field coil
6. Decrease in Pole strength.
7. Some stator coils are connected in wrong sequence probably after local repair.

• Air Gap:-

- Air gap is the distance between the rotor and stator windings.
- It should be as small as possible to reduce the eddy current losses due to leakage flux and large gap will increase the winding losses.
- It is kept around 1 to 1.5 mm & it can be checked by inserting a plastic feeler gauge between the stator and rotor. It should be uniform all around.
- Also used fo cooling

• Residual Magnetism:-

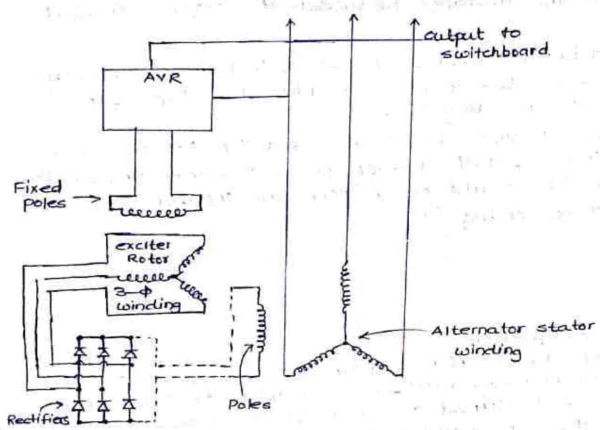
It is a property in which certain amount of excitation remains back in the conductor even after the removal of magnets. It is required as we need some magnetism to start off the generation before the field winding has power to produce full field.

• Flashing up of Generator:-

If the generator has not been running for long time, it may loose its residual magnetism. so flashing up of generator is required.

1. Push the pre- exciter button which will connect 24 V DC supply to the stator of exciter.
2. If pre-exciter is not present, connect a 12-V battery to R for 2- minutes after disconnecting the AVR

- Brushless Alternator:-



In brushless alternator slip rings & brushes are eliminated & excitation is provided not by conventional direct current exciter but by a small alternator.

- Here AVR sense load & produce as DC excitation
- Residual magnetism is at DC stator excitor winding

- Working:-

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The casing pole coils (fixed poles) are supplied with direct current from AVR. 3-phase current generated in the windings on the exciter rotor passes through a rectifier assembly on the shaft and then to the main alternator poles. No slip-rings are needed.

The silicon rectifiers fitted in a housing at the end of shaft are accessible for replacement & their rotation assist cooling. The six rectifiers give full-wave rectification of the 3-phase supply.

- Alternator Trips:-

1. Undervoltage/No voltage/Trip:-

- Field flashing:- It is a process to restore residual magnetism by passing a 12 V DC supply to winding for 5 sec.
- If generator is ideal for long time, no DC flowing & hence residual magnetism is lost.
- Heat, shock, vibrations are the other means.

Q:- How to test if residual magnetism is there or not.?

Soln:- . When we start an alternator, a residual voltage builds up at terminals.
- This residual voltage must be greater than 5V AC.
- If less than 5V AC, alternator won't be able to produce rated voltage.
- This indicates loss of residual magnetism
- Field flashing is done to restore residual magnetism.

- Alternator Safeties:- (Relays)

1. Differential Relay:-
   - It is connected to CT, connected to either sides of stator winding.
   - This provides protection against internal faults within stator winding.
2. Earth leakage Relay:-
   It is connected to a core balanced CT
3. Under voltage/Over voltage relay:-
4. Under frequency/Over frequency relay
   These both are connected with a PT connection.
5. Reverse Power Relay:-
   This requires both CT & PT connections.
6. Over current relay:
   This is operated when we have a very high voltage fault current
7. Negative phase sequence relay

⇒ All these relays are connected to a master relay which will finally opens circuit breaker.

- Alternator Trips:-

1. Overcurrent trip
2. Reverse power trip
3. Under voltage trip

Procedure to take alternator on load:-

1. IN AUTO MODE:-

1. Turn the relevant mode selection switch at MSB synchronization panel to the AUTO Position.
2. Turn the relevant ACB control switch at MSB synchronization panel to close MSB
3. The ACB receives a close command & closes & the load shared with other running generators.

2. In MANUAL MODE:-

1. Turn the relevant mode selection switch at MSB synchronization to MANUAL Position.
2. Turn the synchronoscope switch at the main switchboard synchronization panel to the incoming generator positron (G11 or G12 or G13). The LED indicator ring on the synchroscope will begin to rotate.
3. Adjust the GOVERNOR CONTROL switch (raise/lower) until the synchroscope is moving slowly in the clockwise (fast) direction (approx one revolution every five to ten seconds)
4. As the synchroscope approaches the 12'o clock position (synchronism), turn the ACB CONTROL switch at MSB synchronization panel to close position.
5. The ACB will receive a close command & will close. The CAN close indication at the relevant generator panel will be lit. Turn the synchronoscope switch to OFF position.
6. Thus manual balancing of load is achieved by use of the GOVERNOR control switch.

Switchboard:- Switchboard are also known as 'open' or 'dead-front'.

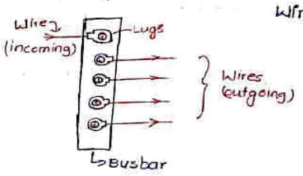
Open:- All essential components such as circuit breakers, switches, links and terminals are exposed on the front of insulated base

Dead-front:- As name implies, all live parts are concealed behind steel sheeting or build into steel cubicals and only the operating handles, instruments, lenses of indicating lamps appears on the front.

- Except for voltage of 55 V to earth & below, for A.C installation open type panels are not permitted (for safety reason)
- So modern switchboards are dead-front type (∵ use high voltage)

Switchgear:- The main section & sub-switchboards throughout a ship, switching & protective devices such as circuit-breaker and fused isolator are collectly called switchgear.
Switchgear controls the electric power.

Busbars:- Busbars may be seen if the rear doors of the switchboard cubicle are opened. Short copper bars from each generator's respective circuit breaker connect it to busbars, which run through the length of switchboard. Busbar may be in a specially enclosed busbar duct. Busbar are insulated, hard drawn, high conductivity, electrolytic copper, mounted on permali-type of insulators, firmly secured to the inside of the cubicle. Busbar are rigidly mounted in order to maintain clearances under short-circuit conditions. All copper joints are bolted and the joining surface are tinned.



Wires are connected to busbar with the help of lugs and bolts so that wire don't get loose.

- Busbar Maintenance:-

1. Can be done when ship is in blackout condition i.e when generators are not running i.e when generators are not running & no power is supplied to main & emergency switchboards.
2. The best time to do busbar maintenance is when ship is in dry dock.
   - → Use rubber gloves & PPE
   - → Put lock out panel
   - → Ensure main gen & eme gen are isolated.
   - → carry out visual checks of copper bars bolts & nuts.
   - → Tap plates to check any loose connection.
   - → Use torque wrench to tighten nuts & bolts.
   - → check tightness of wire connections which is connected to circuit breaker.
   - → clean busbar & switchboard area by vacuum cleaner.

Circuit Breaker:- A circuit breaker is a switching device which can be operated manually or automatically for controlling and protecting an electrical machine

It automatically breaks the circuit upon sensing a huge draw of current flow due to overloading or short circuit.

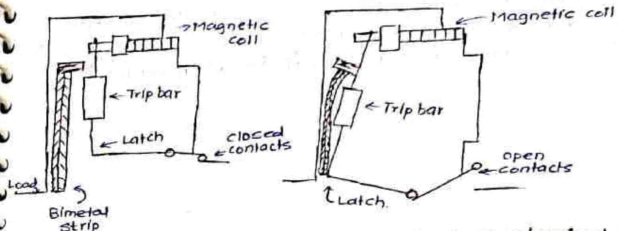
A circuit breaker breakes the supply to the circuit when the current exceeds its rated current. The current may exceed due to various reasons such as overloading, short circuit, voltage spikes etc.

Overloading:- Overloading occurs when the load draws a very huge current more than the rated current.

short circuit:- It occurs when two exposed wires come into contact with each other by any means.

- A circuit breaker is designed to tolerate a specific range of fault current without damaging its terminals.

- MCB (Miniature Circuit Breaker) (5 - 100 Amp)



MCB is an automatically operated electromechanical device used for the protection of the circuit from overloading or short circuit. MCB is used for protection of low voltage circuit 240/415 V AC having a wide range of current ratings.

MCB doesn't trip (switch off) instantly, instead there is a time delay between fault occurence & the breaking of contacts. Generally they are designed to have a time delay of less than 2.5 milliseconds for short circuit and 2sec to 2 min for overloading. It is to make sure the CB does not trip every time with a momentary surge or starting of inductive load due to high inrush current from such loads such as electrical motors.

When continuous overcurrent flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bi-metallic strip releases a mechanical latch. As this mechanical latch is attached with operating mechanism, it causes to open the MCB contacts and the MCB turns off thereby stopping the current to flow in circuit. To restart the flow of current, the MCB must be turned ON. This mechanism protects from the faults arising due to overcurrent or overload

During short circuit condition, the current rises suddenly, causing electromechanical displacement of plunger associated with a tripping coil or solenoid. The plunger strikes the trip lever causing immediate release of latch mechanism consequently open circuit breaker contacts.

- MCCB (Moulded Case Circuit Breaker) (50 - 1500 Amp)
  - It is very small & compact fitted in moulded plastic case.
  - It have thermal overcurrent setting & adjustable overcurrent trip for short-circuit protection.
  - It's operation to close is by hand operated lever.
  - It is Reliable, trouble free & have negligible maintenance.

• Switch:- A switch is a device, which can make or break an electrical circuit automatically or manually. OR
An electrical switch is a controlling device which interrupts the flow of current or changes the direction of current in a circuit.
Almost all the system contains atleast one switch, which is used to make the device ON or OFF. In addition, a switch is used to control the circuit operation where a user may activate or deactivate the whole or certain parts or process of a connected circuit.

Fuse:- A fuse is an electric/ electronic or mechanical device which is used to protect circuits from overcurrent, overload & make sure the protection of the circuit.

construction & working of fuse:-

A general fuse consists of low resistance metallic wire enclosed in a non-combustible material. It is used to connect and install in series with a circuit and device which needs to be protected from short circuit & overcurrent, otherwise electrical appliance may be damaged in case of absence of the fuse and circuit breaker as they are unable to handle the excessive current according to their rating limits.

The working principle of a fuse is based on the 'Heating effect of current" i.e whenever a short circuit, overcurrent or mismatched load connection occurs, then the thin wire inside the fuse melts because of the heat generated by the heavy current flowing through it. Therefore, it disconnects the power supply from the connected system. In normal operation of the circuit, fuse wire is just a very low resistance component and doesnot affect the normal operation of the system connected to the power supply.

• Rewirable Fuses:-

The most famous kit-kat fuse (also known as rewirable fuse) mostly used in industries and home electrical wiring for small current applications in low voltage (LV) systems.

Rewirable fuse contains 2 basic parts. The inner fuse element as fuse carrier made of tinned copper, Aluminium, Lead etc and the base made of porcelain have the IN and OUT terminals which is used to be in series with the circuit to protect.

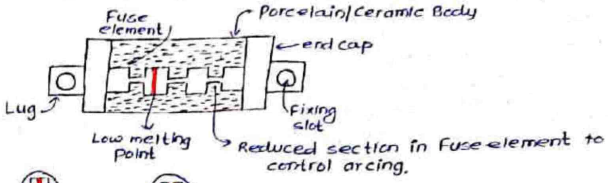
The main advantage of rewirable fuse is that it can be rewired easily in case it is blown due to short circuit or over current which melts fuse elements. ~~Simple~~ Then put another wire of fuse elements with the same rating as before.

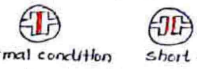
Thermal Fuses:-

Thermal Fuse is a one time used only fuse. They are temperature sensitive fuse and the fuse element is made of temperature sensitive alloy. They are known as Thermal cutouts (TCO) or Thermal links.

In a thermal fuse, the fuse element holds a mechanical spring which is normally closed. When high currents due to over current and short circuit flow through the elements of fuse, the fuse elements melts down which lead to release the spring mechanism and prevent the arc and fire and protect the connected circuit.

• HRC (High Rupturing Capacity) Fuse:-





Normal condition Short circuit/overload

This type of fuse contains a fuse wire in it, which carries the short circuit current safely for a given time period. During this period, if fault is removed, then it does not blow-off, otherwise it will melt and remove the circuit from electrical supply hence, the circuit remains safe.

The most common material which is used to make HRC fuse is glass (but not always).
other chemical compounds are also used in HRC manufacturing and construction based on different factors. Its external enclosure is made fully tight fully air tight in order to avoid the effect of atmosphere on the fuse material.
Main concern for HRC fuse is low & uncertain breaking capacity of semi-enclosed fuse.

Construction & Operation of HRC fuse:-

HRC fuse consists of highly heat resistant material (such as ceramic) body having metal-end caps, which is welded by silver current carrying element. The fuse body internal space is completely packed with filling powder. This filling powder can be plaster of Paris, Quartz, Chalk, Marble, Dust and cooling mediums etc. That's why it normal current without overheating. The heat being produced vaporizes the silver melted element. chemical reaction taking place between silver vapour and filling powder results in high resistance substance, which helps in quenching the arc in fuse.

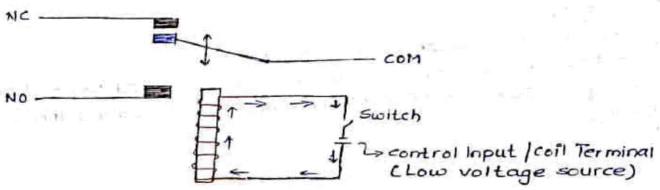
• Advantages of HRC Fuse:-
- Do not deterlorate with age.
- Have high speed operation
- Requires no maintenance
- Gives consistent performance
- Cheaper than other circuit interupting device with same rating
- Fusing action is fast without noise & smoke.

• Disadvantages:-
- After each operation, they have to be replaced
- Heat being produced by the arc may affect the nearby switches.

Q:- Ordering fuse onboard:-
Ans:- These specifications has to be matched
1) Voltage rating
2) current rating
iii) Type of fuse
iv) fusing factor
v) size

• Relay :- A switch is a component that opens (turns off) & close (turn on) an electrical circuit whereas, a relay is an electrical switch that controls (switch on & off) a high voltage circuit using a low voltage source. A relay completely isolates the low voltage circuit from the high voltage circuit.

Construction of Relay:-



Generally there are four Types of Terminals in Relay

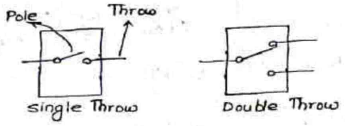
1) Control input or Coil Terminals:-
control input terminals are two input terminals of a relay that controls its switching action
A low power source is connected to these terminals to activate and deactivate the relay. The source can be AC or DC depending on the type of Relay.

COM or Common Terminal:-
This is output terminal of the relay where one end of the load circuit is connected.
This terminal is internally connected with either of other two terminals (NO or NC) depending on the state of relay.

• No Terminal :- No or Normally Open terminal is also a load terminal of a relay which remains open when the relay is not active.
The NO terminal becomes closed with the COM terminal when the relay activates.

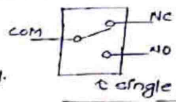
• NC Terminal :- NC or Normally closed terminal is the other load terminal of relay. This terminal is normally connected to COM terminal of relay when there is no control input.
When relay activates, the NC terminal disconnects from the COM terminal & stays open until the relay is deactivated.

Poles & Throw :-
• Pole refer to the switches inside a relay.
• The number of switches inside a relay is called poles of relay.
• The no. of circuits being controlled per pole is called throw of relay.



A single throw relay can control only one circuit i.e either ON or OFF, while a double throw relay can control two circuits i.e alternating from one circuit to another by opening one circuit and closing another during switching (ON & OFF)

Relay operation:-



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∴ single Pole Double Throw

consider a single pole double throw (SPDT) relay.
When there is no power source, the relay is is inactive & the position of its pole remains at NC terminal, which in the above-mentioned case happens to be the upper terminal. This results in an electrically short path between the COM terminal & NC terminal. Thus it allows the flow of current through the circuit connected to COM & NC terminal.
When the relay is powered on using a low voltage power source, the pole of relay shifts to NO terminal. Thus the NC terminal becomes open & COM terminal becomes closed or electrically short to NO terminal. Subsequently, allowing the flow of current through the circuit connected with COM & NO terminal.

A.C Motors

The motor that converts the alternating current into mechanical power by using electromagnetic induction phenomenon is called an A.C Motor. This motor is driven by an alternating current.

Classification:-

1. A.C Motors (on principle of operation)

- Synchronous
- Asynchronous (or induction)
  - Induction motor
    - Squirrel Cage
      - single cage
      - Double cage
  - Commutator Motor
    - series
    - compensated
    - shunt
    - Repulsion

2. On basis of current:- i) Single ϕ, ii) 3 ϕ

3. On basis of Speed:- i) constant speed ii) variable speed
   iii) Adjustable speed

4. On basis of structure:- 1) Open 2) Enclosed 3) Semi-enclosed
   4) Ventilated 5) Pipe-ventilated
   6) Riverted frame eye

→ Asynchronous motor is also known as Induction motor.

• Synchronous and Induction motor have the same stator configuration for producing the rotating magnetic field but they have different rotor constructions due to difference in their ways of generating the rotor magnetic field. In synchronous motors, the rotor magnetic field is generated from field winding excited by a direct current (D.C) power source. For small to medium-sized synchronous motors, permanent magnets are commonly used for generating the rotor magnetic field. In induction motors, the rotor magnetic field is produced by AC power. This AC power is transferred from a stator by electromagnetic induction.

Construction:- The induction motor has two main components, the stator and rotor. The stator carries three separate insulated phase windings that are spaced 120° apart and lying in slots cut into a laminated steel magnetic core. The ends of stator windings are terminated into stator terminal box, where they are connected to the incoming cable from the 3-ϕ AC power supply.

The rotor winding consists of copper or aluminium conductor bars that are connected together at their ends by short-circuiting rings to form a cage winding. The conductor bars are set in a laminated steel magnetic core. The essential reliability of the induction motor comes from such robust, simple rotor.

Motor Ratings:-

1. Rated Full Load Current (FLC):- This is maximum value of current that the motor can continuously take from the supply without exceeding the temperature limit for the insulating material used.

2. Rated voltage:- At Rated voltage, motor is designed. If the supply voltage exceeds the rated voltage limit, overheating, stalling and burnout of the stator winding can result.

3. Rated Frequency:- Motor speed and motor losses are directly affected by the supply frequency. If motor is operated at any frequency other than rated frequency, overheating can occur.

4. Power Rating :- This is shaft power output of the motor, when it is connected to rated voltage and frequency when drawing its rated current from supply.

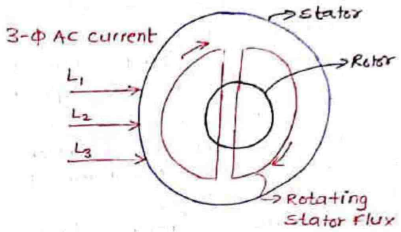
5. Rated speed:- This is full load speed of the motor when connected to rated voltage and frequency.

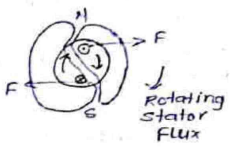
6. IP Number:- It indicates the degree of protection given by motor enclosure.

Motor safeties :-

1. Overcurrent & single phasing protection relays
2. Under voltage relay
3. short circuit relay (Trigger fuses for HV systems)
4. Temperature sensor for motor insulation

Induction motor operation:-





When 3-ϕ AC supply voltages are connected to three stator phase windings, the resulting phase currents produce a multi-pole magnetic flux (ϕ). This flux is physically rotated around the stator core by the switched sequence of L_1-L_2-L_3 current at a speed called synchronous speed (n_s). The value of synchronous speed depends on how many magnetic pole-pairs (p) are fixed by the stator winding arrangement and by the frequency (f) of the voltage supply connected to the stator winding.

$$n_s = \frac{f}{p} \text{ rev/s} \quad ; \quad N_s = \frac{f \times 60}{p} \text{ rev/min}$$

The stator rotating magnetic flux cuts through the rotor conductors to induce an alternating emf into them, since the rotor conductors are connected together at the ends, the induced emf setup rotor current.

The rotor currents also produces a magnetic flux, which produces a torque (T) on the rotor conductor bars.

- The direction of rotor torque causes the rotor to rotate in the same direction as rotating magnetic field.

Note:- An induction motor can't run normally at synchronous speed. This is because the rotor conductors would then be stationary with respect to the rotating magnetic field. No emf would be induced in the rotor and there would be no rotor current and no torque developed. Even when, the motor is on no load, the rotor speed has to be slightly less than synchronous speed (n_s) so that current can be induced into rotor conductors to produce the torque to overcome the mechanical rotational losses of friction and windage.
i.e there should be a relative motion b/w rotor conductor and rotating magnetic flux.

Slip:- Slip is the difference b/w the synchronous speed (n_s) of rotating magnetic flux and actual rotor speed (n_R).
·Slip is usually expressed as a percentage of the synchronous speed (n_s)

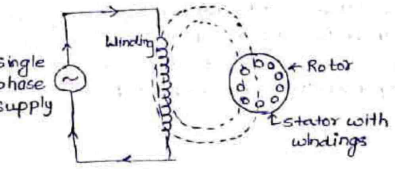
$$S = \left[\frac{n_s - n_R}{n_s}\right] \times 100$$

→ If the load torque on the motor shaft is increased, the rotor will tend to slow down (slip increases) which allows the rotor conductors to cut the flux at an increased rate. This causes more current to flow in the rotor, which is matched by more stator supply current to meet the increased shaft torque demand. The motor will now run at this new, slightly reduced speed. The fall of motor speed b/w no load and full load is very small (between 1% to 5%) so induction motors are considered to be almost constant speed machine

· At startup the motor develops more torque than the necessary to turn the load, so the motor and load accelerate. The speed increases until the torque developed by the motor is same as the torque required by the load at that speed. The motor and load will then run at this steady speed, as the torque supplied exactly matches the demand.

- Single Phase Induction Motor:-

Q:- Why single phase IM are not self starting.



- Here due to varying nature of AC, varying flux is produced.
- EMF will be in the rotor, it experiences a force & torque is produced but Rotor will not rotate (why?)

Reason ∵ $\boxed{\phi \propto NI}$

→ As I alternates, flux also alternates.
→ Due to this, torque will be clockwise as well as anticlockwise due to alternating flux.
→ This causes the net torque to be 0 (zero) & rotor won't rotor.
→ This is the reason why single phase induction motor are not self starting.

So we need to go for split phase IM.
So we need 2 fluxes to produce phase shift 90° because only 1 flux will produce alternating current & torque will be 0.

Uses:-

3φ IM = FW, SW, JCW, LO
3φ SM = BT
Main electric propulsion motor
Synchronous condenser
Shaft Generator

1φ IM = Exhaust fan, galley
1φ SM = Viscotherm, Gyro compass, Radar Motor

Note:- E/R crane- 3φ IM with VFD
Turning Gear motor - Double cage IM.

- Motor flooded in sea water & require overhaul

Procedure:-

1. Put off the breaker.
2. Remove Fuses.
3. Put tag 'MAN AT WORK'
4. Remove terminal box cables and wind them in insulating tape
5. Dismantle the motor
6. Clean all parts with fresh water. Make sure all salts has been removed.
7. If oil is present then use oil decreaser to remove
8. Dry it with help of powerful lamp around 100W-500W or with low power heater. upto (50-60)°C else insulation get damage
9. keep proper ventilation to remove all moisture
10. check insulation
11. Apply Air drying insulation varnish to the winding and leave it for some time to dry.
12. Check the bearings
13. Check insulation resistance
14. Assemble back the motor
15. Run it idle for sometime and then load it gradually.
16. check for Noise/Vibration/Temperature/Smell & any other abnormalities.

Polarization Index :- The polarization index (PI) is used as an indicator of motor insulation health and is useful in identifying accumulation of contaminants as well as physical change in the insulation. To polarize means is to cause something to obtain polarity. The test (PI Test) involves applying a positive charge to motor conductors and a -ve charge to motor frame, therefore polarizing of insulation.

The test effectively measures a change in current over time.

Due to absorption properties, healthy & clean insulation will 'charge' over time, reducing the amount of current. This is an increase in resistance.

LOSSES in IM :-

i) Core loss
ii) Copper loss
iii) Friction loss

Q :- After overhauling, motor not rotating. Reasons :-

Ans :- 1. Connections to motor are loose.
2. Motor has tripped on overload, so reset.
3. Emergency stop of motor active
4. Fuse gone
5. Windings damaged
6. check motor & pump alignment

Q :- Why motor is rated in kW instead of kVA.

- Motor has fixed power factor i.e motor has defined power factor (p.f) and the rating has been mentioned in kW on Motor nameplate data table. Hence motor is rated in kW or HP (Kilowatts / Horsepower) instead of kVA. Motor only consumes active power & provide mechanical power in HP or kW at motor shaft.

Also

Motor is a device which converts electrical power into mechanical power. In this case, the load is not electrical but mechanical (Motor's output) & we take into account only active power which has to be converted into mechanical load. Moreover, the motor power factor doesn't depend on the load & it works on any power factor because of its design.

- Difference b/w Synchronous & Induction Motor:-

Synchronous Motor	Asynchronous Motor (Induction motor)
1. The synchronous motor is a type of AC motor that runs at synchronous speed.	1. The asynchronous motor is a type of AC motor that runs at speed less than the synchronous speed.
2. It operates on the principle of magnetic interlocking between rotor & stator field.	2. It operates on the principle of electromagnetic induction between stator & rotor.
3. There is no slip i.e the slip of synchronous motor is 0.	3. There is slip in induction motor & it is always greater than 0.
4. The speed of motor depends on supply frequency & the number of stator poles. $N_S = \frac{120f}{P}$	4. The speed of the motor depends on the load, rotor resistance & the slip(s). It is always less the synchronous speed. $N = N_S(1-s)$ s= slip $N < N_S$
5. The speed doesn't vary with varying the load connected to the motor.	5. The speed varies with varying the motor load.
6. It is not self start and require extra winding for starting the motor.	6. These are self start & do not require extra mechanism.
7. The rotor requires an extra current supply	7. The rotor of induction motor don't need extra supply
8. Separately excited synchronous motor requires extra DC source to energize its rotor winding.	8. It doesn't require extra source
9. Needs slip rings & brushes to supply DC to its rotor windings.	9. It doesn't require slip rings, however wound type can use slip rings to control speed.
10. The motor speed is only controlled by supply frequency through VFD.	10. The motor speed can be controlled using variable rotor resistance as well as VFD devices.
11. The input voltage supply doesn't vary the speed or torque of synchronous motor	11. The input voltage supply can be used to vary the torque & speed of induction motor.
12. The fluctuation in main supply voltage do not affect motor operation.	12. The mains voltage fluctuation affects its speed and operation.
13. Initial cost is higher than induction motor.	13. Induction motors are cheaper.
14. Operation is complicated.	14. Operation is simple.
15. offers great efficiency & precision.	15. These are not as efficient as synchronous motor.
16. Can easily be operated at very low speed using VFD	16. It is difficult to operate at low speeds.
17. It operates best at lower at very low speed usually below 300 rpm.	17. It is best suited for operation at low speed above 600 rpm. carbidee@ybl
18. It can be operated in lagging leading or unity power factor by adjusting its excitation	18. The induction or asynchronous motor always runs at lagging power factor.
19. It can be used for power factor correction at the same time by utilizing it in leading power factor.	19. It can't be used to correct power factor but only to drive mechanical loads.
20. Since it runs on constant speed, sudden variation in load will cause fluctuation in the drawn current.	20. There is no such phenomenon in induction motor.

Conclusion:- Synchronous motors are efficient but costlier and are used for ultra low rpm applications while offering power factor correction feature. On the other hand, the induction motors are used for high rpm applications with variable speeds while being inexpensive & easier to operate.

• Speed control of Induction Motor:-

From Stator side

i) By changing the applied voltage

Voltage is directly proportional to the torque (i.e $V \propto T$) so if supplied voltage is decreased, the developed voltage decreases.
Hence for providing the same load torque, the slip increases with decrease in voltage & consequently, the speed decreases.

ii) By changing Applied frequency

∵ Synchronous speed is given by $N_s = \frac{120f}{P}$ (RPM)
Hence, the synchronous speed changes with change in supply frequency.
Actual speed of an induction motor is given by $N = N_s(1-s)$

iii) Constant V/F control of Induction Motor:-

The magnitude of stator flux is proportional to the ratio of the stator voltage & the frequency. Hence, if the ratio of voltage to frequency is kept constant, the flux remains constant.
Also by keeping V/F constant, the developed torque remains approximately constant.

iv) changing the Number of stator Poles:-

∵ $N_s = \frac{120f}{P}$ Here P = no. of poles

This method is generally used for squirrel cage induction motor as squirrel cage induction motor adapts itself to any number of stator poles.
change in stator poles is achieved by two or more independent stator windings wound for different number of poles in same slots.

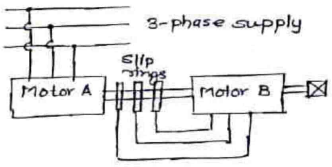
Speed control from Rotor side:-

i) Rotor Rheostat Control :-

This method is similar to that of the armature rheostat control of DC shunt motor. But this method is only applicable to slip ring motors, as addition of external resistance in the rotor of squirrel cage motors is not possible.

ii) Cascade Operation

In this method of speed control, two motors are used. Both are mounted on same shaft so that both runs at same speed. One motor is fed from a 3-phase supply and the other motor is fed from the induced emf in first motor via slip-rings.



iii) By injecting EMF in Rotor Circuit

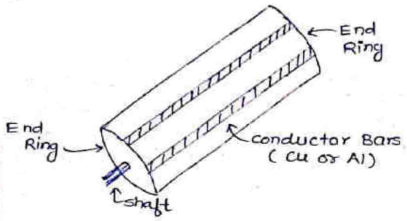
In this method, speed of an induction motor is controlled by injecting a voltage in rotor circuit. It is necessary that voltage (emf) being injected must have same frequency as of slip frequency.

TYPES OF IM:-

- Based on construction:-
  - → Squirrel cage IM
  - → Wound rotor motor
  - → Double cage

} In all, stator construction is same

1. Squirrel cage IM.



- Here conductors ~~are~~ bars are shorted to end ring.
- Conductor bars are skewed wrt shaft.
- Cogging & crawling are two phenomenon occurs in squirrel cage induction Motor.

• Motor Maintenance:-

1. Routine cleaning of dust, dirt, grease, oil from outside & inside motor. Dust can be removed by blowing air (not more than 1.75 bar)
2. Contamination by oil & grease from motor bearing is often cause of insulation failure.

Stator:-
- check for damaged insulation
- discoloured insulation → overheating

3. Check IR of stator & rotor
4. Bearings must be cleaned, lubricated & renewed.
5. Housing must be clean & dry.

Rotor:-
- check for signs of damage & overheating in cage winding & laminated steel core.

6. Cooling fan to be in good condition & well cleant.

Motor maintenance after being flooded:-

1. The main job is to restore IR of stator windings
2. salt contamination to be removed by washing with clean FW.
3. Any grease or oil on winding to be removed by a degreasant.
4. Dry stator winding with an electric heater or lamp.
5. Once windings are clean & dry, apply good quality insulating varnish.
6. Finally carry out IR test.

Q:- Motor overhaul procedure:-

• In motor, very fine air gap is there between rotor & stator. If there is a deviation of shaft, rotor will start touching stator leading to short circuit or burning of winding.
- Before overhaul, check IR of stator winding by multimeter. 1 probe of winding & other to earth & switch in resistance mode

1. Before overhaul, marking on motor housing & wires is very important. This will ensure correct boxing back procedure.
   Also check direction of rotation of motor.
2. Safely remove coupling between motor & pump.
3. Check bearing condition.
4. If insulation of motor is less, clean winding by cleaner. Apply insulation coating & keep a powerful halogen lamp for it to dry.
5. clean cooling fan
6. clean bearing housing & body of motor.

STARTERS

1. DOL starter (Direct online starter):-

The induction motor draws huge current at startup. This starting current can damage the motor windings. ~~In~~ To avoid it, we use starters which protect motor from overloading and overcurrent.

DOL starter is also known as 'across the line starter'. Here motor is directly connected to full voltage through MCCB or circuit breaker and Relay for overload protection. This is why such a starter is used with motor rated below 5 hp. $1\ hp = 746\ W$; $1kW = 1\ J/s$

In direct online starter method of motor starting, the motor stator windings are directly connected to main supply where the DOL protects the motor circuit from high ~~inrush~~ inrush current. (inrush current is initial current drawn by a device when switched on). This inrush current may damage the overall circuit as the initial current is much more higher than the full rated current (about 5-7 times)

Protection offered by DOL starter:-

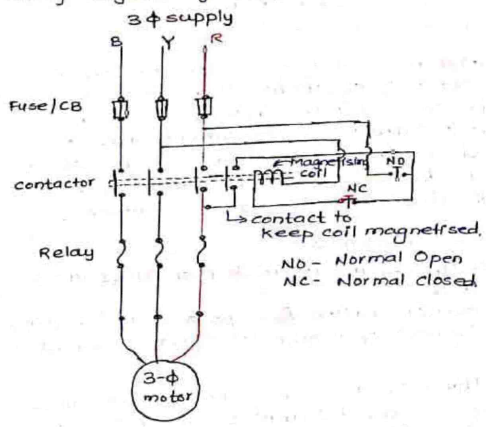
i) Overcurrent Protection:- Circuit breaker or fuses are provided for overcurrent
The overcurrent breaker's rating is kept a bit higher than the rated starting current of motor (∵ starting current is high).

ii) Overload protection:- Relay is provided for overload
The overload relay monitors the current and breaks the current flow when it exceeds a certain limit for a period of time

Parts of DOL starter:-

1. Relay
2. Fuse or Circuit Breaker.
3. Magnetic Contactors :- A magnetic contactor is an electromagnetic switch that operates electromagnetically to switch the power supplyed to the motor. It connects and disconnects multiple contacts conveniently.

Wiring Diagram of DOL:-



↳ contact to keep coil magnetised.

NO - Normal Open
NC - Normal closed

Working Principle:-

DOL works on full voltage or across-the-line technique where the motor is directly connected to the full voltage supply. Since there is no voltage reduction, the starting current is very high that leads to high starting torque.

When the motor starts, it will draw a huge current generally 5 to 6 times that of its rated full speed current. The huge current drawn will cause a dip in the line voltage. The gradual increase in the speed will decrease the current drawn from the lines but not below a certain speed (normally at 75%). Once the motor reaches its rated speed, the current drawn and line voltage will return to normal.

Since the DOL provides high starting current, the motor generates a high starting torque. The torque generated also depends on rating of motor. The load connected to the motor affects the acceleration and the time taken to reach full speed. If the load connected to the motor has high torque then the torque delivered by motor, the motor will not accelerate. Then we need to replace it with a motor having high starting torque.

⇒ starting current may damage the windings of motor. Thus, motors having low power rating are connected through the DOL starter (generally below 5hp.)

Note:- DOL starters do not reduce starting current. They only start motor & provide thermal overload protection.

- Starting Period:- It is the period which Induction Motor takes to reach 85% of Full load Speed

Advantages:-

1.- Simple to design, operate & maintain
2- cheapest & economical
3- Compact
4 - Provides 100 % starting torque (i.e high starting torque)
5. Connects the delta windings of motor.

Disadvantages:-

1.- Starting current is very high so it may damage the motor thus only low rating motor should be used.
2. High inrush current causes a voltage dip in the power lines that can be dangerous for other appliances connected in parallel.
3. Starting torque can be unnecessary in some cases.
4. No control on starting current & torque
5. High starting torque can damage / decrease the life span of motor (due to mechanical stress)

Applications:-

- Jacket cooling water (JCW) P/p
- SW P/p
- Compressor
- FO supply
- FO circulation
- ER Fan

- Star-Delta starter:- (Y-Δ starter)

The starting of an induction motor is associated with high inrush current. This inrush current is 4 to 5 times the Full Load Current (FLC) of motor. and it can damage motor as well as circuit also.
This problem is with high rated motors (generally above 5hp).
To avoid this issue we use star-delta starter.
To start the induction motor, it is connected in star using a tripple pole double throw relay. The phase voltage in star connection is reduced by the factor $1/\sqrt{3}$ & it reduces the starting current as well as the starting torque by 1/3 of normal rated value. Current also reduces 1/3 times

When the motor accelerates, a timer relay switches the star-connection of the stator windings into the delta connection, allowing the full voltage across each winding. The motor runs at rated speed.
The received starting current is about 30 % of starting current of DOL starter & starting torque is reduced to about 25% of the torque available at DOL starter.
→ First motor is started at star connection & later it is shifted to delta connection. This is starting method that reduces the starting current and starting torque.
- The motor must be delta connected during a normal run,

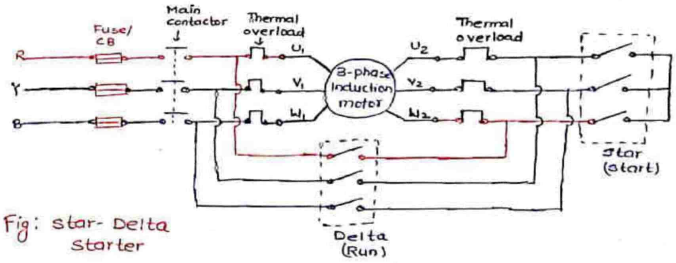


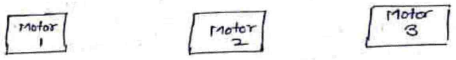
Fig: Star-Delta Starter

• Timing :-
connected in star → for 5 sec
connected in delta → after 5 sec.

• Run-up time:- It is time taken by motor to reach 80% of speed.

Q:- Why 440 volt for motor & 110/220V for lighting ?
- Motor load current are large. Motors have 3-phase loads. A 440 higher 440 volts volts means lesser current for some Power (∵ P = VI) & hence losses & size of cables are lower. Lighting is a single phase load & its load current are small. Hence lower voltage means less insulation in the cable wire.

Sequential starter:-
Sequential starter is used to start the multiple motors in the sequence.
If a motor is assigned particular number to start, then the motors behind it can't be started until this motor is started.



Let there are three motors 1, 2, 3 & assigned sequence is 1 → 2 → 3
From sequential starters (if they are used) then motor 3 can't be started unless motor 2 is running.
Silly motor 2 can't be started unless motor 1 is running.
The NO terminal of 1st is connected to NC terminal of 2nd & so on. & also to MCB of 2nd.

- Soft-Starter:-

Basics (Why we need starter)

Induction motor draws a huge amount of current at starting. This is due to low impedance of the windings of the motor at standstill(rest position)

It is very essential for safe operation of induction motor. It is due to low rotor impedance of the motor in rest position. The rotor impedance depends upon the slip (Relative speed blw the rotor & stator) of induction motor.

The slip of induction motor is not constant & varies throughout its operation, thus the rotor impedance also varies. It is inversely proportional to the slip of motor. i.e

$$\text{impedence} \propto \frac{1}{\text{slip}}$$

{ impedence → it is opposition of current by circuit. It is like resistance but not resistance. Unit → Ω }

At standstill (rest position), the slip of induction motor is max i.e 1. Thus the rotor impedence is minimum. Connecting the motor to power supply draws a huge amount of current in the stator winding due to this low ip impedance called inrush current. The alternating current in the ~~circuit~~ stator generates a rotational magnetic field (RMF) that induces current in rotor windings.

The rotor current generates its own magnetic field that try to cancel its causes & starts rotating in the direction of RMF. Thus the rotor experience torque & as its speed starts increasing, the slip of motor decreases (i.e the rotor RMF speed approaches near stator RMF speed). Since the slip is reduced, the impedance of the rotor increases & the motor starts drawing normal rated current.

The high inrush current is 5-8 times larger than the full load rated current of the motor. Induction motor can't tolerate such amount of current as it can quickly damage or burn the windings, reducing the performance & lifespan of the motor. Such high currents can also cause huge dip the the line voltage which is dangerous for other appliances connected to same line.

- In order to prevent such high inrush current, we use motor starters that reduces the initial current for a short duration. Once the motor gains certain speed, the normal power supply is resumed. It also offers protection against low voltage & overcurrent.

These motor starters are usually used for heavy power rated motors. Small motors below 1Hp doesn't require motor starter due to their high impedance. However they need overcurrent protection which is available in the DOL starter.

Note:- DOL starters do not reduce starting current. They only start motor & provide thermal overload protection.

- Star-delta, Auto transformers, Soft starters help to reduce starting voltage which reduces starting current but their starting torque reduces.

• Soft- starter:- A soft starter is a device that reduces the starting torque & gradually increases it in a safely manner until it reaches its rated speed. Once the motor attains its rated speed, the soft starter resumes the full voltage supply through it.

• It prevents any mechanical tear & jerking due to sudden supplying of full voltage.

- The torque of an induction motor is directional proportional to square of current (i.e $T \propto I^2$) & current depends on supply voltage (i.e $V \propto I$). So the supply voltage can be used to control the starting torque. In a normal motor starter, applying full voltage to the motor generates maximum starting torque which causes mechanical hazards to motor. To avoid this we use soft starters.

• During motor stopping through soft starter, the supply voltage is gradually reduced to smoothly decelerate the motor. Once the speed reaches zero, it breakes the input voltage supply to motor.

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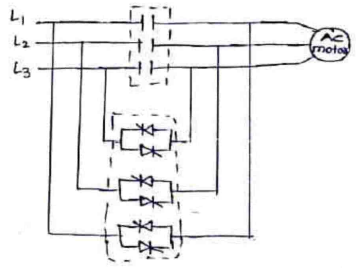
Working:-

The main component of soft starter is thyristors or SCR. These components reduce the incoming voltage to the motor and can allow operators to keep voltage constant until full speed is achieved. These are commonly used in three pairs (TRIACS) to account for each phase of the motor as three phase motors typically require soft starting



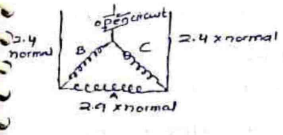
Upon startup, each phase will run through each TRIAC before getting to the motor. The thyristors will reduce the voltage (and therefore current also) and will allow signal to pass to motor. The current is monitored until the motor reaches full speed, where the thyristors are then bypassed by connecting the motor directly to the power source via the contacts (also known as powering the motor 'across-the-line.')

- Speed - Control of Motor:-

→ Single Phasing:-

For proper working of 3 phase induction motor, it must be connected to 3 phase AC power supply. Once these 3-ϕ motors are started, they will continue to run even if one of 3-ϕ supply line gets disconnected.

- The loss of current through one phase in a 3 phase supply is known as single phasing.
- The motor running with a single-phase fault will carry excess current in the remaining supply cables. And this current is generally 2.4 times of normal current.



- Causes of single phasing:-
  - When one or more out of three fuses blows.
  - If one of contractor is open circuited. (Motor have 3 contractor)
  - If a protection device have wrong or improper setting.
  - If relay contacts for motor is damaged.
  - If one of wire for motor circuit is broken.
  - If short circuit in one phase of star connected or delta connected motor.
  - If contactor are coated with due to oxidation & hence not conducting.

• Effect of single phasing:-

- If the motor is in stopped condition, it can't be started as a single phase motor can't be self starter and also due to safety system provided in 3-ϕ motor to protect it from the overheating.
- If the motor is running & single phasing occurs, motor will continue to run (unless provided by additional safety cut-out system) because of torque produced by the remaining two phases which is produced as per the demand by the Load.
- As current in two other phases is more than the normal, they will be overheated which may result in critical damage to the windings.
- Single phasing reduces speed of motor and its rpm fluctuate
- Abnormal noise and vibration will be there (it is because of uneven torque produced by other two phases)
- If someone comes in contact with motor, he/she may get electrical shock.
- It may cause overloading of power generation machine i.e auxiliary machine.

- Protection from single phasing:-
- All motors above 500 kW are to be provided with protection devices or equipment to prevent any damage due to single phasing (except for motors of steering gear system.) on steering gear system on single phasing alarm will come but motor will not stop as continued operation of steering motor is essential for safety or propulsion of ship.

→ Protection Devices are:-

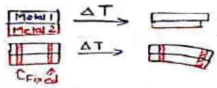
1. Electromagnetic Overload device:-

In this device, all the three phases of motor are fitted with an overload relay. If there is an increase in the value of the current, then this relay activates automatically and the motor trips.

2. Thermistors:-

Thermistors are small thermal devices which are used together with an electromagnetic overload relay. The thermistors are inserted in the windings of motor. Any increase in current will cause heating in windings, which is detected by thermistors that sends signals to amplifier.
The amplifier is connected to the electromagnetic relay. As soon as signal is received from thermistor about overheating, this amplifier increases the current value in the coil of an electromagnetic relay which activates the trip and motor stops.

3. Bi-metal strip:-



Here bimetallic strip is placed in such a way that it detects the overheating in the circuit. As soon as overheating is detected, this bimetallic strip is tries to expand and because two metals have different coefficient of expansion, the strip attempts to bend towards the metal having a high coefficient of expansion (α) and finally completes the trip circuit and the motor trips.

- Detection of single phasing fault.
- Unusual Humming sound coming from motor
- Higher vibration in motor than usual
- Smell of hot & burnt copper (insulation)
- Visible light smoke/ fumes from motor casing.

- Actions for single phasing fault:-

1. If single phasing fault is confirmed, stop motor immediately and start the stand by motor.
2. Do proper visual inspection of motor winding and check earth continuity & Resistance Test.
3. Once the problem is located, rectify it.
4. Before putting motor on load, do a test run and check all the rated parameters (i.e voltage, current, rpm, temp etc.)

• VFD (Variable Frequency Drive):-

A variable frequency drive is a semiconductor based motor starter. It can safely start & stop electric motors as well as fully control the speed of motor during its operation. It can control the supply voltage as well as its frequency. Since the speed of induction motor depends on the supply frequency, VFD is mostly used for varying the speed of motor during its operation.

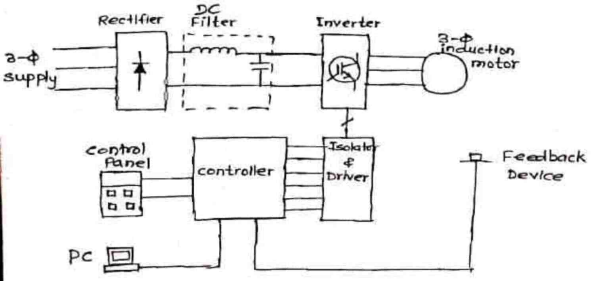


Fig:- Block Diagram of Typical VFD (AC Drive)

A VFD has three circuits i.e Rectifier, DC Filter & Inverter. First, the AC line voltage is converted into DC using the rectifier circuit. It is then smoothen by passing through the DC filter. The steady DC voltage is then converted into AC using the inverter circuit. The inverter's logic circuit control circuit allows to vary the voltage as well as frequency of the output AC voltage. It can be used to smoothly increase the speed of the motor from zero (0) RPM to its rated speed & sometimes above its rated speed by increasing the frequency. Therefore it offers a complete control over the torque speed characterstics of the motor. It uses IGBt to do so.

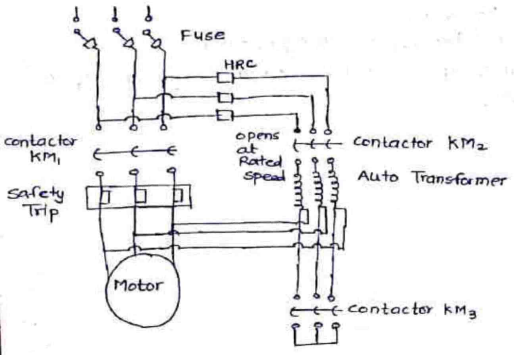
• The VFD can vary the speed of the motor during its operation by varying the frequency of the supplied voltage. Therefore it is used in applications where the speed of motor needs to be varied.

Eg:- i) A fan speed based on temperature

ii) A water pump speed based on the pressure of the incoming water.

- Auto - Transformer starter:-

Main supply 440 V



Note:- HRC fuse is not a part of starter circuit, starter doesn't have short-circuit operation.

- Starter only reduces high starting current and sustained overcurrent protection by thermal bimetallic strip.
- Starters

  Upto 5 HP → DOL starter

  5-20 HP → star-Delta starter

  20 HP & above → Auto-Transformer starter

- Working:-

HRC switch must be ON with the start button pushed 'ON' contactor KM_2 & KM_3 does close together. The motor gets reduced voltage supply as per tapped position of Auto-transformer. The motor starts with reduced starting current. If it can overload torque on motor. The reduced voltage in this case can be changed by varying the taped position of transformer which was not available in star-Delta.

As the motor speed up and reaches 80% of rated speed, a timer opens the contactor KM_3 and closes the main contactor KM_1. There is no possibility of short-circuit or open circuit in λ-Δ (star-delta) starter.

If KM_3 is open & KM_1 get to close through auto-transformer which will not act as transformer but as a reactor coil, there will be slight drop in voltage. motor will be never without power supply so no-open circuiting.

- Main 440 V reduced voltage through transformers never be short-circuit if KM_3 is yet to open & KM_1 closes because of No short-circuit point. As the motor reaches a rated speed as second timer opens contactor KM_2 thereby taking Auto-transformer out of circuit.

• Self - Induction:-
It is a phenomenon in which emf is induced in a coil because of current flowing in same coil.

• Mutual - Inductance:-
It is a phenomenon in which emf is induced in a coil because of current flowing in another coil.

Note:- Auto-transformer works on principle of mutual Inductance.

* Steering Gear safetics
• Hydraulic safeties:-
• Level switch, Low level, low low level alarm for hydraulic tank
• Relief valve
• Manual bypass valve
• Low pressure valve
• High lub oil temp cutout
• Low level cutout

• Electrical safeties:-
• Electrical & Mechanical stopper for rudder
• Electrical motor overload alarm
• Power failure alarm
• High temp alarm
• self starting after power failure
• short circuit trip
• Phase failure alarm
• 200% insulation in motor (i.e extra protection ∵ steering gear is essential load)

IGBT (Insulated Gate Bipolar Transistor)

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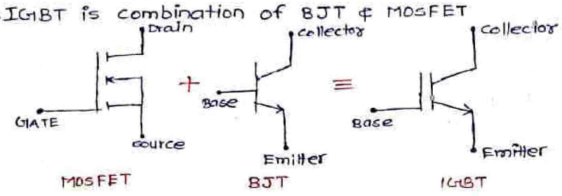
- IGBT is used in the invertor in the VFD.
- IGBT is combination of BJT & MOSFET

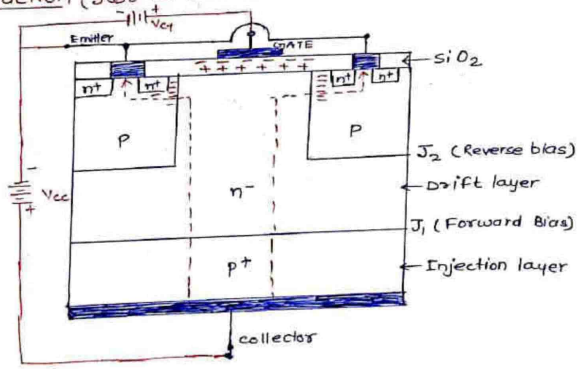


- IGBT is also known as Metal Oxide Insulated Gate Transistor (MOGIST), Gain Modulated Field Effect Transistor (GEMFET), Conductively Modulated Field Effect Transistor (COMFET), Insulated Gate Transistor (IGT).

~~Construction~~:- Advantage

- IGBT is a three-terminal semiconductor device
- IGBT has output switching & conduction characterstics of a bipolar transistor but it is voltage to controlled like a MOSFET. This means it has the advantage of the high current handling capacity of a bipolar transistor with the ease of control of a MOSFET.

Construction (Just for IGBT)

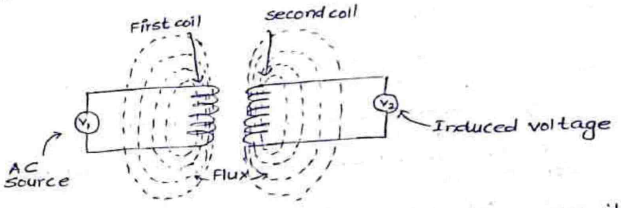


- Here we are connecting V_{cc} Battery to have biasing b/w emitter & collector
- To turn ON IGBT we connect Battery V_{GI}
- Because V_{cc} collector is +ve w.r.t emitter, current will not flow from collector to emitter ($\because J_2$ is Reverse & J_1 is Fwd biased)
- & if we increase V_{GI} voltage of Capacitance (SiO_2) -ve & +ve charges will be separated. Higher the V_{GI} voltage, larger will be charge carrier
- Due to V_{GI}, charges are formed & due to which a channel is formed which will allow flow of current to emitter (shown by dotten lines)

TRANSFORMERS

A transformer is defined as an electrical device that transfers electrical energy from one circuit to another through the process of electromagnetic induction. It is generally used to increase (step-up) or decrease (step-down) voltage levels between circuits.

Working Principle:-



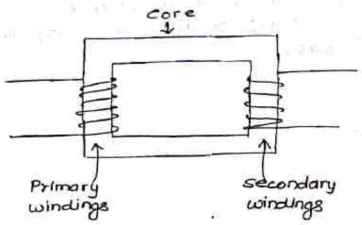
If one winding or coil is supplied by an AC source, it will produce continuous changing and alternating flux that surrounds the winding.

- If another winding is brought close to this winding, some portion of this alternating flux will link to the second winding. As this flux is continuously changing its amplitude and direction, there must be a changing flux linkage in the second winding or coil.

According to the Faraday's law of electromagnetic induction, there will be an EMF induced in the second winding. If the circuit of this secondary winding is closed, then the current will flow through it.

- The above diagram is theoritical and not possible practically because in the open air only a very small portion of the flux produced from the first coil will link the second coil. So the current that flows through the closed circuit connected to the secondary winding will be very small and it will be difficult to measure.

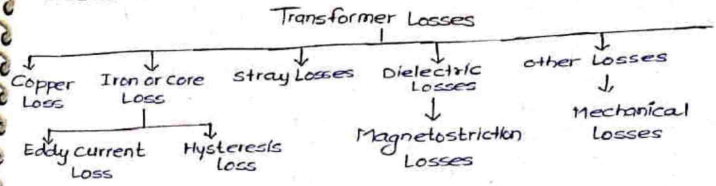
To avoid this, we use core type transformer practically. This provides a low reluctance path common to both of the windings. (Reluctance - It is Resistance/opposition offered by a magnetic circuit to magnetic flux)



The purpose of the transformer core is to provide a low reluctance path, through which the maximum amount of flux produced by the primary winding is passed through and linked with the secondary winding.

- The current that passes through the transformer when it is switched on is known as transformer inrush current.

Losses in Transformer:-



Copper loss :- Copper loss is also known as winding loss. Since the material used for windings is generally copper and copper will offer some resistance due to which there will be some power loss ($P_{loss} = I^2R$) so the loss is known as copper loss.

$$P_{cu} = I_1^2 R_1 + I_2^2 R_2$$

It is clear that copper loss is proportional to the square of the current. As the current depends upon the load connected to the transformer. The copper loss varies with variation in load and hence it is also called 'variable loss.'

Note:- Copper loss is variable loss.

• Iron or Core Losses :-

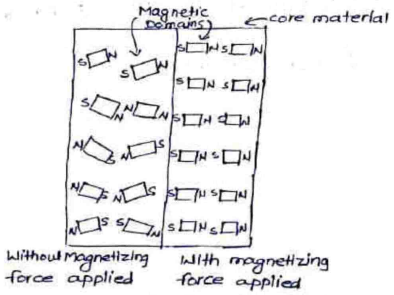
The losses in the magnetic core which links both the windings by magnetic induction are called iron or core losses of the transformer. The iron practically remains constant under all load conditions i.e they are independent or irrespective of the load condition. Hence the iron losses are also called constant losses.

Note:- Iron losses are constant losses.

Two types of Iron losses

i) Hysteresis loss ii) Eddy current loss

i) Hysteresis loss:- Since the given supply given to the transformer is alternating, the nature of magnetic flux in the core will be also in alternating nature. Due to this, the randomly oriented magnetic domains which behaves like a small magnet will be oriented in the direction of mmf (magnetomotive force) applied. As the nature of magnetic flux applied is alternating, the core material undergoes a cycle of magnetization and demagnetization effect.



Due to this, the one directionally oriented domains will take the reverse direction for every cycle. So that there will be extra energy consumed in the form of power loss known as 'Hysteresis loss.'

Eddy current loss :- The core of the transformer is made up of conducting material. The laminated sheets which forms the core limb will induce their own emf in each sheet when subjected to alternating flux. This results in the circulation of currents in each sheet and causes power loss known as 'Eddy current loss'.

Since the frequency and flux density of the core material remains constant, these losses are also called 'constant losses'

Note:- • Eddy current loss is constant loss.
• The total iron or core loss is sum of both hysteresis and eddy current loss.

- Minimization of Iron losses:-
• The hysteresis losses of the transformer can't be eliminated completely but can be reduced by choosing a low hysteresis coefficient material like silicon steel.
• The eddy current losses can be reduced by making very thin laminations of silicon steel.

• Stray loss :-

The transformer works on the principle of mutual induction i.e emf induced in the secondary winding is by linkage of flux produced by the primary winding. But, in practice, all the flux produced by the primary doesn't link with secondary winding completely. There will be wastage of flux which does not link with secondary winding as the leakage. This leakage flux cause some losses in the transformer known as 'stray Loss'.

• Dielectric Loss :- As the name suggests, these losses depends on dielectric strength of the insulating medium used in the transformer (generally oil). Due to the continuous operation of the transformer, the dielectric material used, losses its dielectric strength and causes some losses which reduce the overall efficiency(η) of the transformer. These losses can be minimized by periodic testing of the insulating material used.

• Why Transformer is rated in kVA instead of KW

We know that there are two types (mainly) of losses in the transformer.

i) Copper Losses

ii) Iron Losses or Core Losses or Insulation Losses

→ Copper losses (I^2R) depends on the current which passes through transformer winding while iron losses or core losses or Insulation losses depends on voltage i.e total losses depends on voltage (V) & current (I) which is expressed in Volt Ampere (VA) and not on load power factor (p.f). That is why the transformer rating may be expressed in VA or kVA & not in W or kW.

Also

When manufacturers design a transformer, they have no idea which kind of load will be connected to the transformer. The load may be resistive (R), inductive (L), capacitve (C) or mixed load (R, L & C).

It means, there would be different power factor (p.f) at the secondary (load) side on different kind of connected load depends on R, L & C.

Hence transformer are rated in VA instead of W.

- Types of Transformers:-

1. Based on Transformers core:-

One of the main difference between a core-type transformer & shell type transformer is how the winding surrounds the core. In shell-type transformers, the core surrounds the transformer's windings, while on a core type transformer, the windings wrap around the core.

a) Core Type Transformer:-

A core type transformer has two cylinders & two horizontal bars forming the frame. The magnetic core is a square form with a common magnetic circuit. The cylindrical coils (HV & LV) are located on two cylinders.

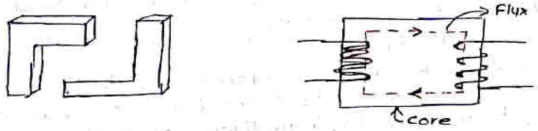
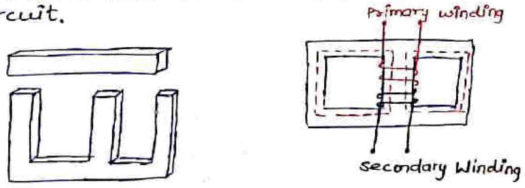


Fig:- Core Type Transformer

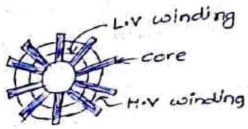
b) Shell Type Transformer:-

A shell type transformer has a center cylinder & two outer cylinder. Both the HV & LV coils of it located on a centre column. This transformer has a dual magnetic circuit.



c) Berry Type Transformer:-

In berry type transformer, magnetic circuit look like a wheel. The metal shell is tightly fixed & filled with oil inside.



2. Type of Transformer based on voltage conversion:-

i) Step-up Transformer:-

The step-up transformer helps the voltage increase on on the output side because the number of turns on the secondary winding is always more than the no. of turns on the primary winding. A high voltage is developed on the secondary side of transformer.

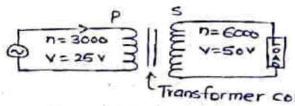
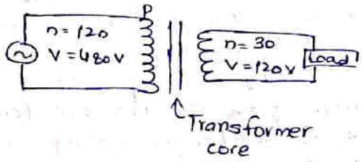


Fig: step-up transformer

ii) Step down transformer:-

A step down voltage transformer reduces the output voltage. It converts high voltage, low current power into low voltage, high current power.

The no. of turns on the secondary winding is less than the no. of turns on the primary winding so less voltage is generated at the transformers output (secondary) end.



3. Types of Transformers based on its purpose.

a) Power Transformer:

These are generally used in transmission of higher voltages. Most of power transformers are rated above 200MVA. They are installed at the generating stations, transmission substations, which need a high capacity transformer.

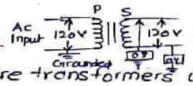
A power transformer is designed for maximum efficiency of 100% & is larger than the distribution transformer.

b) Distribution Transformer:-

A distribution transformer, also known as consumption transformer, is responsible for switching from a low medium voltage source to the voltage used for home appliance & industrial equipments.

Distribution transformer are intended to reduce the voltage for distribution for users or commercial use. This machine has good voltage regulation & can operate 24 hours a day with maximum efficiency at 50% load.

c) Isolation Transformer:-



Isolation transformers are transformers with the primary and secondary windings independently of each other, & there is only a magnetic flux relationship between them. Unlike autotransformers, isolation transformers are composed of primary & secondary windings linked only through a magnetic field. The windings are separated so that they are electrically independent & form the distinct points of the isolation transformer.

- Any point on the secondary coil has a zero relative to the ground. So when we touch any point on the secondary winding, there will be no shock. The voltage is different in the 2 points of the secondary winding, which is most significant advantage of the isolation transformer. It helps to reduce the risk of electrical leakage in the device housing & provides safety during use.
- Each primary & secondary winding has a different volt-ampere characteristics according to the ratio of turns on the primary & secondary windings.

d) Instrument Transformer:

It is an electrical used to transform current as well as voltage level. The most common use of instrument transformer is to safely isolate the secondary winding when primary has high voltage & high current supply.

The measuring instrument, energy meters, or relays connected to the transformer's secondary side will not get damaged.

Two types of instrument Transformer

i) current Transformer

ii) Potential Transformer or Voltage Transformer

e) current Transformer:-

The current transformer is used for measuring electricity and also for protection. When the current is high to apply directly to the measuring instrument, the current transformer is used to transform the high current into the current required value in the circuit.

The transformer's primary winding is connected in series to the main supply & the various measuring instruments like ammeter, voltmeter, wattmeter or protective relay coil to measure & control electricity. They have accurate current ratio & phase relation to enable the meter accurately on the secondary side. The term ratio is significant in current Transformer.

f) Voltage or Potential Transformer:-

Potential Transformer is also known as voltage Transformer. It is used for measuring high voltages. To do so, the primary winding of the transformer is connected across the high voltage lines. On the secondary side, all the measuring tools & instruments such as meters are connected to measure and analyse the voltage level.

The primary winding is earthed or ground where potential transformer step up the value of voltage to a safe level.

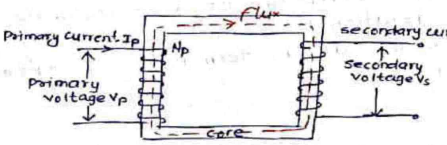
Types of potential transformers

- Electromagnetic: Wire Wound Transformer
- Capacitor Voltage Transformer (CVT):- It uses capacitor voltage divider circuit
- Optical Transformer:- Based on electrical property of optical materials.
- The instrument transformer isolates the measurement circuit from the high power circuit to reduce the risk of getting shocked.

4. Based on Windings:-

i) Two winding Transformer:-

Such type of transformer has two separate windings for each phase i.e primary winding & secondary winding.



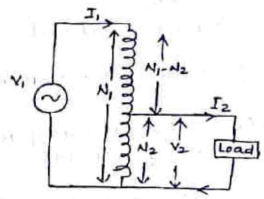
The primary winding is supplied with the AC input while the secondary is connected with the load.

These two winding are electrically isolated but magnetically coupled.

The emf induced in the secondary winding is due to changing magnetic flux caused by the varying current in the primary winding also known as mutual induction. So the output voltage is purely due to induction.

The output voltage depends on the turn ratio of its both windings & it can increase or decrease the input voltage.

ii) Auto-Transformer:-



Autotransformer has only one winding per phase, which is divided into two parts i.e primary & secondary winding.

The winding of autotransformer has 3 tap points, two of them are fixed while the third one is a variable tap point

The variable tap point can be moved to increase or decrease the number of secondary turns. Thus increasing or decreasing the output voltage.

It can be used in either configuration to step-up or step-down the input current & voltage.

The output voltage can be decreased (step-down), if the supply is connected to the fixed terminals. In reverse configuration that is if the supply is connected to the variable tap point, the output voltage will exceed the input (step up)

The secondary winding is electrically connected to the primary, so there is no electrical isolation but it decreases the magnetic leakage flux.

The emf in the winding is also induced due to self induction. So the output voltage is the resultant of conduction & induction.

Based on Insulation Used:-

i) Dry Type Transformer :-

This type of Transformer doesn't contain any liquid cooling system. The windings are covered in epoxy resin to protect it from humidity. So the only cooling medium is Air.

As air is not a good insulator, so dry transformer use large coils & windings material to compensate for high temperature & ratings. This is why dry-type transformers are not available in the rating above 33KV.

Because of poor cooling system, they tend to overheat which makes their lifespan short.

Also, to ensure air circulation, regular inspection is required to maintain its working condition.

They are used in the in-door environment because they are less hazardous to catch fire. They are easy to install.

ii) Oil immersed Transformer:-

Such type of Transformers utilizes combustible oil for cooling purpose. Oil offers better cooling then the dry type transformer which is why they are used for high rating transformers in bars outdoor environments.

The disadvantage of this type of transformer is that they are large in size because of oil tank & the sensors required for the inspection of humidity etc. It contains flammable oil so they are not suitable for an indoor environment.

Based on Phase:-

i) Single phase Transformer:-

Single phase transformer is a two winding transformer having one primary winding & one secondary winding. The transformer is used for single phase application like microwave oven, cell phone charger.

They have two input terminals connected with primary windings & two output terminals connected with the secondary windings.

ii) Three phase Transformers:-

Three phase transformers has 6 windings in which 3 of them are primary winding & 3 are secondary windings for each phase. It has 12 terminals evenly divided on both sides (2 for each phase) considering star & delta connection. You can use 3 single phase transformer together instead of 3-phase transformer.

They are used for power transmission & power distribution for domestic & commercial uses.

Contactor:- A contactor is an electromechanical control device that is used to make or break the connection b/w the load & power supply. The use of contactor is similar to the relay. But the device used for higher current carrying application is known as contactor & the device used for lower current application is known as Relay.

A contactor is controlled by a circuit which has a much lower power level then the switched circuit. Contactors are oftenly used for 150 Hp motor.

A contactor has several contacts as per the application and load. Generally these contacts are normally open (NO) contact. And hence the load is shut off when the coil of contactor is de-energized. But the contactor can design for both normally open & normally closed applications. The most common application of contactor is in the starter that is used to turn ON & OFF the equipment like motor, transformer etc.

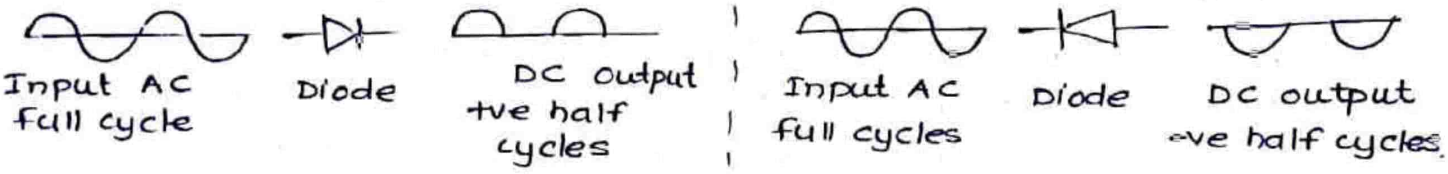
• Rectifier:- A Rectifier is an electrical device that is made of one or more than one diodes that converts the alternating current (A.C) into direct current (D.C). It is used for rectification

Rectification:- Rectification is the process of conversion of Alternating current (which periodically changes direction) into direct current (flow in a single direction).

Types:-

1) Half wave Rectifier:- A type of rectifier that converts only the half cycle of alternating current (A.C) into direct current (DC) is known as half wave rectifier

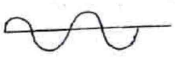
- Positive half wave Rec.
- Negative half wave Rec.



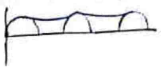
Note:- In all types of rectifiers, a half wave rectifier is the simplest of them all as it is composed of only a single diode

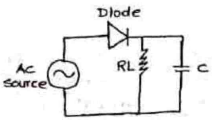
• A diode allows the current flow in only one direction known as forward bias. A load resistor RL is connected in series with the diode.

Input



output





halfwave Rectifier output with capacitor

The output of half wave Rectifier has too many ripples (small waves) & it is not very practical to use this output as DC source. To smooth this pulsating output, a capacitor is introduced across the resistor. The capacitor will charge during the positive cycle and discharging during negative cycle to give out a smooth output signal.

- Such types of rectifiers waste the power of AC input's half cycle.

ii) Full wave Rectifier:-

A full wave rectifier converts both positive and negative half cycles of AC (Alternating Current) into DC (Direct Current). It provides double output voltage compared to the halfwave rectifier.

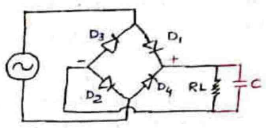
- A full wave rectifier is made up of more than one diode.

2 Type of Full wave Rectifiers are

i) Bridge Rectifier

ii) Center-Tap Rectifier

i) Bridge Rectifier:- A bridge rectifier uses four diodes to convert both half cycles (positive & negative) of the input AC to DC output



During input positive half cycle, the diode D_1 & D_2 becomes forward bias while D_3 & D_4 becomes reverse bias. The diode D_1 & D_2 form a closed loop that provides a positive output voltage across the load resistor RL.

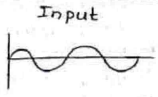
During the negative half cycle, the diode D_3 & D_4 becomes forward bias while D_1 & D_2 becomes reverse bias. But the polarity across the load resistor RL remains the same and provides a positive across the load.

- The output of full wave rectifier has low ripples compared to half-wave rectifier but still, its not smooth & steady.

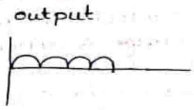
In order to make the output voltage smooth & steady, a capacitor is placed at output. The capacitor charge & discharge which make smooth transition blw half cycles.

Without Capacitor

Input

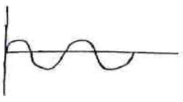


output

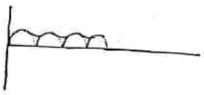


With capacitor

Input



Output



• Working of Bridge Rectifier Circuit:-

- Due to arrangements of diodes Recti bridge Rectifier got its name.

In bridge rectifier, voltage that is given as input can be from any source i.e it can be from transformer, or it can be from fro mains.

- In the first phase of working of rectifier, during the positive half cycle, diodes D_3-D_2 gets forward biased & conducts. Diodes D_1-D_4 gets reversed biased and do not conduct in this half cycle, acting as open switches. Thus we get a positive half cycle at the output. Conversely in the negative half cycle, diodes D_1-D_4 gets forward biased and starts conducting whereas diodes D_3-D_2 gets reversed biased and don't conduct in this half cycle.

Again we get a positive half cycle at the output. At the end of rectification process; the negative part of AC current is converted into positive cycle. The output from the rectifier is two half-positive pulses with the same frequency and magnitude as that of the input.

Average voltage at the output of the full bridge rectifier is double than that of the half-bridge rectifier.

The output voltage waveform after the rectification is not a proper DC, so a capacitor is installed to make it into proper DC. Smoothing or reservoir capacitors that are connected in parallel with the load across the output of the full wave bridge rectifier circuit increases the average DC output level to the required average DC voltage at the output because the capacitor not only acts as a filtering component, but it also periodically charges & discharges effectively increases the output voltage.

• Capacitor charges till the waveform goes to its peak and discharges uniformly into the load circuit when waveform starts going low. So when the output going low, capacitor maintains the proper voltage supply into the load circuit & hence creating DC.

• Main switch Board (MSB) safeties:-

According to SOLAS chapter 2.1 Part D Regulation 45 & 41 except trips:-

1. Busbar material is highly conductive (copper) & should withstand thermal stress & electromagnetic force
2. Tag must be pasted for high voltage with sign of danger.
3. Minimum 15 (15 mm) thick non-conducting (Rubber) mat should be in front & back side of MSB.
4. Fuses & circuit breaker should be there.
5. No pipelines should be nearby MSB.
6. MSB should be 0.6 m away from the Bulkhead
7. Insulated hand grips & hand rails should be provided.
8. Cable entries at the bottom of MSB should be scaled with non-flammable material to exclude the dirt & acts as fire stop.
9. Earth fault indications should be there on switchboard with both 220 V & 440 V with a test switch.
10. MSB earth bar must be securly bonded to the frame of the board & to the ships hull.
11. Panels should be interlocked with supply or it shall not be opened until breaker is off.
12. Surroundings should be free of any flammable material.
13. Portable CO_2 fire extinguisher shall be kept nearby MSB.
14. Dead front & insulated handles should be used.
15. Proper ventilation arrangements should be provided
16. Test switch must be given for checking the lamp on MSB.
17. Circuit breaker, Earth fault indicator, Undervoltage relay, Reverse power trip, preferrential trip, Overcurrent trip, short circuit trip, fuse isolators are provided.

• MSB Maintenance:-

1. Contacts should be checked for any damages & dirt.
2. contacts should be cleaned properly.
3. Using industrial vacuum cleaner MSB should be made dirt free but to do this, MSB should be dead completely.
4. Apply electro clean on the contacts
5. Never scrap or file the contacts. Always change it whenever required.
6. Check all light indications in order
7. check all handles & switches for proper functioning
8. check all interlocks for their functioning
9. check fuses
10. check all connections for tightness
11. All wirings should be checked properly.
12. Check all panels doors are properly earthed
13. Apply electrical lubricant to the moving part contacts
14. Loco

• Engine Room Crane safeties:-

1. limit switch (Port, Stbd, Fwd, Aft, lowering, hoisting) should be checked.
2. Mechanical stopper in case of limit switch fails.
3. Overload trip, thermal protection trip for motor.
4. Electromagnetic brake- Release by electric power (Fail safe arrangement)
5. Rail guard over pulley
6. Mechanical Locking arrangement for rough weather.
7. Locking arrangement and hook for safe carriage of load.
8. clear marking of safe working load on crane.
9. Breakers at various place, one in E/R, other in ECR
10. It shall operate in 5° list & 2° trim.

Q:- ACB safeties:-

Ans 1. UV coil (set at 15% of rated voltage)
2. Overcurrent
3. Longer time delay (105~200 % of FLC)
   Trip time 20~120 sec
4. Short time delay (200~600 % of FLC)
   Trip time 0.1~1 sec
5. Instantaneous (1000% of FLC)
   Instant trip

- Arc contact
- Arc chute
- Arc runner
- Simultaneously closing of all 3 contacts
- Reverse power trip
- Preferential trip

• Thermal Relay (Electro thermal Relay)

A Thermal relay is made up of bimetallic strip (i.e made up of two metals having different thermal expansion coefficients).

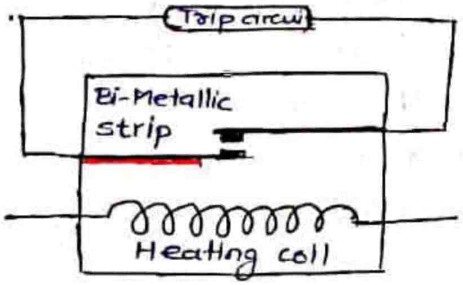


Fig:- Thermal Relay (overload Relay)

When the current flows through the conductor, it produces heat. Due to which the temperature of the bimetallic strip rises and it expands. The metal having high thermal expansion coefficient expands more than the other metal. Due to which the strip bends & closes the contacts to usually activate the trip circuit

• Thermal relay are generally used for electric motor protection.

• Reverse Power Relay:-

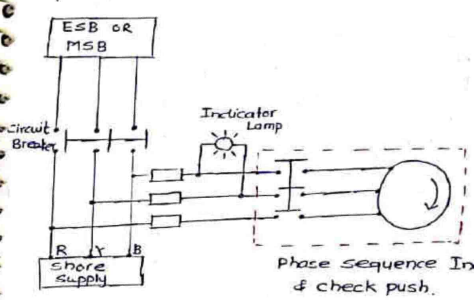
The reverse power relay is a directional protective relay that prevents power from flowing in the reverse direction. The relay is used in installations where a generator runs in parallel with the utility or another generator so as to prevent power from the busbar or another generator from flowing back to the active generator when its output fails.

The relay monitor the power from the generator and in case the generator output falls below a preset value, it quickly disconnects the generator coil to avoid power from flowing into stator coil.

When prime mover fails, the generator stops producing power & may instead drawing power from the other parallel source and gives motoring effects. The reverse power relay senses any reverse direction of power flow & disconnects the generator to avoid any possible damage.

• Shore Supply:-

- Shore supply is generally required so that ship's generator & their prime movers can be shut down for major overhaul during a dry docking period.
- Shore supply connection box is located at the entrance of accomodation or in the emergency generator room.
- The connection box must have suitable terminals to accept the shore supply cable, including earthing terminal to connect the ship's hull to the shore's earth point.



- The connection box must have a circuit-breaker or a switch and fuse to protect the cable linking the connection box to the main switchboard, with a data plate showing details of ship's electrical system (voltage & frequency), including the method for connecting the shore supply cable.
- A voltmeter is fitted to indicate polarity of a direct current shore supply. For an alternating current shore supply a phase sequence indicator is fitted to indicate the correct phase sequence to supply.
- At main switchboard, an indicator is provided, usually a lamp, to indicate that the shore supply is available for connection to busbar via a connecting switch or circuit breaker
- It is not normally possible to parallel the shore supply with the ship's generators & it should never be done.

- The ships generators must, therefore, be disconnected before the shore supply can be connected to MSB or ESB.
- Normally, the shore supply switch on MSB is interlocked with the generator supply breakers so that it can't be closed if the generators are still connected.
- When the incoming shore supply cable is connected and energised, the phase sequence indicator, when operated may indicate a reversed phase sequence. This is overcome by interchanging any two leads of the shore supply cable at the connection box.
- Incorrect phase sequence will cause the ship's motor to run in the reverse direction. & it is dangerous. So, while doing this ensure that the shore supply is cut-off.
- The power supply from ashore may have different frequency or current or voltage of that of ship's system
- A higher frequency will cause motor to run faster, overloaded & overheat while a higher voltage will generally cause equipment to draw excess current & also overheat. It will also cause motor to accelerate more rapidly and this may over-stress driven loads.
- The lower voltage may cause motor to run slower & may cause motor to stall.
- If the shore supply frequency differs from ship's normal frequency, the shore supply voltage should differ in the same proportion.

$$\frac{V_{ship}}{V_{shore}} = \frac{f_{ship}}{f_{shore}}$$ (Ratio of ship to shore)

- Insulation Cables:-
- Electric Cables:-
- Current Rating of Cable:- The current rating of a cable is the current that the cable can carry continuously without the conductor exceeding 80°C with an ambient air temperature of 45°C (i.e a 35°C rise)
- The voltage drop in cables from MSB to the appliance should not exceed 6% (in practice it is about 2%.)
- The cables installed must comply with both the current rating and voltage drop limitation.

Insulation Resistance :- Low Voltage (LV) > 1MΩ

High voltage (HV) > 10MΩ

- Before starting shore supply, emergency generator should be put in manual mode & other generators should be off.
- Once blackout happens, then only shore supply to be made ON.
- An interlock is provided which do not let shore supply come on load if main power or emergency power is ON.

• Electrical shock:- (First Aid Treatment)

1. Isolate the person from electrical supply without endangering yourself.
2. Check for breathing and heart beat, a severe electrical shock will stop the heart.
3. Perform cardiopulmonary resuscitation (CPR) i.e mouth to mouth resuscitation & heart massage.

Shaft Earthing:-

→ In this we electrically isolate the propeller shaft from hull.

• Now as propeller rotates, static charges gets developed which creates potential difference between shaft & hull.

• If potential difference is developed & shaft is not earthed, spark erosion will take place & it will result in pitting of bearing.

- To avoid electrolytic corrosion of shaft, slip ring is clamped to shaft & earthed to hull via brushes.

• This shaft earthing consists of graphite brushes where one end is connected to hull & other end to voltmeter.

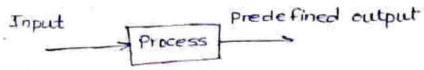
• When ship earthing is OK, it will show below 50mV

• We also connect the rudder stock via bonding cable to hull to equalize pd blw rudder & hull

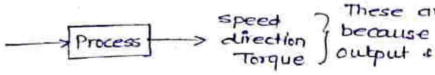
• Routine checks

- clean slip rings & brushes on regular basis
- Record output current & all voltages on daily basis (ICCP)
- check reference electrode voltage on daily basis.
- check & clean the slip rings & brushes of propeller shaft every week.
- Inspect the rudder stock earth strap every month.

- Open Control loop



eg:- Take fan as process



- Lets take 1 process variable & see how to control it.

- So here regulator control the current & voltage to vary speed.
- Set point can be defined as desired value of process variable.

eg:- If we set speed 1, we want out process variable to become 1

- This is open control loop.
- Here we do not aim for process variable to become equal to set point.
- Change in set point will produce desirable change in the process variable.

INSULATION :-

Insulation is very important as it protects cables from the harsh environment.

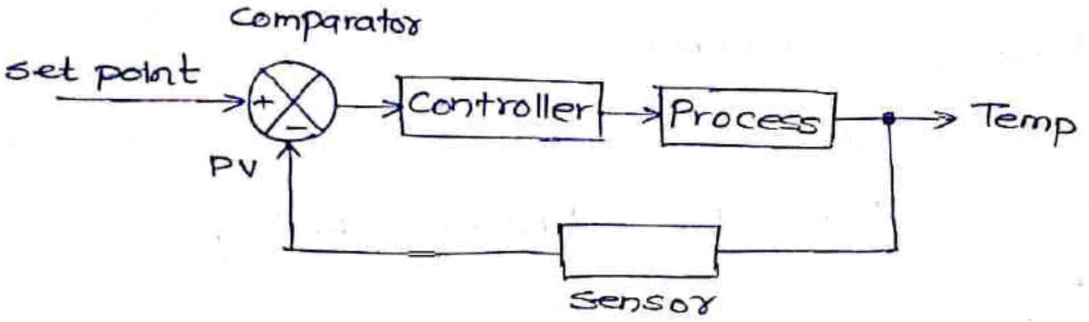
Insulation class

class	Temp limit (max.)	Materials
A	105°C	cotton, silk, paper
B	130°C	mica, glass, fibre, mica products
E	120°C	
F	155°C	Glass, fibre
H	180°C	Wire enamels with a base of pure polymide.

• Closed contrd loop:-

Lets take example of Air condition

• Here process variable is temperature
• Lets see how to regulate this process variable at desired setup.

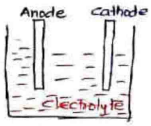


• We can see that we have a sensor which senses temp & sends this value to comparator.
• Comparator continuously compares set point to feedback of process variable
• The error between both are sent to controller
• Sometimes between controller & process, there is actuator.

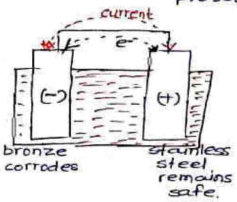
Impressed Current Cathodic Protection (ICCP):-

Corrosion by sea water is an electrochemical process in which the ship's hull acts as electrode and sea water as electrolyte

ICCP is a cathodic protection system installed on ship to protect hull corrosion.



When two similar metals are in contact with each other in the presence of the corrosive medium (electrolyte), the more active metal acts as ANODE and undergoes corrosion and the less active metal acts as CATHODE and is protected by CATHODIC PROTECTION.



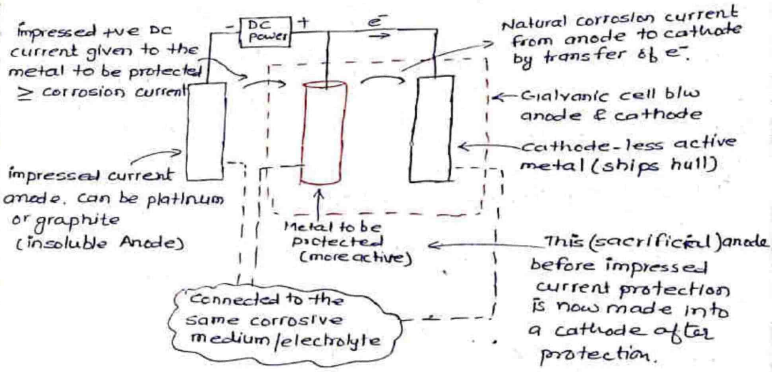
If these two metals are placed in sea water and are in direct electrical contact, a current will pass through the electrolyte from more active metal (anode) onto the least active metal (cathode). This electrical current is referred as corrosion current and is nothing but a metal ion & electron transfer process from the anode, which dissolves and passes into the solution. This simple cell where the corrosion process takes place is called Galvanic cell.

→ Metals such as Aluminium, Magnesium & Zinc are active in nature as compared to steel & have a lower reduction potential.

- The non-uniformity of mild steel in the hull of ship, along with factors such as non-uniformity of hull plate, thickness, paint thickness & quality, variation in the ship structure welding seams, dissimilar metals & oxygen content in the seawater combine to cause areas in the hull to work as cathodes & anodes & thereby forming a galvanic cell.

What ICCP do:-

It makes the hull to remain always cathode by keeping the potential difference to a minimum and introducing a current opposite to natural corrosion current, thereby protecting the anode and avoiding current corrosion.



In the ICCP, the metal to be protected is connected to an insoluble anode and current is passed during using a DC source opposite to the corrosion current, so that the corrosion metal gets converted from anode to cathode and is protected from corrosion. This insoluble anode can be either platinum, platinized titanium or any other inert elements.

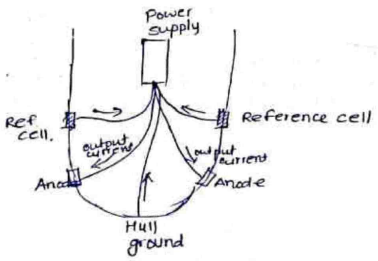
In fig. under normal circumstances, without the insoluble anode, a corrosion current is setup which corrodes the anode, but here if we pass DC current opposite to the natural corrosion current between the anode and cathode.

This DC current has to be equal or slightly greater than the natural corrosion so that the anode is now protected and doesn't corrode.

In the ship, a contact point is taken on the hull of the ship & is connected to a reference electrode. This reference electrode is completely passive insoluble metal. The reference electrode measures the natural corrosion current & which is potential diff blw hull & this reference cell.

We supply DC current which is either equal or slightly greater than it (in the opposite direction) to the impressed current anode.

This in turn, supplies a protecting current to the hull of ship, making the hull a cathode protected from corrosion.



- Marine Growth Prevention System (MGPS):-

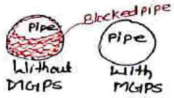
Marine Growth:-

- Sea water have various purpose onboard ship like cooling, cleaning etc. Also used for heat exchanging process.
- But sea water contains certain bacteria such as sea worms, Molluscs, Barnacles, Alage
- These micro-organism along with sea-water enters in pipelines and grows when the get following
  i) Favourable temp (10-30°C)
  ii) Correct pH
  iii) Nutrient which are present in piping system & in sea water.

- Effect of marine growth:-

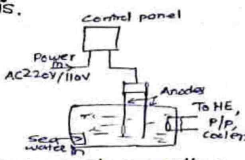
1. Blockage in the pipeline which reduces the flow.
2. Heat transfer rate decreases due to reduced mass flow rate of sea water.
3. Increas in corrosion rate in piping system
4. If marine growth occurs on ships hull, it reduces ship's speed & increases propeller slip.

To prevent it, MGPS is installed on ships.



Note:-
MGPS works on the principle of electrolysis.

Components:-
1. Copper(Cu), Iron(Fe), Aluminium(Al) anode
2. Remote control panel
3. Impressed Current.



Working:-
The system consists of a Remote control panel which supplies impressed current to Anodes. The copper (Cu) anode produces ions, which are carried away by the sea water into the piping and machinery system.
Concentration of copper in the solution is less than 2ppm but it is enough to prevent marine life from settling.
MGPS works on electrolysis. The process involves usage of copper, Aluminium & Ferrous Anodes.

- Max. current for MGPS sys is 2A ~ 10A
- At normal sea condition Cu = 0.9A
  Al = 1.1A

Q:- Why ICCP system turned off at ports?

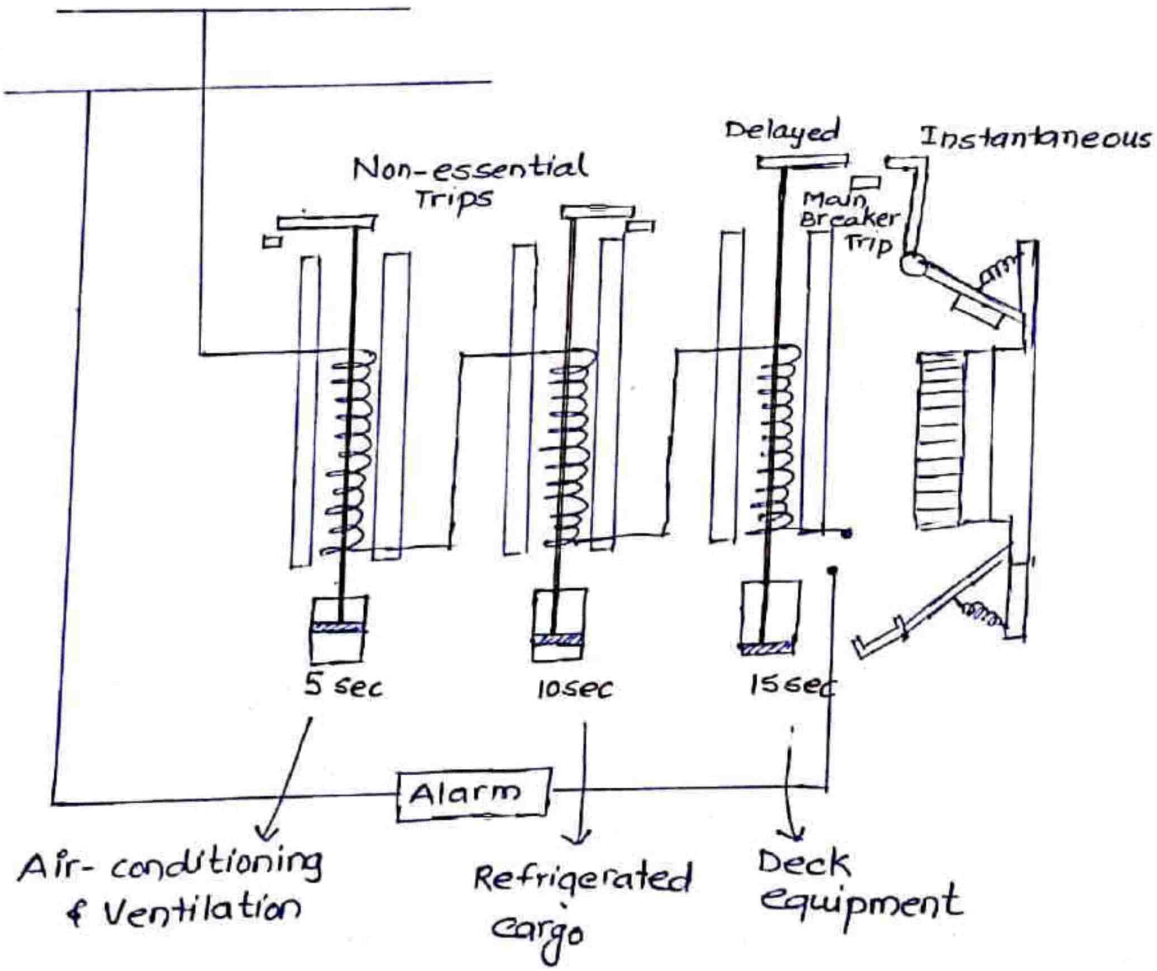
- Stray current arising from ICCP system circulates in structures made of metals (at ports) which may initiate corrosion or accelerates process.
- At ports, ICCP will try to protect jetty & thereby increases current in system leading to overload.
- So ICCP kept turned off.

checks on ICCP system

1. Record the output current & voltages of reference electrode.
2. Check & clean propeller shafts, slip rings & brushes. (because shaft is earthed)
3. Inspect rudder stock earth strap.

• Preferential Trips :- Preference trips are used onboard to reduce the electrical load on the distribution system in the event of a partial power failure or an overload situation, this should ensure that any generator still connected to the system will not be overload & trip off. A distribution system will have several levels of preference tripping, the first equipment to be disconnected will include the least equipment while the essential equipment will not be disconnected by a preference trip.

Preference tripping is achieved using overload relays, if a generator overload develops, the preference trip relay sets an alarm and acts to trip selected non-essential loads.



- A method for operating all the overload-type trips from one load-current-carrying coils uses two instantaneous levers. The top lever is arranged as an instantaneous short-circuit trip & opens the breaker directly through linkages. The bottom lever closes instantaneously at the lower overload current setting & by doing so, completes the circuit through two (or more) non-essential circuit trips and a main breaker trip, all incorporating dashpot time delay. These relays will trip out non-essential at 5 & 10 seconds interval based on their priority & finally if the overload persists, the main breaker after 15 seconds.
- Warning of overload is given by the alarm.
- overload protection is provided on both poles.

- Reverse Current Trip :- / Reverse Power Trip :-

Loss of excitation of prime mover causes a drop in generator voltage. If two generators are running in parallel, and if one generator becomes faulty then current will start flow in the faulty generator from normal generator and reverse current will motor the generator (i.e faulty generator will behave like motor) which may damage its prime mover and overload the remaining power source.

- With direct current (D.C) systems, reversal of flow can be monitored by using the change of direction of associated magnetic field in a coil (carrying load current) or in the cable itself.
- Reverse current devices are to be fitted in the pole opposite to that in which the series windings are connected when there is an equalizer (i.e the positive pole)

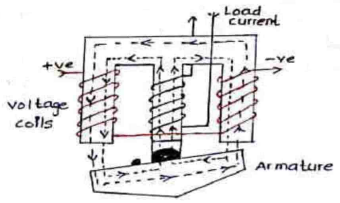


Fig:- Reverse current trip mechanism (DC)

- The armature spindle of the device carries a trip, which opens the breaker.
- Anti-clockwise movement of the armature operates it. During normal working conditions, current passing through the windings on the middle leg of the E-shaped laminated iron core creates a magnetic field.
- The direction of this field and of those on the outer two legs are marked in fig.
- The high-resistance (voltage) coils on the outer legs are connected across the main positive and negative generator outputs.

- The armature is pivoted on the load current coil leg & the load current magnetic field extends through the iron core and the armature. This flux (shown by dotted lines) is superimposed on those due to the voltage coils (shown by dotted lines).
- It increases field strength on the left hand side, pulling the iron armature clockwise against the stop, and reduces that in the right hand side.
- Reverse current in the centre (load current) leg reverse its magnetic field, the superimposed field now weakens the left-hand field and in strengthening the flux in the right hand gap, pulls the armature anti-clockwise to trip the breaker.

Testing of Reverse power trip:-

Reverse power trip can be tested by load shifting with the help of Governor control. When the load has shifted sufficiently from the Generator to be offloaded (approx 10% of max. rated), reverse power relay will open ACB of the same generator. This relay can be tested by simulation using boost test push button on the relay to see if it gives a trip signal.

- Under-Voltage Trip / Under voltage Release:-

Our aim is to ensure that the main circuit breaker can't be closed unless the generator is running and generating it rated output can be added into the under-voltage trip. This is done to open the breaker if there is loss of excitation for any reason and has a built-in time delay circuit.

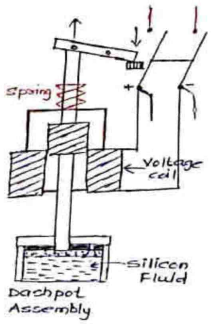


Fig:-

- The solenoid is wired across the main leads on the generator side of the circuit breaker and when not energised, leaves the plunger in the 'tripped' position & the breaker can't be closed.
- Normal voltage output with the machine running energises the coil & the plunger is pulled down against the loading spring to release the trip. This allows closure of the breaker and means that the device is set.

- Alternator Protection:-

PLC :-

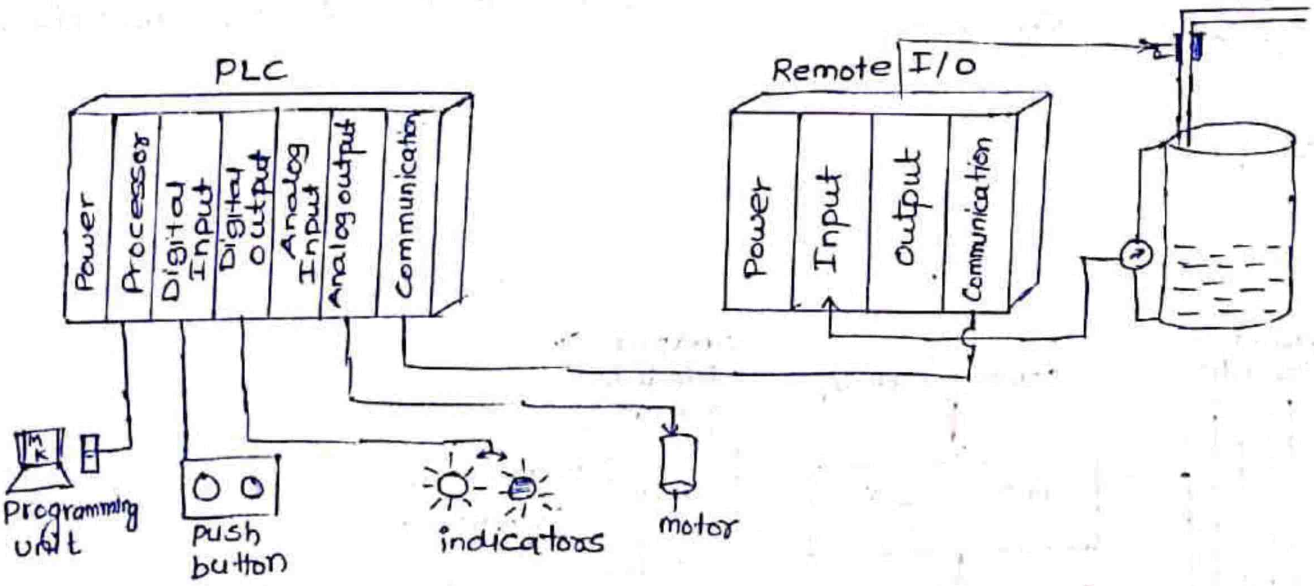
PLC stands for "Programmable Logic Controller". A PLC is a computer specially designed to operate reliably under harsh industrial environments- such as extreme temperatures, wet, dry, or dusty conditions.

PLC is like PC (∵ both have power supply, CPU, I/O, O.S (operating software)) but PLC can perform discrete & continuous functions that a PC can't do, & a PLC is much better suited to rough industrial environments.

A PLC can be programmed according to operational requirement of the process.

eg:- Suppose we are asked that by switching on, bulb should glow after 30 seconds. In hand-wired setup, we have to take out wire, & we have to add timing relay to do so, but PLC doesn't require any additional. It just require a code.

- PLC overcomes such hand wiring associated with relay control circuits not by performing such switching task, but also performing the operations like processing of analog signals, counting, timing, sequencing, comparing etc. ~~The princi~~



- PLC continuously monitors various sensor outputs connected to its input modules & produces output decisions to the actuator connected to output modules according to the control function implemented in its programme.
- Since the PLC has some memory, once the programme is written, tested & downloaded to PLC, it takes charge control of a process, thus increases the reliability.

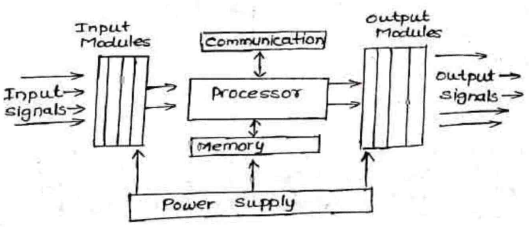
• A PLC can communicate with other PLCs or computers or any other smart instruments via a communication network to perform the functions like downloading of programs, remote monitoring the device, facilitating supervisory control, etc.

• Types of PLCs
i) Fixed PLC ii) Modular PLC.

i) Fixed PLCs :- These are cheaper, smaller & easier to install. It consists of predetermined digital & analog modules (of a fixed number of channels) along with processor and power supply units.
For an expanding I/O channels, fixed PLC requires separate interconnectable components.

ii) Modular PLC :- These offers flexibility to the user in order to match the controller components to the specific needs. It has an extendable I/O capacity, larger memory size & communication with remote unit capability.

Parts of PLC:-



• 1. Power Supply Unit :- It converts AC mains voltage to PLC operating low DC voltage & supplies the power to the modules that are plugged into the rack. The specification of the power depends on the type of PLC being utilized in the application.

2. Mounting Rack :- It provides the means of mounting processor, I/O modules, communication modules & power supply module. It is a metal framework with PCB backplane consisting of several racks for all the modules.

3. Processor or CPU :- This unit consists of microprocessor, system memory, serial communication ports & LAN link. It is brain of PLC which executes the control logic (implemented on its program) by accepting the input from various I/O modules & then determines the appropriate output signals to output modules.

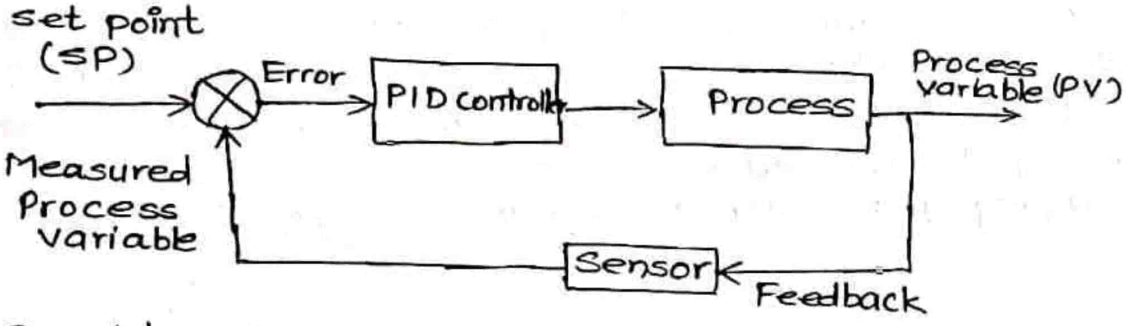
4. Input/Output (I/O) Modules :- I/O modules interface the field devices (both input & output devices) in the control environment to the processor. These input devices include sensors, push buttons, limit switches, etc. & output devices include motors, relays, solenoid valves etc.

Note :- PLC offers five diffent languages to program control logic for the application.
Most common is ladder logic among all.

PID controller:-

A combination of proportional, integral & derivative actions is referred as PID action & hence the name PID (Proportional-Integral-Derivative) controller.

- It gets the input parameter from the sensor which is referred as actual process variable. It also accepts the desired actuator output, which is referred as set variable, and then it calculates and combines the proportional, integral and derivative responses to compute the output for the actuator.



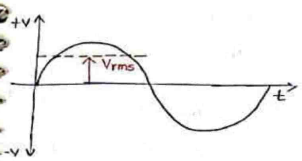
Consider the typical control system shown above in which the process variable of a process has to be maintained at a particular level. Assume that the process variable is temp. (in °C). In order to measure the process variable (i.e temp), a sensor is used.

A set point is the desired response of the process. Suppose the process has to be maintained at 80°C and then the set point is 80°C. Assume that the measured temperature from the sensor is 50°C (it is a process variable) but the temperature set point is 80°C.

This deviation of actual value from the desired value in the PID control algorithm causes to produce the output to the actuator (here it is heater) depending upon the combination of proportional, integral & derivative responses. So the PID controller continuously varies the output to the actuator till the process variable settle down to the set value. This is also called as closed loop feedback control system.

• RMS Value:-

The RMS (Root Mean Square) value (also known as effective or virtual value) of an alternating current (AC) is that value of direct current (D.C) which when flowing through a circuit or resistor for a specific time and produces same amount of heat which is produced by the alternating current (AC) when flowing through same circuit or resistor for same specific time.



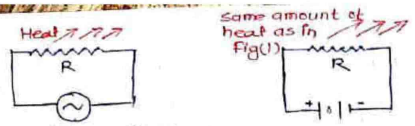
The value of an AC which will produce the same amount of heat while passing through a heating element (like resistor) as DC produces through the element is called RMS value.

OR

The RMS value of an AC is that when it compares to DC, then both AC & DC produce the same amount of heat when flowing through the same circuit for a specific time period.

For a sinusoidal wave $I_{RMS} = \frac{I_m}{\sqrt{2}}$; $V_{RMS} = \frac{V_M}{\sqrt{2}}$

$I = 0.707 \times I_M$; $V = 0.707 \times V_M$



Fig(1) Fig(2)

The RMS value of a sine wave is the measurement of heating effect of sine wave. For eg:- when a resistor is connected to across AC voltage source, it produce specific amount of heat (Fig(1)). When the same resistor is connected across the DC voltage source (in fig(2)).

By adjusting the value of DC voltage to get the same amount of heat generated before in AC voltage source (in Fig(1)). It means the RMS value of a sine wave is equal to the DC voltage source producing the same amount of heat generated by AC voltage source.

Insulation Resistance:-

Degree of protection for an Enclosure:-

IP - Ingress protection

IP XX

First characteristic Numeral	Short description	Definition
0	Non-Protected	No special protection
1	Protected against solid objects >50mm (2")	A large surface of the body, such as a hand (but no protection against delibrate access). Solid objects exceeding 50 mm (2") in diameter.
2	Protected against solid objects >12 mm (0.5")	Fingers or similar objects not exceeding 80 mm (3.15") in length. Solid objects exceeding 12 mm (0.5") in diameter.
3	Protected against solid objects. >2.5 mm (0.1")	Tools, wires etc. of diameter or thickness >2.5 mm (0.1"). Solid objects exceeding 2.5 mm (0.1") in diameter.
4	Protected against solid objects >1 mm (0.04")	Wires or strips of thickness >1 mm (0.04"). Solid objects exceeding 1mm (0.04") in diameter.
5	Dust Protected	Ingress of dust is not prevented, but dust does not enter in sufficient quantity to interfere with satisfactory operation of the equipment.
6	Dust-tight	No ingress of dust.

Table :- Degree of Protection- indicated by the First characteristic numeral.

First characterstic Numeral	short Description	Definition
0	Non-protected	No special Protection
2	Protected against dripping water when tilted upto 15°	Vertically dripping is to have no harmful effect when the enclosure is tilted at any angle upto 15° from its normal position.
3	Protected against spraying water	Water falling as a spray at an angle upto 60° is to have no harmful effect.
4	Protected against splashing water	Water splashed against the enclosure from any direction is to have no harmful effect.
5	Protected against water jets	Water projected by a nozzle against the enclosure from any direction is to have no harmful effect.
6	Protected against heavy seas.	Water from heavy seas or water projected in powerful jets is not to enter the enclosure in harmful quantities
1	Protected against dripping water	Dripping water (vertically falling drops) is to have no harmful effects.
7	Protected against the effect of immersion	Ingress of water in a harmful quantity is not to be possible when the enclosure is immersed in water under defined conditions of pressure & time.
8	Protected against submersion.	The equipment is suitable for continuous submersion in water under conditions, which are specified by manufacturer.

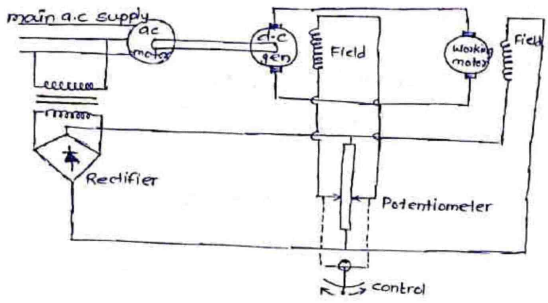
Table:- Degree of protection - indicated by the second characterstic Numeral.

Eg:-
Q:- What is IP 67

Ans:- 6:- • complete protection against contact with live or moving parts inside enclosure
• protection against ingress of dust

7:- Protection against ingress of dust.

Ward - Leonard System :-



- Ward - Leonard system is used for fine control of d.c electric motor speed for from zero to full in either direction.
- It is able to give the motor a robust torque characterstic.
- This system was used for the motors of electric (as opposed to hydraulic) steering gears of ship with d.c electrical power.
- Today it is used onboard with a.c electrical power for deck machinery such as windlass.

⇒ The working motor which powers the steering gear, windlass or other equipment is a d.c machine, because speed control of these is easy.

- The method is to change the applied voltage through the brushes to the armature windings of the d.c motor ; no change is made to the current in the field windings.
- The voltage is increased or decreased not with the use of resistances but by arranging an individual d.c generator with controllable output voltage as the power supply for the main armature of working motor
- Speed and direction of the working motor vary with the magnitude and direction of applied voltage

- Current for the windings of the field poles is derived from the source of main power. Where there is a.c main power, current of the windings is transformed to lower voltage and rectified.
- The d.c generator is driven by a simple one-speed, DOL start, squirrel-cage motor (a.c powered ship).
- Output of generator is varied by changing the current to its field windings through a variable control resistor (potentiometer). As magnetic field strength is changed by the change of field current, so too is the generated voltage.
- Switch of direction of current flow through the field poles, also with the potentiometer, will cause the direction of the poles magnetic fields to change.
- This changes the direction of generated current supplied to the motor & thereby also the running direction of the motor.
- The control lever can, by moving the potentiometer contacts in opposite directions away from the mid-position as shown in fig., set the polarity & strength of the generator field poles.
- By governing generator output to the armature of the working motor, this in turn gives stepless speed control of the working motor in either direction.

• Insulation Resistance :-

All electrical equipment has insulation. The purpose of the insulation is to prevent direct current contact with live conductors. The value of insulation resistance must be high enough to prevent current leaking away from conductors.

Insulation resistance is measured between:

- Conductors & earth
- Conductors

Donate (using UPI)
carbide @ybl

The minimum acceptable value of insulation resistance is limited by the relevant register regulations.

The purpose of insulation resistance testing is to measure the value of insulation resistance between two conductors or between a conductor & earth, the resistance should be very high in the MΩ for voltages upto 1000 V.

- Insulation materials are non-metallic. Insulation is affected by many factors such as humidity, temperature, electrical & mechanical stress, vibrations, chemicals, oil, dirt & old age.

- IR is the resistance offered to conductor to prevent current from leaking away.
- Unit of IR is Ω (ohm) & measured by megger.
- For upto 440 V IR value (acceptable) = 1MΩ
- For high voltage (above 1000 V) IR value (") = KV+1MΩ

• Procedure for Insulation testing between a winding & Earth:-

1. Ensure the circuit to be tested is electrically dead.
2. Connect both test leads together, set the meter on the ohms scale, the meter should show 0 resistance. This proves the leads are not broken.
3. Find two good earth points and connect one lead to each, again test the resistance with the meter on the ohm's scale. This proves that a good earth point has been found.
4. Remove on lead, do not move the other and connect it to one end of winding to be insulation tested, set the meter to the mega ohm scale and test. The reading should give a value of at least one mega ohm.

⇒ Before performing a Megger test on any piece of electrical equipment, all circuit components that may be damaged by the high voltage must be isolated from the test. This is very important when testing generators as A.V.Rs are easily damaged due to Megger Testing.

⇒ To test IR of motor fully, the resistance between each phase must be tested. This requires that the star and delta winding connections are disconnected and between each phase & earth.

Q:- Why IR is measured by Megger & not by Multimeter.

Sol^{n}:- From ohm's law

$V = IR \Rightarrow I = V/R$

We know that insulation resistance is of the order $1 M\Omega$. When we connect multimeter from the insulator, it becomes a closed circuit. There is 9V battery in multimeter which powers the circuit, when we set the knob to measure the resistance of circuit.

$\because I = \frac{V}{R} \Rightarrow I = \frac{9V}{10^6} \simeq 10^{-5}$ Amp which is very small.

This is a very small current which will not be able to deflect the galvanometer inside multimeter & Hence it is impractical & impossible to measure the insulation resistance with multimeter.

A megger is used to measure the IR which itself is powered by a DC generator or batteries having 500 V.

• Hazardous Zones:-

Hazardous areas ashore are classified into zones which indicate the probability of an explosive air-gas mixture being present and therefore the likelihood of an explosion occurring.

Zone 0:-

In which an explosive air-gas mixture is continuously present or present for long periods.

Zone 2:-

In which an explosive air-gas mixture is not likely to occur in normal operation and if it occurs will exist for only a short time.

~~Note~~ Zone 1:- In which an explosive air-gas mixture is ~~not~~ likely to occur in normal operation

Note:- An area which is not classified Zone 0, 1 or 2 is assumed to be non-hazardous or safe area. Eg:-

Zone 0:-

Interior spaces of oil cargo tanks, pipes, pumps etc.

Zone 1:-

Enclosed or semi-enclosed spaces on the deck of tanker, the boiler firing area on a gas carrier using methane boil-off as a fuel & batlery rooms.

Zone 2:

Open spaces on the deck of a tanker

• Types of Explosion Protection:-

Explosion protected equipment can be identified by symbol 'Ex' followed by a letter indicating the type of protection employed.

Symbol	Type of Protection
Exd	flameproof enclosure
Exi	intrinsic safety
Exe	increased safety
Exn	non-sparking
Exq	Powder filled (not applicable to ships)
Exo	oil immersed (not applicable to ships)
Exp	pressurisation
Exs	special protection

Note:- Some equipment may use more than one protection in its construction. In this case, the primary type of protection is quoted first. eg:- An increased safety motor with a flameproof terminal box would be marked Exe d.

Equipment may also be marked with a prefix 'E' which denotes compliance with European standards

eg: EExe d.

1. Exd Flameproof Enclosure:-

Type 'd' protection, code EExd, uses a flameproof enclosure to contain the electrical apparatus. The internal apparatus may include parts which may arc & surfaces which becomes hot. Gas may be inside the enclosure so it must fulfill three conditions:-

i) The enclosure must be strong enough to withstand an internal explosion without suffering damage.

ii) The enclosure must prevent the flame & hot gases from being transmitted to the external flammable atmosphere.

iii) The external surface temperature of the enclosure must remain below the ignition temperature of the surrounding gas under all operating conditions.

2. Exi Intrinsic Safety:

These are circuits in which no spark nor any thermal effect produced under prescribed test conditions (which include normal operations & specified fault conditions) is capable of causing ignition of a given explosive atmosphere. Generally, this means limiting the circuit conditions to less than 30V & 50mA.

Naturally this restricts the use of Exi protection to low power instrumentation, alarm & communication circuits.

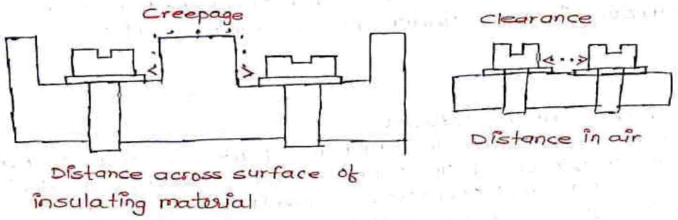
The design of the circuit will depend on the type of gas present (gas grouping)

• Exe Increased safety :-

Increased safety equipment is based primarily on the elimination of open sparking as at relay and switch contact or on the commutators or slip-rings of motors & generators & on the close control of surface temperatures.

Also the construction of the equipment should be of very high standard to prevent fault developing.

Extra insulation is used, creepage distances between end terminals are made longer & special enclosures to protect against damage due to entry of moisture and mechanical damage are also specified.



The enclosure is made to withstand impact & to prevent ingress of solids & liquids

Applications includes cage-rotor induction motor, luminaires & connection boxes. Special Exe cable glands, metal or plastic are used with Exe apparatus.

• Exn Non-Sparking :-

Similar to Exe, the designation Exn applies to equipment which has no arcing contacts or hot surfaces which can cause ignition.

The Exn requirements are less strict than for Exe & designs are very close to that of normal electrical apparatus.

The main consideration is extra care to ensure locking of terminal connections to avoid any risk of electrical sparking or flashover.

• Exp Pressurised Enclosure:-

Clean, dry air or an inert gas is supplied to the equipment slightly above atmospheric pressure to prevent entry of the external flammable gas. This method is sometimes used for motors, instrumentation enclosures & lighting.

• Exs Special Protection:-
This includes precautions taken to prevent explosions which are not specifically covered by any other designation.

• High Voltage:-
On ships $V \leq 1000$ Volts is considered as low voltage and voltage above 1000 Volts is considered as high voltage.

• Advantage of high voltage:-
- Ship have high voltage demanding machinery such as bow thruster electric motor, reefer containers in container ships, cargo cooling machineries in gas carrier etc.
- High voltage machinery have much reduced size and weight as compared to low voltage machineries.
- This will leads to increased space for cargo which will result in more profit.
- Easy for installation.
- In high voltage systems, copper loss or I^2R losses are much reduced when compared to low voltage system, as the current flow is less.
- Approx $1/3^{rd}$ reduction in cost compared to low voltage syste

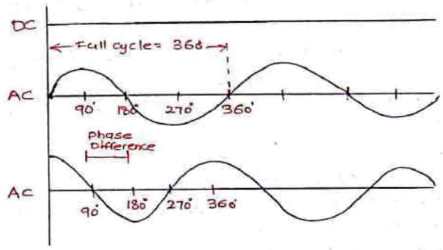
• Disadvantage of high voltage system.

Phase, Single phase, Three phase

There is no two phase power supply. Generally three phase power is used for heavy loads while single phase is used for powering small loads.

• Phase:-

Unlike direct current DC, the Alternating Current AC swings between zero to its peak value. The current constantly varies to form a sinusoidal waveform.



• Frequency:- The frequency of electric signal is the numbers of cycles per second.

• Phase:- Phase is the point or position in the time of the waveform & it is always mentioned in degrees or in radians.

In electrical system phase refers to the number of distinct sinusoidal AC waveforms having same frequency but having a common phase difference.

AC power supply usually has 50/60Hz frequency depending on the region. While the phase of system depends on the type of electrical system being used. There are 360° in one cycle. A single phase power supply has has only one AC wave.

While the three phase supply has three equally separated waveforms having same frequency. The 360° of phase per-cycle is evenly divided into three parts. Therefore, the phase difference between any two phase is 120°.

• Single Phase Power Supply:-

The type of AC supply where all the voltages in the system varies in a some sinusoidal pattern is called single phase power supply. It is delivered using only two wires i.e the power wire also known as hot wire or live wire or line or phase wire & a neutral wire.

The power flows between the phase & neutral wire through the load. The phase wire is used for supplying the power to the load while the neutral wire provides a return path for the current flowing through the load. Sometimes it is called as split phase.

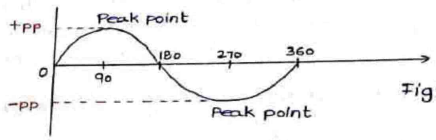


Fig:- Single Phase Power Supply

In fig. AC voltage & current waveform for a single phase supply is shown. The voltage fluctuates between zero and peak points. Where the maximum peak points occurs at 90° and the minimum peak point occurs at 270°. The voltage does go to zero some times. That is why single phase power supply is not very consistent as compared to a three phase power supply & can't be used to power high rated machines. Generally it is used for the machinery below 1000 W.

Since it requires only two wires, it is simple & cost is also less but it is not reliable because a fault in the line can lead to Power failure.

The downside of a single phase supply is that it can't run motors on its own as it can't generate rotating magnetic field (RMF) in an induction motor. It requires extra motor starting circuitry for proper operation.

• Three Phase Power Supply :-

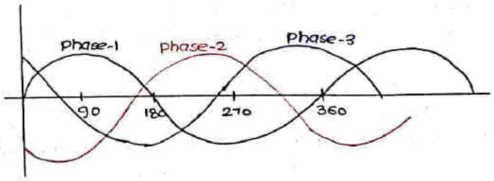


Fig:- 3-phase (3-ϕ) power supply.

• Three phase power contains three voltage that are 120° apart individual sinusoidal waveform. The three phase power supply consists of three individual power conductors i.e 3 different colour coded wires for individual phases. While the voltage & current between any two power conductors is 120° phase apart. Three phase power supply is also known as Poly-phase power system.

Three phase power supply used for powering a load can be connected in either of two configuration i.e delta configuration & star or wye configuration (star & Delta represented by Y (wye) & Δ respectively).

In delta configuration, there is no neutral cable. It only uses 3 phase cable or power cable to supply power to the load.

While in star configuration, there is fourth neutral cable. The neutral wire is extended from the common point of combination of 3 phase windings in a transformer or generator. Therefore star configuration requires four cables to supply three-phase power supply including three power cables & one neutral cable.

3 phase power supply contains three individual AC waveform with 120° difference between them. As shown in fig, the instantaneous voltage at any time does not react 0 point. Therefore the power delivered by three phase is much more consistent & supply more power than a 3 single phase power lines. It is used for powering heavy loads greater than 1000W. There is no power failure in case of fault in one phase because the other two phases still delivers power.

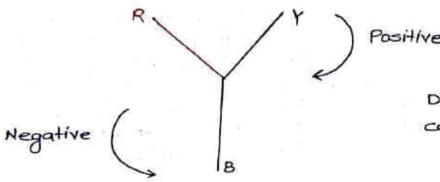
• Single Phase Power Supply	• Three Phase Power Supply
1. The AC power where all the voltages has same sinusoidal pattern.	1. The AC power where all there are 3 sinusoidal voltages having 120° phase difference
2. It requires only two wires to complete the circuit.	2. It requires 3 or 4 conductors depending on configuration
3. know as Split Phase system	3. known as Poly phase system
4. Simple	4. Complex
5. For small loads (<1000W)	5. For heavy loads (>1000W)
6. Power failure occurs due to fault in power line	6. Fault in one line doesn't leads to Power failure.
7. less reliable & efficient	7. More reliable & efficient
8. Voltage & current goes to zero in a cycle.	8. Voltage & current never goes to zero.
9. It can't generate RMF in induction motor. It uses extra circuitry.	9. It can generate Rotating Magnetic Field (RMF) without any extra circuitry.
10. The supplied voltage is equal to the voltage difference between phase & neutral.	10. The phase to phase voltage is equal to $\sqrt{3}$ times the phase voltage, while phase to voltage neutral voltage is equal to single phase voltage.
11. Carries less power	11. Carries more power.
12. Used for power distribution over short distances	12. Used for power distribution over long distances because of low copper losses.
13. High power losses	13. Low power losses.
14. It needs expensive converters to convert into three phase power supply.	14. Star arranged three phase supply can offer 3 single-phase using either phase wire & neutral wire.

• Phase sequence:-

In a three-phase system, the order in which the voltages attains their maximum positive value is called Phase sequence.

There are three voltages or EMFs in the three phase system with the same magnitude but the frequency is displaced by an angle of 120 degree electrically.

Taking an example, if the phases of any coil are named as R, Y, B then the positive phase sequence will be RYB, YBR, BRY ; also called clockwise sequence & similarily the Negative phase sequence will be RBY, BYR, YRB respectively & known as anti-clockwise sequence.



– Phase sequence is important because:-

1. The parallel operation of three phase alternator is only possible when its phase sequence is known.
2. The rotational directions of three-phase induction motor depends on its sequence of phase on three phase supply. Hence to reverse its direction, the phase sequence of the supply given to the motor has to be changed.

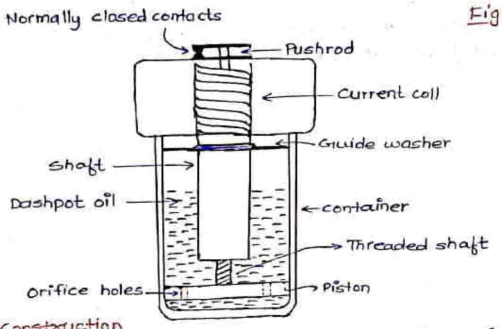
• Purpose of choke in Tubelight:-

When the switch is ON, the tube light choke acts as inductor which is used to induce high voltage across it. The inductor (choke) ionize the gases in the starter due to its induced high voltage and heats the bimetallic strip that is caused to be bent to connect to fixed contacts. Current starts flowing through con- starter.

Dashpot Timer :- / Dashpot :-

A dashpot timer is used in overload relays. It consists mainly of a piston, shaft & container. It provides time delay for the relays to operate.

Eg:- Dashpot Timer



Construction

A dashpot timer is basically a container, piston & a shaft. The piston is placed inside the container & the container is filled with a special type of oil called dashpot oil. Dashpot oil maintains a constant viscosity over a wide range of temp. The type & viscosity of oil used is one of the factors that determines the amount of time delay for timer. The other factor is the setting of the opening of the orifice holes in the piston. Orifice holes permits the oil to flow through the piston as it rises through the oil. The opening of the orifice holes can be set by adjusting the sliding valve on the piston.

- The dashpot overload relay contains a coil that is connected in series with motor.

Working :-

As current flows through the coil, a magnetic field is developed around the coil. The strength of the magnetic field is proportional to the motor current. This magnetic field draws the shaft of the dashpot timer into the coil. The shaft's movement is retarded by the fact that the piston must displace the oil in the container. If the motor is operating normally, the motor current will drop to a safe level before the shaft is drawn far enough into the coil to open the normally closed contact. If the motor is overloaded, however, the magnetic field will be strong enough to continue drawing the shaft into the coil until it opens the overload contact. When power is disconnected from the motor, the magnetic field collapses & the piston returns to the bottom of the container.

Use :-

- Dashpot is filled in overload trip, pre-ferential trip, under voltage trip.

Essential Loads/Service :-

- Essential loads are those required for the safety of personal & for the safe navigation & propulsion of ship.
→ These includes certain supplies to navigation aids, machinery spaces, control stations & steering gear.

Non-essential loads :-

- These loads has no effects on the safe navigation & main propulsion unit when they are cut off.
- These includes Air-conditioning system, some blower fans except engine room blowers, galley power etc.

What is intrinsically safe circuit or equipment?

1. An electrical circuit or part of circuit is intrinsically safe, if any spark or thermal effect produced normally (eg by breaking or closing circuit) or accidentally (eg. by short circuit or earth fault), is incapable of igniting a prescribed gas mixture, under prescribed test condition.
2. An equipment, which can't released sufficient electrical or thermal energy, under any condition to ignite a particular flammable vapour in its vicinity.

Circuit Faults, how to test & effects?

- An Open circuit Fault will not allow the motor to start. If the fault occurs in 1 phase when the motor is running, the current in other two phases will increase and burn out motor
- A short circuit Fault will cause high current to flow in the windings which may burn out.
- An earth fault provides an easy path for current to flow through the wires & earth.

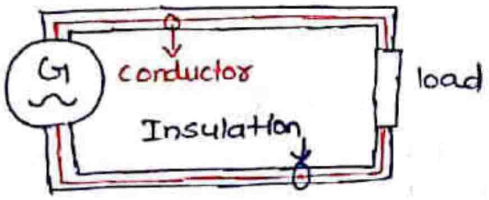
How to check?

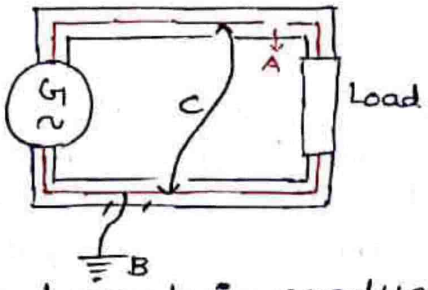
Open circuit Fault:- Earth one end of wire & using multimeter or megger switched to resistance value, check between wire at different points & earth. Resistance should show minimum value.

Earth Fault:- Open circuit where possible & check the resistance between wire near 'open' ends & earth. Resistance should show maximum value.

Short circuit Fault:- Remove the terminal at the panel. Turn all switches for that circuit to ON position. Check for resistance between positive & negative sides of conductor. A reading of less than infinite indicates the fault.

Consider diagrams below:-





- Open-circuit Fault is due to break in conductor, here at point A, so current don't flow
- Earth Faut is due to break in insulation (here at B). conductor touches hull or earthed metal enclosure
- short circuit Fault: It is due to double break in the insulation (here at C). It allows both conductors to be connected so that a very large current by-passes or short circuits the load.