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"~~SPIRIT OF MOE~~"

NAME : Kumar Nitin STD. MEO-CLASS 4 SEC. : Part B ROLL NO. : ELECTRICAL

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Electrical : Basics

Current :- it is the flow of electric charge (electrons) in a conductor.
(I)
Unit : Ampere (flow of electric charge through a surface at the rate of 1 co[...]
Measured by : ammeter

Electromotive Force (EMF) :- it is the force which causes the flow of electrons in a close[d] cir[cuit]
(E)
$\boxed{OR}$ It is the voltage developed by any source of electrical energy.
Unit : Volts.

Voltage :- it is the electric potential difference b/w two points or the diff in the electric potential energy of a unit charge transported b/w 2 points.
(V)
Unit : Volt (potential diff. across a resistance of 1 Ω carrying a current of 1 A)
Measured by : voltmeter

Resistance :- it is the opposition to the passage of an electric current through a conductor
(R)
Unit: Ohm (Ω) [transmitting current of 1 Amp when subjected to a p.d of 1 V]
Measured by : ohmmeter
Factors affecting resistance :- (i) Length of the wire
(ii) Cross-sectional area of the wire
(iii) material of the wire.
(iv) temperature.

Specific Resistance (Resistivity of material)

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

length of the wire
cross-sectional area of the wire.

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

temp co-efficient
Resistance at t°C
Resistance at 0°C
temp (t)

Resistance in series :- $R = R_1 + R_2 + R_3 + \dots$

Resistance in parallel :- $1/R = 1/R_1 + 1/R_2 + 1/R_3 + \dots$

Ohm's law :- current through a conductor b/w 2 points is directly proportional to the p.d across the two points.

$$V = IR$$

ohm (Ω)
Volts (V)
Ampere (A)

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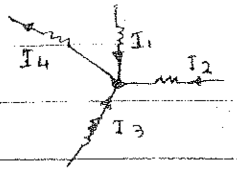
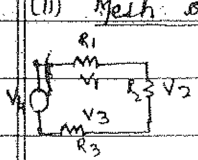
Kirchhoff's law :- determines equivalent resistance of a complex network & the current flowing in various conductors.

(i) Point law or Current law :- algebraic sum of currents at any junction (point) is zero (OR) sum of current flowing towards a point is equal to the sum of current flowing away from it.



$I_1 + I_2 + I_3 = I_4 \Rightarrow I_1 + I_2 + I_3 - I_4 = 0$

(ii) Mesh or Voltage law :- the sum of all voltages around the loop is equal to zero (OR) the sum of the emf's in any closed loop is equal to the sum of the p.d in that loop.



$V_4 = V_1 + V_2 + V_3 \Rightarrow V_1 + V_2 + V_3 - V_4 = 0$

→ Dielectric :- is a electrical insulator that can be polarized by an applied electric field. [When dielectric is placed in an electric field, practically no current flows in them because, unlike metals, they have no loosely bound or free electrons. Instead, the ~~positive~~ charges within the dielectric are displaced minutely in the direction towards or opposite to the electric field. This slight separation of charges or polarization reduces the electric field within the dielectric]

Eg:- mica, ebonite

dielectric strength is the max kilovolt per millimeter strength a material can withstand without breakdown. Eg:- Mica → 20-60 KV/mm @ 20°C.

→ Power :- Rate of doing work. $\boxed{OR}$ rate at which electric energy is transferred by an electric circuit.

Unit :- Watt [J/s]

$P = \frac{Q \times V}{t} = I \times V = I^2 R$

electric charge in coulombs

time

Measured by wattmeter

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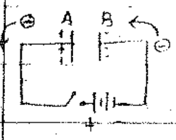
Capacitor (Condenser) :- used for storing electrical energy and to release when ...
It consists of 2 conductors separated by an insulating medium (...)



Consider 2 conductors A & B connected across a d.c supply.
When supply is on there is momentary flow of electrons from A to B. i.e (-)vely charged electrons from A is withdrawn, it becomes (+). These (-)vely charged electrons is collected on B, it becomes (-)ve. Hence, a p.d is established b/w plates A & B. The transient flow of elect. me give rise to charging current. The strength of the charging current is max^m when 2 plates are uncharged but it decreases & finally ceases when p.d across plates become equal & opposite to the battery emf.

Capacitance :- amount of charge required to create a unit p.d b/w its plates.
$C = Q/V$
Unit : Farad (Coulomb / volt)
Factors affecting capacitance :- i) distance b/w plates
ii) area of plate
iii) dielectric constant

dielectric const.
$$C = \frac{\varepsilon_0 A}{d}$$
A ← area
d ← dist

Capacitance in series :- $1/C = 1/C_1 + 1/C_2 + 1/C_3 + \cdots$
Capacitance in parallel :- $C = C_1 + C_2 + C_3$

Magnetism and ~~Ele~~ Electromagnetism

- **Law of magnetic forces (By Coulomb)** :- Force b/w magnetic poles in a medium $\propto$ pole strength
$\propto$ 1/square of dist. b/w poles
$\propto$ 1/absolute permeability of surrounding medium

- **Magnetic flux (ϕ)** :- magnetic lines of force passing in a magnetic field.
$\phi = B \times A$
B ← flux density
A ← area of magnetic core
Unit :- weber (wb)

- **Flux density** :- no. of lines of magnetic flux per unit area

- **Magnetomotive force (mmf)** :- work done in joules in carrying a unit magnetic pole through the entire magnetic circuit.
  Unit :- ampere - turns (AT) (product of no. of turns in magnetic circuit & current in those turns)

- **Magnetic Reluctance** :- opposition offered to the passage of magnetic flux through a material.
  Unit :- AT / Wb.
  $= l/\mu A$ ← area
  absolute permeability.

- **Residual Magnetism** :- magnetism which remains in a material when effective magnetising force has been reduced to zero.

- **Diamagnetic** :- materials repelled by magnet
  Paramagnetic :- materials attracted by magnet
  Ferromagnetic :- materials strongly attracted by magnet.

- **Relation b/w magnetism & electricity**

whenever an electric current flows through a conductor, a magnetic field is created in the space surrounding the conductor i.e we can say that when electrons are in motion, they produce a magnetic field. The converse of this is also true i.e when a magnetic field embracing a conductor moves relative to the conductor, it produces a flow of electrons in the conductor. This phenomenon whereby an emf & hence current (i.e flow of electrons) is induced in any conductor which is cut across or is cut by a magnetic flux is known as "ELECTRO MAGNETIC INDUCTION"

→ **Faraday's Law of Electromagnetic Induction**

1st law :- whenever a conductor cuts the magnetic flux, an emf is induced in that conductor.

2nd law :- magnitude of the induced emf is equal to the rate of change of flux linked with the conductor.

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final flux linked. initial flux linked

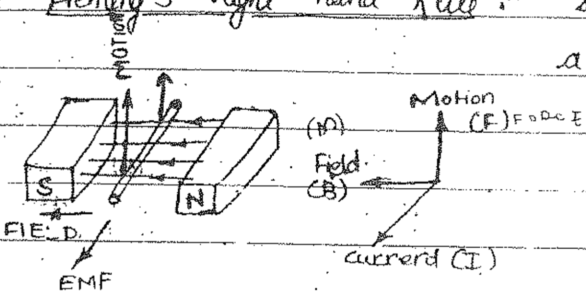
Induced emf $(e) = \dfrac{N\phi_2 - N\phi_1}{t}$ ← time   N is the no. of turns

$$e = \frac{N(\phi_2 - \phi_1)}{t} = N\frac{d\phi}{dt}$$

$$\boxed{e = -N\frac{d\phi}{dt}}$$

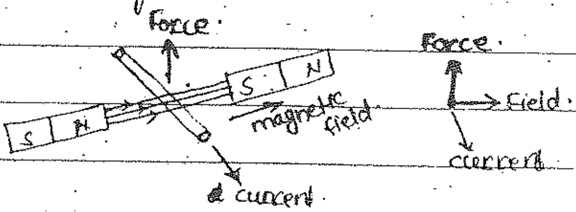
(−) sign signifies that induced emf sets up current in such a direction that magnetic effect produced by it opposes the very cause producing it.

→ Fleming's Right Hand Rule :- shows the direction of induced current when a conductor moves in a magnetic field [Generators]

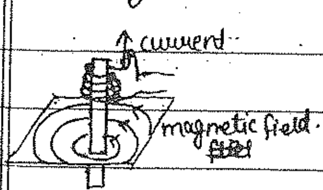


Is used when emf is induced due to flux cutting (i.e dynamically induced emf)

→ Fleming's Left Hand Rule :- whenever an electric current carrying conductor is placed inside a magnetic field, a force acts on the conductor, in a direction perpendicular to both direction of electric current & field. [motors]



→ Lenz's Law :- when emf is generated by a change in magnetic flux acc to Faraday's law, the polarity of the induced emf is such that it produces a current whose magnetic field opposes the change which produces it.



- used when emf is induced due to change of flux linkages (i.e statically induced emf)

◆ Inductance :- it is the behaviour of a coil of wire in resisting any change of electric current through the coil.

[OR] may be defined in terms of emf generated to oppose a given change in current.

$$Emf = -L\frac{di}{dt}$$ ← rate of change in current

↑ inductance (Henry)

→ Self Inductance :- the property of the coil due to which it opposes any increase or decrease of current & hence flux
This ~~proaction~~ induces emf which is opposite in direction to the applied emf, Also Known as BACK EMF.

→ Mutual Inductance:- ability of the a coil (or circuit) to produce emf in a nearby coil (or circuit) by induction when current in first coil changes. This action is reciprocal i.e the 2nd coil can also induce emf in the 1st when current in the 2nd coil changes;

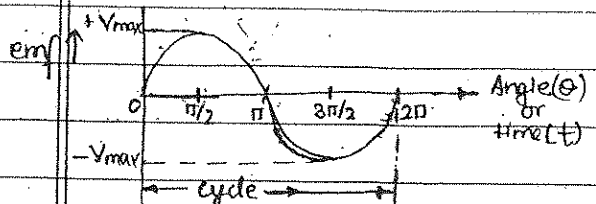
→ Inductance in series :- $L = L_1 + L_2 \pm 2M$

→ Inductance in parallel :- $L = \dfrac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M}$

(+) – oppose
(−) – assist

→ A.C FUNDAMENTALS

- Alternating voltage may be generated by rotating a coil in a magnetic field or by rotating a magnetic field within a stationary coil.
- The value of voltage generated depends upon (i) no. of turns in coil.
  (ii) strength of the field.
  (iii) speed at which coil or magnetic field rotates.



cycle :- one complete set of (+)ve & (−)ve values of alternating quantity.

Time Period (T) :- time taken by an alternating quantity to complete one cycle.

Frequency (f) :- No. of cycles per second.
Unit :- Hz.

$\boxed{f = 1/T}$

$\boxed{f = \dfrac{PN}{120}}$ where P = no. of poles.
N = revolutions in rpm

Amplitude :- max value, (+)ve or (−)ve of an alternating quantity.

- Instantaneous value of voltage :- $e = E_m \sin\theta$

Eg:- If $E_m = 200$ then at $90°$, $e = 200 \sin 90° = 200$ V
at $180°$, $e = 200 \sin 180° = 0$ V

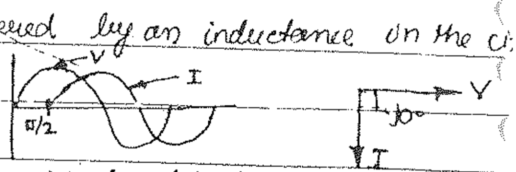
• **Root Mean Square value (RMS)** :- it is the value of the steady current (d.c) which when flowing through a given circuit for a given time produces the same heat as produced by the alternating current (a.c) when flowing through the same circuit for the same time.

$V_{RMS} = V_{max}/\sqrt{2}$ $\quad I_{RMS} = I_{max}/\sqrt{2}$

• **Inductive reactance** (Ω) :- effective opposition offered by an inductance in the circuit.

$X_L = 2\pi f L$ ← inductance
↑ frequency

$I = \frac{V}{X_L}$

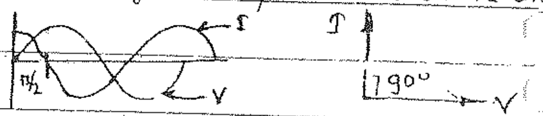


current lags behind voltage by 90°

• **Capacitive Reactance** (Ω) :- effective opposition offered by a capacitance in the circuit

$X_C = \frac{1}{2\pi f C}$

$I = \frac{V}{X_C}$



current leads voltage by 90°

• **Resistance circuit** (Ω) :- current & voltage are in phase. $\longrightarrow I$ $\longrightarrow V$

• **Impedence** :- total opposition offered by a series circuit containing resistance, inductance & capacitance.

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

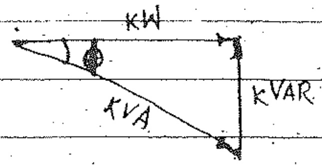
Advantages of AC over DC.

i) produce voltage upto 30,000 V.
ii) voltage can be ↑ or ↓ using stepup or step-down transformer.
iii) transmission & distribution is economical.
iv) A.C motors for same H.P as D.C motors are compact, light & cheaper.
v) Can be easily converted to D.C

Power factor :- i) cosine of angle of lead or lag.
ii) Ratio of Resistance & Impedence (R/Z)
iii) Ratio of $\frac{\text{True power}}{\text{Apparent power}} = \frac{\text{watt}}{\text{volt-amp}}$

Active and Reactive Components of an Electrical circuit

- Active components consume power in the circuit.
- Reactive components are responsible for lead or lag of current from voltage.



As current lags or leads voltage in the circuit, power (KVA) also lags or leads. This power is called apparent power.

Apparent power has two components

(i) Active component KW i.e True Power

$$KW = KVA \cos\phi$$

(ii) Reactive component KVAR which is responsible for lead or lag

$$KVAR = KVA \sin\phi$$

power factor (p.f) = $\frac{\text{True power}}{\text{Apparent power}}$

$$\boxed{\cos\phi = \frac{KW}{KVA}}$$

If reactive component is made equal to active component, p.f will be unity.

Effect of low power factor:-

i> ↑ Cu loss & ↓ η of the apparatus & system.

ii> Overloads generators, transformers & transmission.

iii> Cost of transmission ↑ due to ↑ in current, use of thick wires & bigger switches

→ P.f can be improved by connecting capacitor in parallel.

" " " " " using synchronous motor ∵ here V & I does not depend on load but on excitation field.

Electronic Equipments

→ Conductors :- materials which have large no. of free electrons which can take in current flow. Eg:- Copper, Aluminium etc

→ Insulators :- materials which do not have free electrons and hence do not allow current flow. Eg:- Glass, Rubber etc.

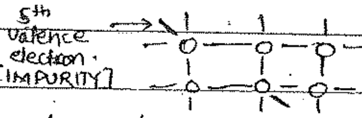
→ Semiconductor :- materials which are neither good conductors nor good insulators. Eg:- Silicon and germanium.

Conductivity is related to no. of free electrons available to take part in current flow and in case of semi-conductors they are bound into the crystal structure sufficiently tight to make them poor conductors but not well enough to make them insulators. Here each atom is associated with four others in the covalent bond. At absolute zero temp. all the valence electrons are firmly held making the material an insulator.

When heat is applied, thermal agitation causes a few electrons to detach and move freely leaving holes. These holes will attract another electron, so leaving another hole. This lead to random movement of free electrons & equally random movement of position of holes. Thus a very small leakage current can flow if voltage is applied across the semiconductor. So we can say that they act as inferior insulators rather than conductors.

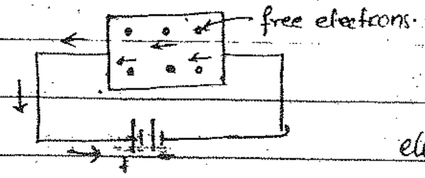
Addition of certain traces of elements [DOPING] can make them conduct more.

◆ N- type semi-conductor

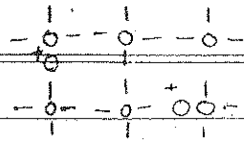


N or (-)ve - type semiconductor have enhanced conductivity as a result of addition of impurity with 5 valence electron such as arsenic, antimony and phosphorus which could "donate" an extra free electron.

- current flow is based on the movement of these electrons i.e (-)ve charges.

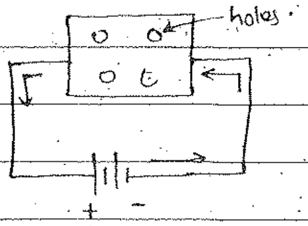


As voltage is applied, free electrons in the crystal ~~will be~~ directed towards the (+)ve terminal, causing current to flow.



◆ P-type semiconductor

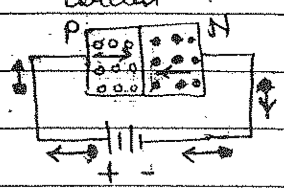
- made by adding impurities such as aluminium, borium or indium which has only 3 valence electrons.
- each of these is able to produce the apparent effect of removing (-)ve electrons so leaving (+)ve holes which transmit charge.
- current conduction is due to holes i.e (+)ve charge.



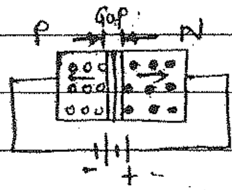
when voltage is applied, the holes being (+)vely charge is directed towards the (-)ve termale, causing flow of current.

◆ Semi-conductor junction. (p-n junction)

- p-type semiconductor is suitably joined to n-type semiconductor.
- there is a tendency for the free electrons from n-type material to diffuse over to p side & holes from p-side to n-side. This process is called diffusion.
- when sufficient amount of free electrons & holes are transferred from one side to other, further transfer stops & a barrier is set which is known as Potential Barrier.
- Forward Biased :- when external voltage is applied in such a way that p is connected to (+)ve terminal & n is connected to (-)ve ~~termal~~ terminal, resistance becomes zero & current flows in the circuit.

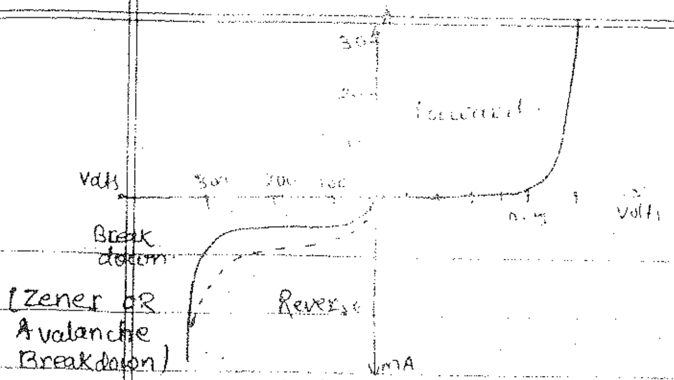


Forward



Reverse

- Reverse baised :- when (-)ve terminal is connected to 'p' and (+)ve terminal is connected to 'n', potential barrier increases & charge flow across the junction stops i.e a high resistance path is established hence no current flow in the circuit.



characteristic curve

- shows a rise in current flow as forward voltage reaches about 0.5 V. Very large current flow is produced by quite small further voltage increase.
- reverse voltage causes negligible 'leakage' current up to a value at which reverse breakdown occurs. This is called breakdown voltage [Zener or Avalanche break down]

◆ **Diode** :- an electrical device allowing current to move through it in one direction with far greater ease than in other. i.e it has low (ideally zero) resistance to current in one direction & high (ideally infinite) resistance in other direction. [Most commonly used is semiconductor diodes]

Eg:- Semiconductor diode
Vacuum tube diode.
Zener diode.
Light emitting diode (LED)
Photo diode

Advantages of p-n diode over vacuum diode :-
- smaller & compact
- no heating required.
- Less power consumption.
- Mechanically steady / rigid.
- not effected by vibrations.
- Life is very long (unlimited practically)
- solid state device.

➡ **Zener diode** :- p-n device which is designed to operate in its breakdown region. These diodes are connected in the reverse direction i.e anode to (-)ive terminal & cathode to (+)ive terminal. Breakdown occurs as soon as the applied voltage reaches the appropriate level. Once breakdown voltage is reached, the zener diode can allow the flow of heavy current maintaining the voltage same. This sudden increase in reverse current at breakdown voltage is known as Zener Current.

Typical applications are voltage regulation, voltage comparison in AVR's and stabilised voltage supplies.

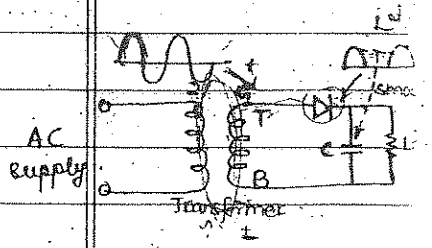
- Breakdown voltage is governed by the material, amount of impurity added and

◆ Thermistors :- se onductor devices whose resistance changes with temp. Can be manufac ured to have both (+)ve & (-)ve temp. coefficients. Thermistor materia are doped with elements such as antimony, nickel, cobalt etc. The property of the emp. co-efficient of resistance is used in devices for temp measurement thermal compensation and thermal relays for protection against overheating. Thermistors with pposite characteristics, of a rising resistance with increase of temp, are pe ferred for some applications.

→ Rectification :- flo of current is permitted in one direction only i.e used to nvert a.c (where current changes its direction) to d.c (where d ection of current is in one direction only).

◆ Half wave rectifica on :- Refer secondary winding TB of transformer. when T is (+)ve & B is (-)ve, current flow through diode. But, when B is (+)ve & T is (-)ve, current flow is resisted. Thus the half sine wave indicates unidirectional current although not continuous.

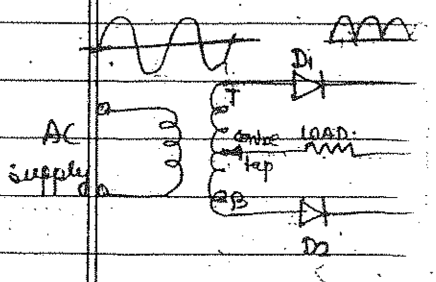
To obtain d.c with less ripple, capacitor is used.



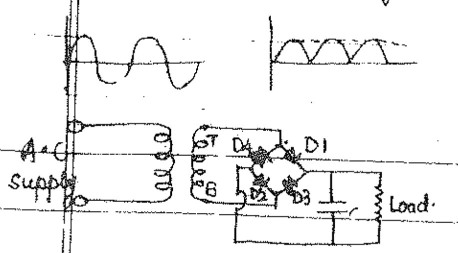
◆ Full wave rectifica ion :- Both half wave of a.c input can be applied to the load with an arrangement of 2 diodes & a transformer having centre tap.

Each p-n diode conducts in turn when the end of the secondary winding which supplies it has full potential relative to the centre tap.

Requires a high voltage transformer. So cost is high.

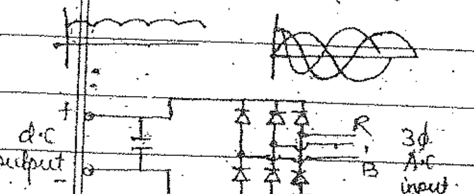


◆ Full wave Bridge Rectifier :– 4 p-n diode in a bridge circuit b/w transf. secondary & load will give full wave rectified without the need for a centre tap. So transform. less voltage & size can be used.

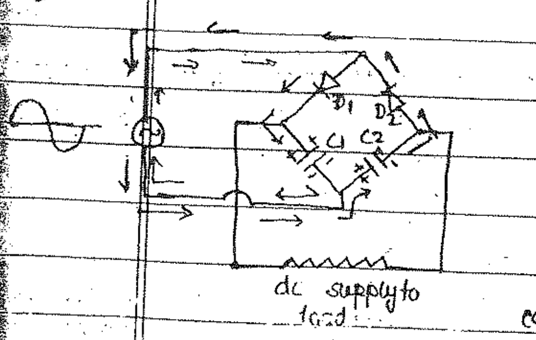


Diodes work in series pairs to complete a circuit carrying current through the load. When terminal T transformer secondary has higher potential than B, then current follows path from T through diode D_1 to the load & completes. It travel through D_2 to terminal B of the secondary. Current flows in opposite direction when B has higher potential than A via D_3 & D_4. Thus a unidirectional current is provided for the load.

◆ Three phase rectification :– one, two or 4 diode circuit for rectification of single phase a.c gives unidirectional o/p but quality of d.c is poor bcoz of ripple. Smoothing of d.c is required. For large power it may increase the cost. So for better results, bridge of 6 diodes is used for rectification of 3 ϕ supply.



→ Voltage Doubler :– used to produce a voltage across the load which is almost twice the peak value of a.c input, provided the load current is small.



- 2 diodes & 2 capacitors form a bridge. AC input will flow clockwise & then anticlockwise as shown by the arrows. Clockwise flow via R_1 ~~with~~ will charge capacitor C_1 to approximately peak of +ive voltage wave. While anticlockwise flow via R_2 will charge capacitor to approximately the peak of -ive voltage wave.

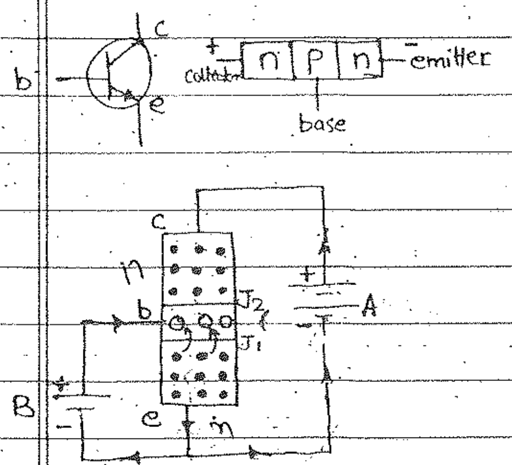
The 2 capacitors are in series with each other & also with the load. They discharge to the load, & being in series their opposite voltage add & give doubling effect.

Used in TV & radars as an alternative to a heavier, larger & more expensive transformer & rectifier arrangement.

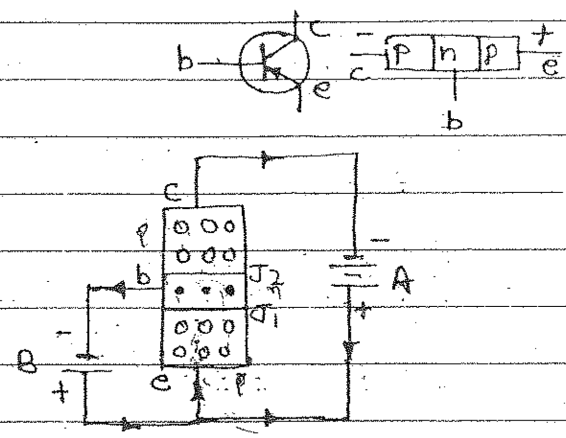
→ Transistors :- a semiconductor device having 3 layers (npn or pnp) used to amplify & switch electronic signals & electrical powers.
Their operation is based on the principle that application of voltage will make (-)ve current carriers move in one direction & (+)ve carriers in other.

3 layers :-
i) Base :- responsible for activating the transistor
ii) Collector :- positive lead in npn & (-)ve in pnp
iii) Emitter :- negative lead in npn & (+)ve in pnp.

npn



pnp



- With one battery A in the circuit, current flow through the transistor is restricted by junction J_2 since the junction is Reverse biased.
- When battery B is connected, b/w base & emitter, current flow through the junction J_1 which is forward biased. Thus a current path is set in the transistor with the help of minority charge carriers [electrons in npn & holes in pnp].
- Current flow from battery A is thus governed by the strength of the input voltage from B. Variation of this will cause change in current flow through the device from battery A.
- So we can see that transistors enables a signal, too weak in itself to be of direct use, to control a large power source (here Battery A). The control by a small available power over a large usable power is called Power Gain OR Amplification

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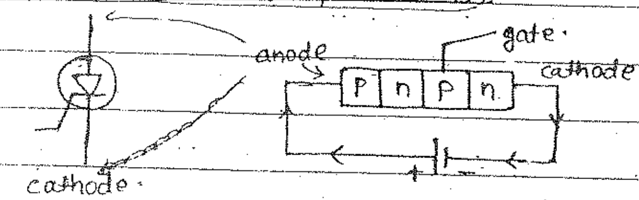
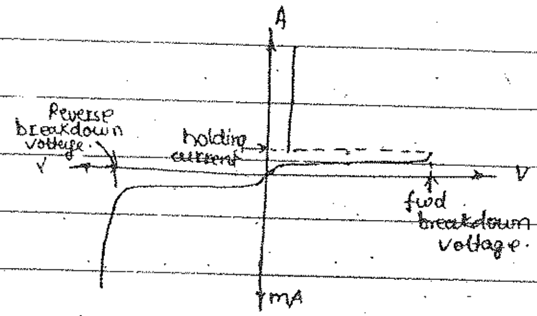
Thyristors :- solid state switches which are turned on by application of a lo level signal voltage through a trigger connection known as gate.
eg:- Silicon Controlled Rectifiers (SCRs) — 4 layer semiconductor device
Triacs — more than 4.

- have no moving parts to wear or ~~contacts~~ contacts which can be damaged by
- electrical 'turn on' makes it ideal for remote operation & its small size makes it convenient component of control circuits.
- can control current greater than 1000 amps & voltage in excess of 1000 V.
- operates much faster than mechanical switches & some are used in server when switching rate is 25,000 times per second.

Silicon Controlled Rectifiers [SCRs]

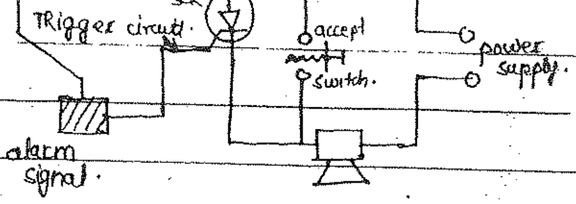




when small current flows into the gate, this allows a larger current to flow from the anode to cathode. Even the current into the gate stops the thyristor continues to allow current flow.

[During normal operation the SCR is turned on by a gate signal or trigger with the anode/cathode voltage much lower than that required for breakdown. This trigger needed for a time measured only in microseconds. The SCR will remain switched on unless current flow drops below a certain holding value.]

SCR used in Alarm Circuit :- The alarm condition is used to apply the trigger & switch the alarm circuit through su. When alarm acceptance button is pressed & released it momentarily allows current to bypass the SCR which then switches itself off and break the alarm circuit.



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Batteries

→ **Cell :-** Any two substances of an electro-chemical series will form a couple in conjugation with electrolyte which is referred to as cell, emf of which is normally b/w 1V to 3V.

[Chemical energy is converted into electrical energy]

Full charged cell, Voltage – ~~2.2V~~ 2.0V 1.95 ON LOAD, Sp. gravity – 1.280
Discharged cell, Voltage – 1.8V, Sp. gravity – 1.120

Ideal temp:– 15 to 25 °C.

→ **Types of cells :-**

i) **Primary cell :-** two substance of electrochemical series form a couple in which inherent chemical energy of the substance is converted into electrical energy during discharging. When ~~the~~ chemical energy is used up, the cell has to be discarded [not rechargable]

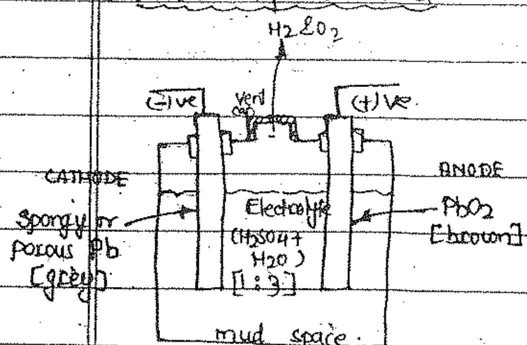
– marine use of primary cells are in life saving equipments and are more often sea water activated.

ii) **Secondary cell :-** electrical energy is converted into chemical energy during charging & stored up in the cell. During discharging stored up energy is converted into electrical energy.

On board ship, secondary cells are used for as emergency source of power supply → (i) Lead Acid Cell & (ii) Alkaline cell.

→ **Battery :-** is a no. of cells connected together.

◆ **Lead Acid Cell**



During discharging, as within the electrolyte current flows from cathode to anode. H^+ ions moves to anode and SO_4^- ions move to cathode.

~ At Anode, $PbO_2 + H_2^+ + H_2SO_4 \rightarrow PbSO_4 + H_2O$.

~ At Cathode, $Pb + SO_4^- \rightarrow PbSO_4$.

• So on both plates, sulphation takes place & both plates have a coating of whitish $PbSO_4$. Due to the formation of water, specific gravity of electrolyte decreases.

• Cell voltage ↓ & cell gives out energy.

• When voltage drops to 1.8V & sp. gravity to 1.12 battery should be charged.

• Over discharging will cause permanent sulphation of plates.

During charging, the cell is connected to d.c charging supply of corr voltage. Flow of current from charging source reverse the discharg action of the cell; thus lead sulphates on the plate are broken down. The sulphates goes back into the solⁿ as SO_4^{2-} leaving the plates as pure lead. Water in the electrolyte breaks down returning H^+ ions to the solⁿ & allows the oxygen to recombine with lead of the positive plate & form lead peroxide.

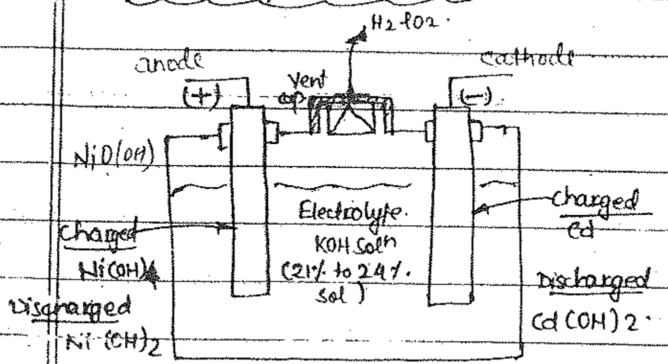
At cathode, $PbSO_4 + H^+ \longrightarrow Pb + H_2SO_4$.

At anode, $PbSO_4 + SO_4^{2-} + H_2O \longrightarrow PbO_2 + H_2SO_4$.

- Due to consumption of water specific gravity of electrolyte increases.
- Cell voltage rises and energy is absorbed by the cell.

→ Gas emission :- Towards the end of charging & during overcharging, the current flowing in the cell causes breakdown of water in the electrolyte, shown by bubbles at the surface. Both H_2 & O_2 is released through cell vent cap. There is an explosion risk if H_2 is allowed to accumulate (flammable range is 4% to 74% of H_2 in air). Thus good ventilation & protection against naked lights or sparks must be provided.

Alkaline / Ni-Cd Cell



During discharging,

At anode, $Ni(OH)_4 + 2K^+ \longrightarrow Ni(OH)_2 +$

At cathode, $Cd + 2OH^- \longrightarrow Cd(OH)_2$

During charging,

At anode, $Ni(OH)_2 + 2(OH^-) \longrightarrow Ni(OH)_4$

At cathod, $Cd(OH)_2 + 2K^+ \longrightarrow Cd + 2K^+$

There is no formation of water, so sp. gravity does not change during charging or discharging. So sp. gravity is not an indication for the state of charge.

→ Gas emission :- Same as lead acid battery. Release H_2 & O_2. Provided with vent cap having a NRV, since CO_2 in atmosphere can react with electrolyte to form Potassium

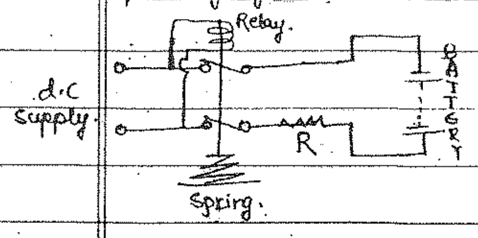
Battery Maintenance :-
- Ensure all terminals tight & corrosion free
- Vents clear

Lead - Acid Battery	Ni- Cd Battery
• Check level of electrolyte. Add distilled water if low	• Check level of electrolyte. Add distilled water if low.
• Check specific gravity.	• Check voltage.
• Check voltage.	• Keep clean & dry (grease terminal with petroleum jelly.
• Keep clean & dry (grease terminals with petroleum jelly)	

Comparision of lead acid & alkaline cell.
i) alkaline cell discharge at very high rate.
ii) voltage of alkaline cell is low.
iii) KOH solⁿ has high resistance, so no self discharging.
iv) Capacity of alkaline cell is ↑ but efficiency is ↓.
v) Alkaline cells are costlier.

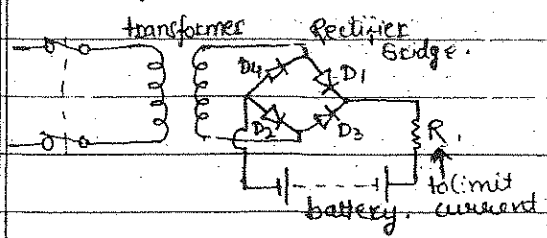
Battery Charging

i) Charging from d.c mains :- includes a resistance in series to reduce the current flow.



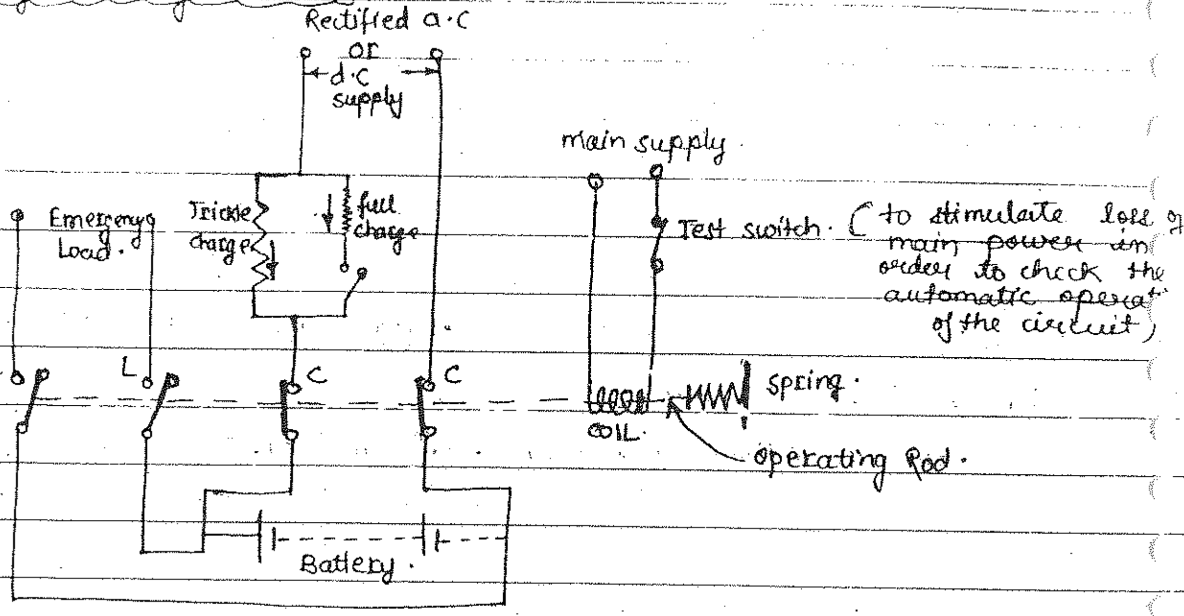
Feedback from battery is prevented, as mains failure occurs, by the relay (which is de-energized) and spring, arranged to automatically disconnect the battery.

ii) Charging from a.c mains :- a.c main voltage is reduced by transformer to a suitable value & then rectified to give a direct current for charging.



[30 volts supply for charging 24 V batteries.
Each clockwise wave of current will travel through D_1 & D_2 while anticlockwise will travel through D_3 & D_4 thereby giving current in only one direction.

Emergency Battery Circuit



This circuit shows the charging of emergency battery and automatic connection of emergency batteries upon loss of main power to supply for emergency loads.

In normal condition the batteries are on standby with load switch (L) open & charging switches (C) closed. This position of switches is held by the electromagnet coil against the pressure spring. Loss of main supply will denergize the coil and the operating rod will be pushed by the spring force to disconnect the charging switches (C) & connect the load switch (L).

Quick charge / Boost charge :- when battery have been discharged on load, we put it on quick charge. It requires the same current as needed for discharging. Takes 3-4 hrs.

Trickle charge / Float charge :- Batteries get discharged if not used due to local action. 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 [50 to 100 mA per 100 amp-hr battery capacity).

→ Battery Ratings :- ampere - hour
A battery with capacity 1 - amp-hr should be capable of continuously supplying a current of 1 amp for 1 hr or 2amps for 1/2 hr or 1/3 amps for 3 hrs etc. before becoming completely discharged.
for higher ratings like 300 Amp-hr → 30 amps for 10 hrs.

→ REGULATIONS :- SOLAS CHAPTER II-1 Part-D Reg. 42 & 43.
i) shall be suitably located for use in an emergency which shall operate without recharging while maintaing the voltage of the battery throughout the discharge period within 12% above or below its nominal voltage.
ii) automatically connect to the emergency switchboard in event of failure of the main source of electrical power.
iii) immediately supply at least for the following services for half an hour :-
- emergency lighting at every muster & embarkation station.
- emergency lighting in all alleyways, stairways, exists and escape trunks; machinery spaces & main generating station; ~~cont~~ control stations, mk control room; main & emergency switchboard; stowage position for fireman's outfit; steering gear; fire p/p; sprinkler p/p; emergency bilge p/p & starting position of their motors; in all cargo p/p rooms of tankers
- navigation lights; VHF radio; MF radio; ship earth station; other lights required by International Regulations for Preventing Collisions at Sea.
- internal communication equipment; fire detection & fire alarm system; intermittent operation of daylight signalling lamp, ship's whistle, manually operated call points & all internal signals required on an emergency.

Other requirements
i) Constructed to prevent spilling of electrolyte & emission of spray.
ii) Assembled in crates/trays supported on non-absorbent insulating.

materials. Insulated stands for voltage above 120V.

iii) Deck below battery room to be protected with acid resisting alkaline resisting material [floor & upto 150 mm on all sides]

iv) Notice of "prohibited naked lights & smoking" must be displayed.

v) Battery bank > 2KW – in battery room, or locker on deck.

0.2 - 2KW – in battery room, locker on deck or in m/c spaces or in open with cover.

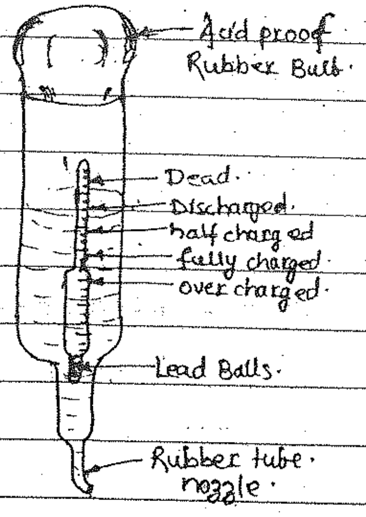
< 0.2KW – in open with protective cover.

vi) Batteries not to be installed in accomodation (sleeping quarters)

vii) Natural or forced air circulation required to prevent accumulation of flammable gases.

viii) Lighting in battery room to be explosion proof.

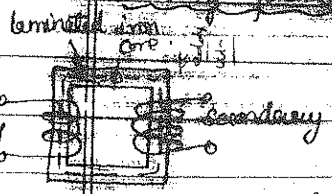
→ Hydrometer



instrument used for measuring the specific gravity of electrolyte.

Rubber tube nozzle is put inside the electrolyte and Rubber bulb is pressed & released. Electrolyte enters into the tube. The hydrometer moves up & down & then float at a stable position indicating correct specific gravity.

TRANSFORMERS

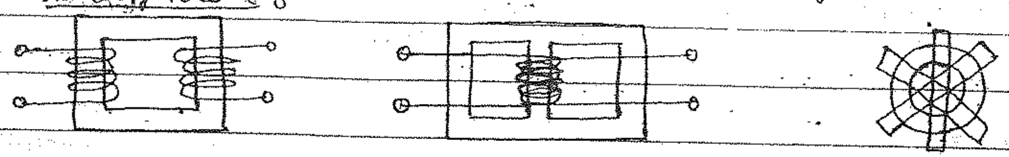


→ Working principle:- works on mutual inductance b/w 2 circuits linked by common magnetic flux. It consists of two inductive coils which are electrically separated but magnetically linked through a path of low reluctance. The two coils possess high mutual inductance. If one coil is connected to a source of alternating voltage, an alternating flux is set up in the laminated core, most of which is linked with the other coil in which it produces mutually induced emf. If second coil circuit is closed, a current flows in it. & so electric energy is transferred from first coil to the second. The first coil in which electric energy is fed from the a.c supply mains is called PRIMARY while the other from which energy is drawn out is called SECONDARY.

→ Function & Types

★ A transformer is a static (or stationary) piece of apparatus by means of which (i) electric power in one circuit is transformed into electric power of the same frequency in another circuit. (ii) It can raise or lower the voltage in a circuit but with a corresponding increase or decrease in current.

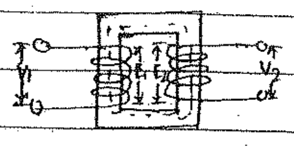
- According to core :-



Core Type. Shell type Berry type.

- According to voltage :- Step Up & Step Down.
- According to phases :- Single phase & 3 phase.
- According to power :- Lighting transformer & Power Transformer.
- According to cooling :- Self air cooled ; self oil cooled ; forced air cooled ; Forced oil cool.

→ Voltage Transformation Ratio (K)

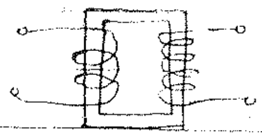


$$K = \frac{E_2}{E_1} = \frac{N_2}{N_1}$$

For ideal transformer, input VA = output VA.

$$V_1 I_1 = V_2 I_2 \quad \text{or} \quad \frac{V_1}{V_2} = \frac{I_2}{I_1} = \frac{1}{K}$$

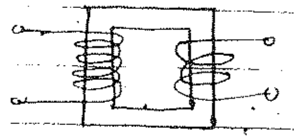
◆ Step up transformer

→ 

→ $N_2 > N_1$ or $K > 1$

→ If primary has 3 loops & the secondary has 30 then voltage is stepped up 10 times.

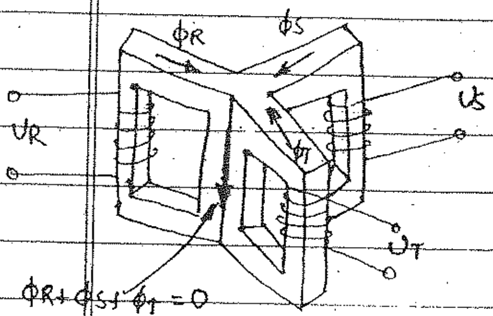
Step Down transformer

→ 

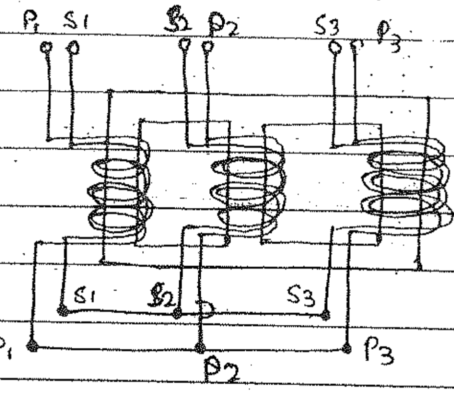
→ $N_2 < N_1$ or $K < 1$.

→ If primary has 30 loops & secondary has 3, then voltage stepped down 10 times.

→ 3 ϕ Transformer



main advantage of 3 ϕ transformer is that it occupies less floor space for equal rating, weigh less, costs about 15% less & further only one unit is to handled & connected.

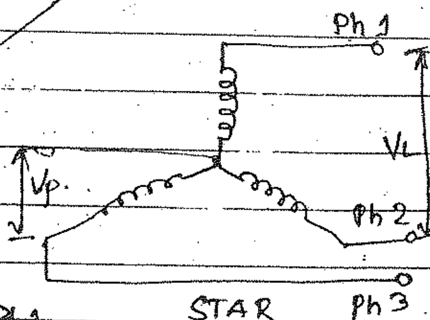


$$K = \frac{N_S}{N_P} = \frac{V_S}{V_P} = \frac{I_?}{I_?}$$

⇒ Different 3 ϕ - transformer connections.

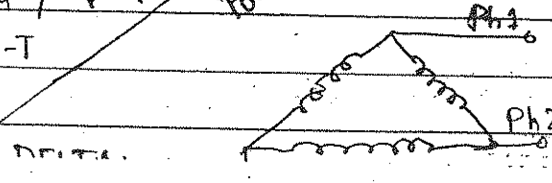
I) Y Y / Star - Star.
II) $\Delta - \Delta$
III) $Y - \Delta$
IV) $\Delta - Y$
V) open delta / V - V
VI) Scott / T - T

Power $= \sqrt{3} V_L I_L \cos\phi$



Line voltage $= \sqrt{3}$ phase voltage

line current = phase current

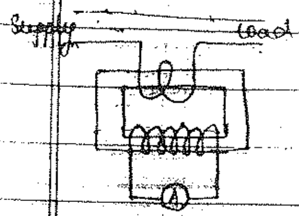


Line voltage = phase ~~voltage~~ current

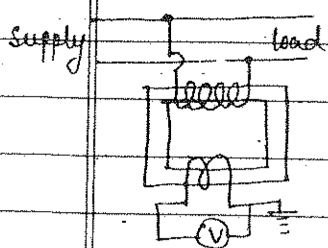
Line current $= \sqrt{3}$ ~~phase voltage~~

[redacted]

→ Current transformer :- are used with low ~~voltage~~ range ammeters to measure currents in high-voltage a.c circuits where it is not practicable to connect instruments and meters directly to the lines.



→ Potential transformer :- are extremely accurate ratio step-down transformers & are used in conjunction with standard low range voltmeters ~~to~~ to measure the high voltage in the a.c circuits.



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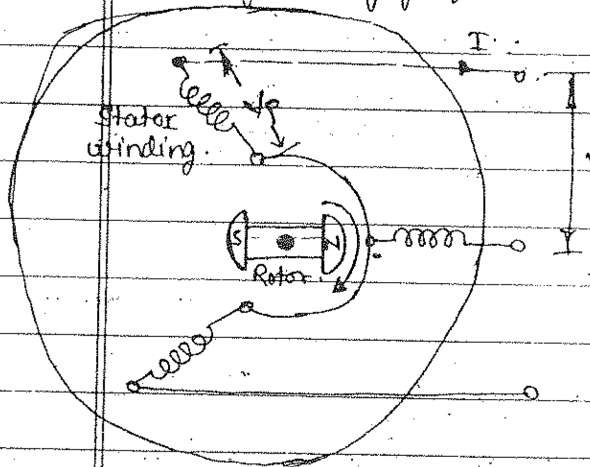
A.C Generators

The electrical power demand on board ship is fulfilled by a.c generator.

→ Working principle:- works on Faraday's law of electromagnetic induct, i.e whenever a conductor moves in a magnetic field, it cuts the magnetic flux and an emf is induced in the conductor. The magnitude of induced emf depends on the strength of the magnetic field, rate of cutting of flux and the length of the conductor.



Here, when rotor rotates, the stator conductors (being stationary) are cut by the magnetic flux and h... emf is induced in the conductors.

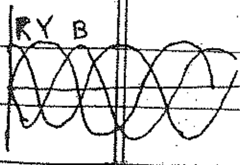
* Advantage of having stationary armature a rotating field system :-

(i) o/p can be led directly from fixed terminals on stator to the load circuit, ~~whi~~ without having to pass it through brush contact.

(ii) rotating field is comparitively light & can run at very high speed & produce very high voltage.

(iii) For high voltage it becomes easy to give insulation to stator winding.

The 3 sets of coils called phase winding is located in the slots of the stator. The emf induced in each phase is 120° out of phase with the other two phases. One end of each phase winding is joined together to form the neutral point of star connection. The other end of the phase windings are connected to outgoing conductors called lines.



* Emf generated $E \propto n \times \phi$ (n: rpm; ϕ: strength of magnetic flux)

frequency ⇒ $f = NP/120$ (N: rpm; P: no. of poles)

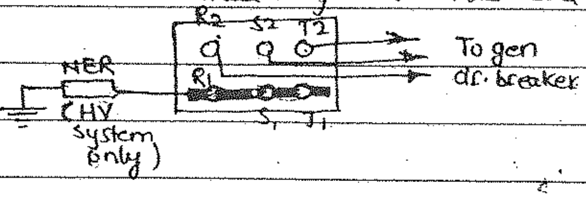
Output power = $\sqrt{3}\, V_L I_L \cos\phi$ ← power factor (About 0.8 lagging) i.e I lags V by 37°

ϕ: phase angle b/w V_{ph} & I_{ph}

→ CONSTRUCTION :-

The two main parts of any rotating a.c machine are (i) STATOR and (ii) ROTOR.

◆ **STATOR** :- fabricated steel stator frame supports the stator core & its 3-φ windings. The stator core is assembled from laminated steel with the windings housed in slots around the inner periphery of the cylindrical core. The stator coils are interconnected to form 3 separate phase windings with 6 ends. These phase ends are found in the stator terminal box.



The main outgoing cables connected to these terminals conduct the generator's electric power to its circuit-breaker at the main switchboard.

◆ **ROTOR** :- provides field excitation for generating electricity from its electromagnetic poles.

2 constructional forms of rotor :-

(i) Salient pole type	(ii) cylindrical type
- has projecting poles bolted or keyed onto the shaft hub.	- The excitation windings are wedged into axial slots around the steel rotor.
- field excitation winding are fitted around each pole.	- Unwound sections of the rotor form the pole faces b/w the winding slots.
- used with medium & slow speed shafts (1800 rpm & below)	- used with large power, high speed shaft (1500-3600 rpm) - steam/gas turbine drive.

◆ The rotor poles are supplied with direct current (d.c) for excitation.

- Static excitation :- d.c current is fed into the field windings via carbon brushes on a pair of shaft mounted slip-rings.
- Dynamic excitation :- brushless excitation in which a shaft mounted shaft mounted a.c exciter is used, the o/p being rectified by shaft-mounted silicon diodes & fed directly to field winding.

◆ COOLING :- Power losses, typically 10% of the generator rating, cause internal heating in the windings & magnetic core of both rotor & stator. heat must be continuously transferred out of the generator to prevent excessive temp. rise causing breakdown of winding insulation.

- Forced air circulation through air cooler & fan.
- Cooling air through ventilation ducts in the stator core, b/w rotor & pole and through the air gap b/w stator & rotor.
- Temp sensors used to monitor the temp. of stator windings & bearings.
- while generator is stopped during standby / maintenance, low power electric heaters within the machine prevent internal condensation forming on the winding insulation [Auto / Manual — 220 V a.c 1φ supply]

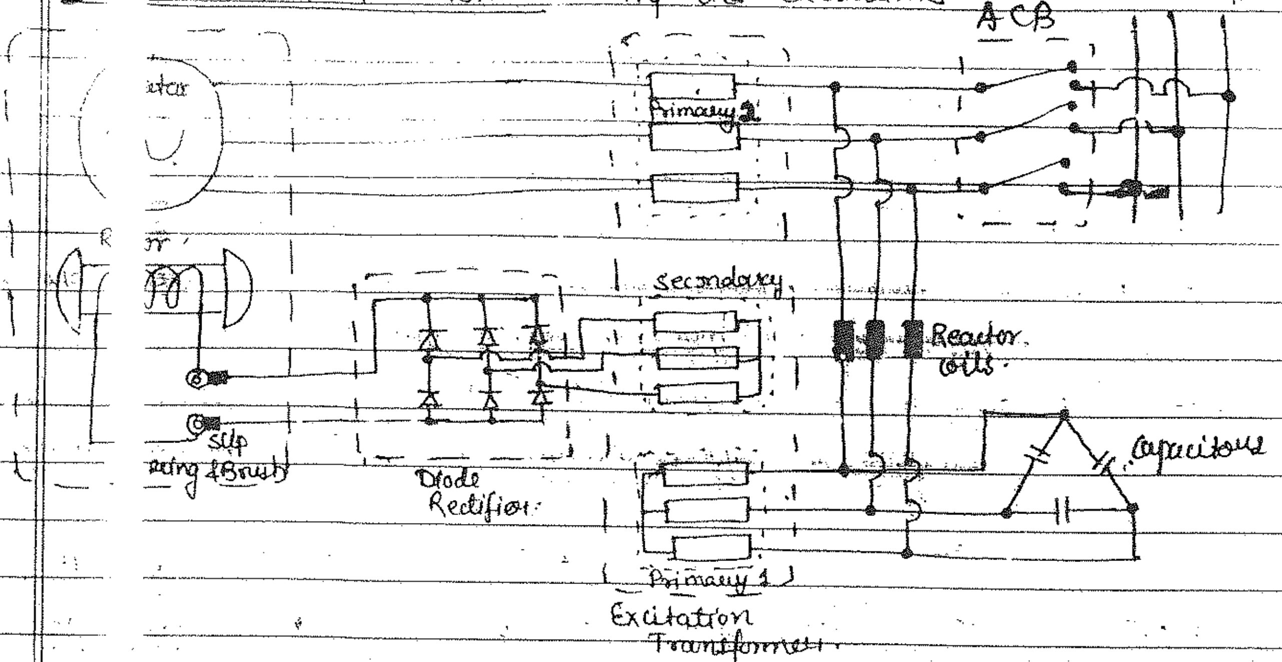
* Air Gap :- For cooling & to avoid unbalanced magnetic pull.
Usually 2 to 3 mm (plastic filler gauge)
should be as less as possible to keepdown the magnetizing current & to improve power factor.

◆ Shaft bearings of large generators are usually insulated to prevent stray current from circulating through. The unbalanced (stray) end-winding magnetic flux induces an emf along the steel shaft. This will cause a current to circulate through the shaft, bearings & bedplate to produce arcing across the bearing surfaces & degradation of oil layer.
To prevent the flow of shaft current, one bearing (usually non drive end) is electrically isolated from earth by a thin layer of insulating material beneath the bearing pedestal. [Effectiveness can be checked by measuring its voltage to earth which may show as a few volts.

EXCITATION METHODS :-

- The excitation system has both to supply & control the d.c for the rotor pole windings. level of the excitation current & resulting pole field strength are automatically adjusted by the voltage regulating component.
- Emf generated depends upon speed & flux. Speed is constant so flux is regulated as per load demand.

1. STA. EXCITATION SYSTEM [compound excitation].



- T. rotor winding have some residual magnetism in it. When the rotor is rotated by the prime mover, some voltage is induced in stator winding. The 'Primary 1' coil the excitation transformer is ~~stat~~ in series with the stator, so it will excite the 'secondary coil' and thus the magnetic field of the rotor becomes stronger. This in turn will ... more emf in the stator winding & the phenomenon continues.
- T. 'Primary 2' coil is also connected in series with the stator. When the ACB is close & load increases, more current is drawn. Therefore, the primary 2 will draw more current thereby giving more excitation in the secondary coil. Thus the required voltage is maintained even without AVR.

Adva. tages:-

i) Sudden response to load fluctuation [15% of voltage dip in 0.1 to 0.2 secs.]. ... very suitable in bulk & general cargo ship.

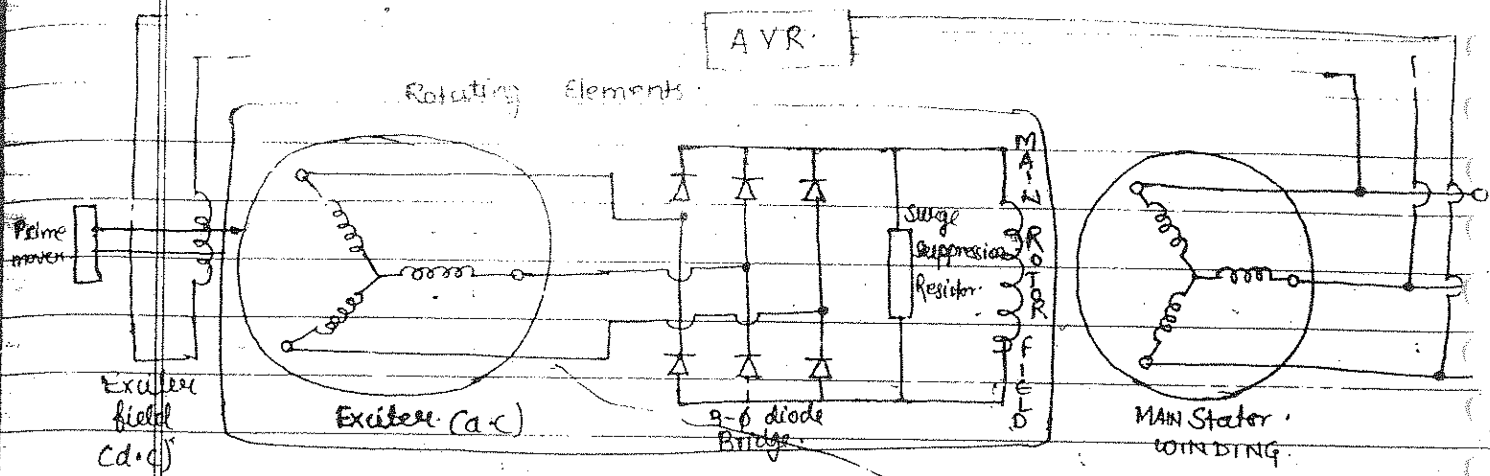
ii) ... AVR

Disadvantage:-

i) ... down of slip rings & brushes may cause sparking.

ii) Maintenance cost is more.

2. BRUSHLESS, SELF EXCITED, ERROR OPERATED EXCITATION SYSTEM



There is some residual magnetism present in the main rotor winding. When the primemover rotates the rotor, emf is induced in the stator winding. This voltage is fed to AVR which in turn gives excitation, rectified by the diode stack to the main rotor winding. Thus the magnetic field becomes stronger & more voltage is induced. This phenomenon continues & the rated o/p is generated.

Advantages :-

- No slip rings & brushes so less maintenance.
- Automatic Voltage Regulation.

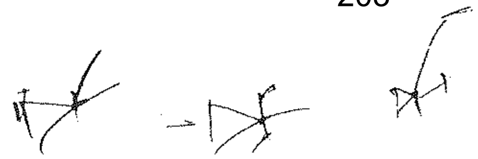
Disadvantage :-

- Sluggish response to sudden load changes.

* If one of the rotating diodes fails & becomes

I) Open circuit :- remaining diodes will continue to supply the main field. The exciter field would be automatically boosted up to maintain the correct voltage. The diode failure is undetected. But the exciter will gradually overheat.

II) Short Circuit :- may lead to short circuit of exciter. Rapid overheat of exciter will occur.



Flashing of Generator :- If the generator has not been running for long time, it may loose its residual magnetism. So flashing of the generator is required.

(I) Push the pre-exciter button which will connect 24 V D.C supply to the stator of the exciter.

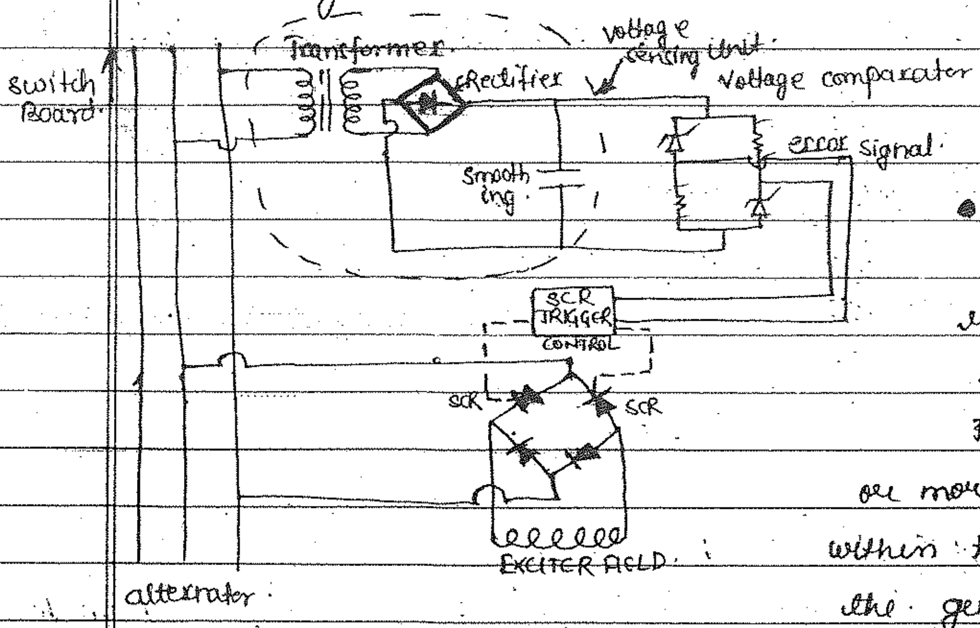
(II) If pre-exciter is not present, connect a 12 V battery to R 15 for 2 minutes after disconnecting the AVR.

Automatic Voltage Regulator [AVR]

(i) maintains the voltage at rated value.

(ii) to ensure equal KVAR load sharing during parallel operation.

(iii) trip the generator at 300 % overload by instant release system during short circuit condition.



- The control circuit of AVR consists of transformers, rectifier, zener diodes, transistors & thyristors. These are mounted on one or more circuit cards fitted within the switchboard or local to the generator.

- The voltage sensing unit transforms down, rectifies & smoothen the ~~gene~~ generator o/p voltage to produce a low voltage d.c signal that is proportional to the a.c generator voltage.

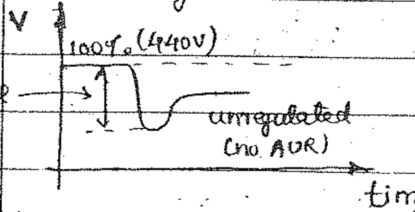
This actual d.c signal is compared with a set d.c value produced by a reference circuit of zener diodes and resistors. A error signal o/p is then amplified and fed to the ~~to the~~ exciter field through

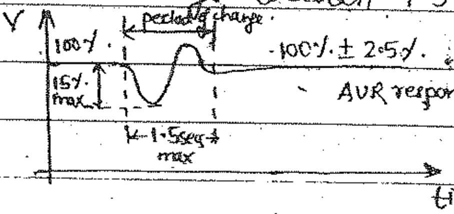
• field regulating circuit that consist of thyristor. [The error signal control firing angle of thyristor through a triggering circuit to give the desired voltage in the brushless alternator]

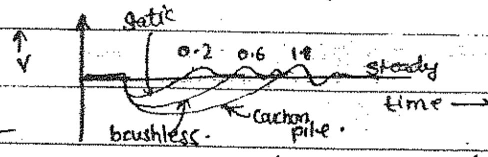
Voltage comparator

★ The zener diodes, as we know, operates in reverse breakdown mode. The zener diode used here have very low reverse breakdown voltage. Once the breakdown voltage is reached, the voltage here remains constant ~~and~~ despite only current changes. So the changes in applied voltage doesn't affect the voltage of the diode but will cause a change in resistance which will cause a change in current. So imbalance of resistances, produces an error signal by which thyristor is triggered.]

- An AVR will control the generator's voltage to ± 2·5 %. (or better) of its set value over the full load range.
- Transient voltage dip is usually limited to 15 % for a specified sudden load change with recovery back to rated voltage within 1·5 seconds.







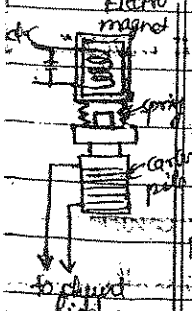
Other methods used for voltage regulation :-

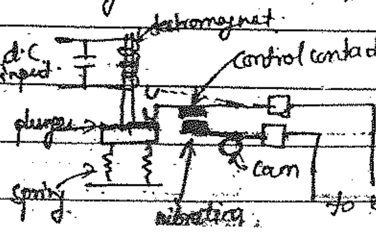
i) vibrating contact regulator. ⟶ Here increase of o/p voltage will produce an increase in the strength of the magnet, & the effect is that the plunger & lever are pulled up together with the control contact. The vibrating ~~contact will touch the control contact.~~ [Note: the vibrating contact is vibrated continuously ~~by a rotating cam at a rate of 120 times per~~] closing the contact has the effect of short-circuiting the resistance in series with the shunt field of the d·c exciter. Since the o/p voltage is ↑ so the closing contact time is very less. Thus the current flow through the exciter ↓.

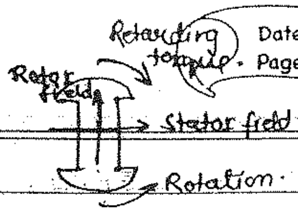
ii) excitation Transformer

iii) carbon pile regulator.

current flow through the excited coil is controlled by a resistance made up of carbon discs packed into a ceramic tube. The resistance of the carbon pile is varied by ~~the pressure applied by springs on an~~ iron armature & relieved by the magnetic field of an an electromagnet coil. When alternator voltage drops, electromagnet ~~get demagnetized &~~ the carbon pile resistance goes low. More current is allowed to ~~flow through~~ the shunt field exciter

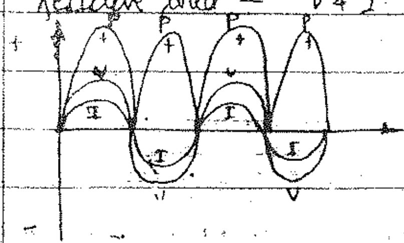






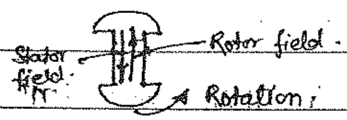
Effect of KW loading on alternator

Resistive load — V & I are in phase — Power = V x I (always +ve)



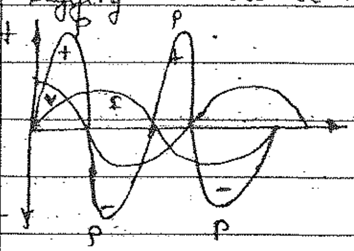
when generator supplies KW power, energy flow is from generator to load & fuel has to be burnt in the generator to produce energy.

KW load applied — stator supplies current to load — stator current in phase with stator emf produces rotating magnetic field — stator field lies across rotor field & is cross magnetizing — produces a retarding pull / torque on rotor — rotor tends to slow down — sensed by governor & fuel is increased.



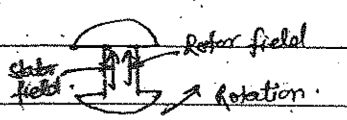
Effect of KVAR loading [lagging] on alternator

Lagging — inductive load — current lags voltage — Power can be (-)ve or (+)ve.



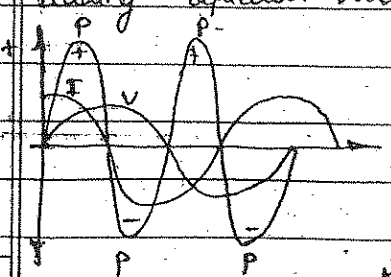
— here energy flow is backward & forward b/w generator & load. The prime mover is not involved so no fuel required.
Power in 1/4 cycle is (+)ve & next 1/4 cycle is (-)ve.

KVAR (lagging) load applied — stator supplies current which lags the stator emf by 90°, producing rotating magnetic field — stator field in line with rotor field but in opposite direction — this reduces the main field — generator emf reduces — AVR senses & increases the excitation.



Effect of KVAR loading [leading] on alternator

leading — capacitive load — current leads voltage by 90° — Power (+)ve or (-)ve.



— here energy flow is forward & backward b/w generator & load. Prime mover not involved. so no fuel requirement.

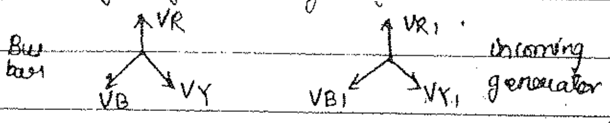
KVAR (leading) load applied — stator supplies current which leads stator voltage by 90°; producing rotating magnetic field — ~~stator~~ field in with rotor field & in same direction — main field is increased — generator emf increases — AVR senses & decreases the excitation.

Parallel Operation of Generation.

Generators run in parallel to share load.

Conditions for synchronising / paralleling.

1) voltage of incoming generator must be same as that of the "bus" bar.



$V_R = V_{R1}$; $V_Y = V_{Y1}$; $V_B = V_{B1}$

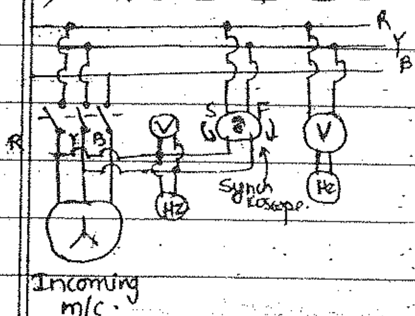
2) Frequency of incoming machine must be as that of the bus bar.

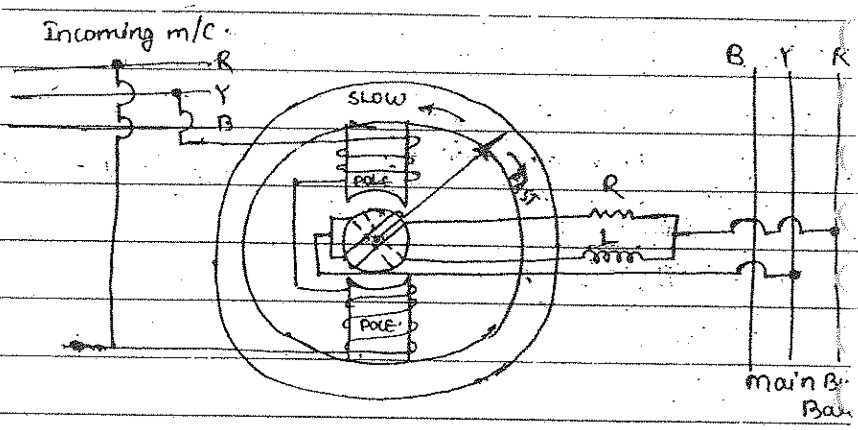
3) Phase sequence of both should be same.

4) Phase angle must be same. i.e line to line voltage must reach their max. value at exactly same instant.

Methods of synchronising:

1) Synchroscope method :-





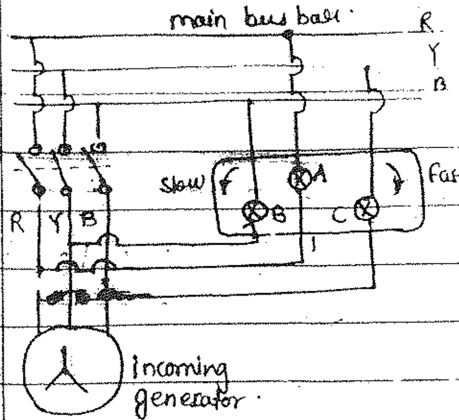
Synchroscope is a small motor with coils on two poles connected to the 2 phases of incoming m/c. The armature winding of rotor is supplied from two phases of the main bus bar. This circuit incorporate a resistance & an inductance connected in parallel. Inductance has the effect of delaying current through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

The polarity of the poles will alternate N/S by altering phases not in the incoming m/c. Rotating field with react with the poles by turning the motor clockwise or anticlockwise.

CLOCKWISE → Incoming m/c is too fast. ANTICLOCKWISE – Incoming m/c is slow

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

2) Three Lamp Method :-



Bulb A → across phase R-R
Bulb B → across phase B-Y
~~Bulb C → across phase Y-B~~

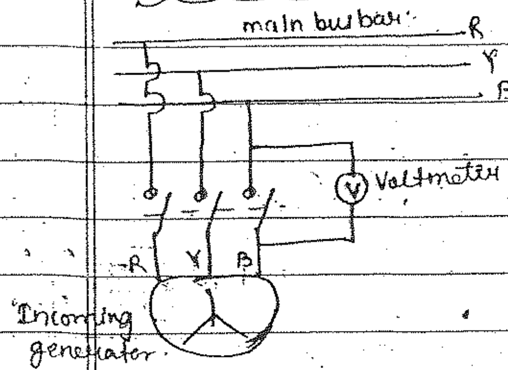
Rotation of lamp brightness indicates whether incoming m/c is running fast (clockwise) or slow (anticlockwise)

Correct synchronization when Lamp A is dark & B and C are equally bright.

A is dark because R-R connected i.e same voltage.

3) Voltmeter method :-

(when above two methods fails)



- Connect a voltmeter b/w any ~~any~~ one phase of incoming m/c & bus bar. i.e across one phase of circuit breaker.

Adjust the generator speed until the voltmeter very slowly fluctuates from zero to max.

Close the breaker when the voltmeter indication passes through zero.

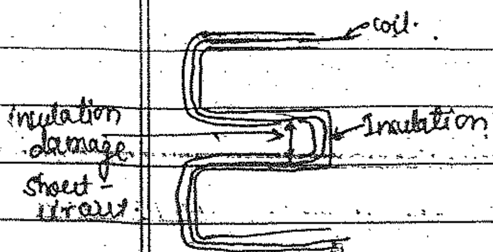
→ Consequences of Incorrect synchronizing.

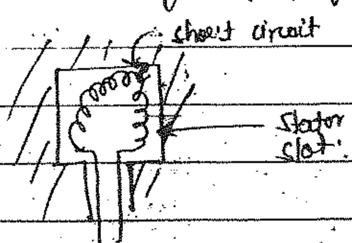
If the incoming generator voltage & bus bar voltage is not ~~the~~ same during closing of circuit breaker, the incoming m/c will start drawing power from bus-bar & will start motoring.

Result :- Black out.

Short-circuiting ; physical damage to generator & prime mover

Overheating & burning of equipment.

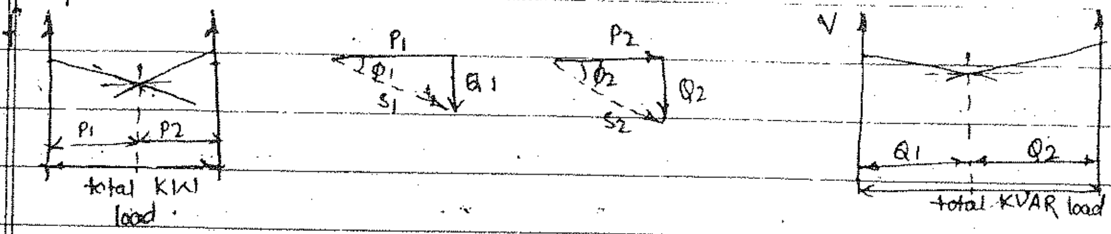




Load sharing

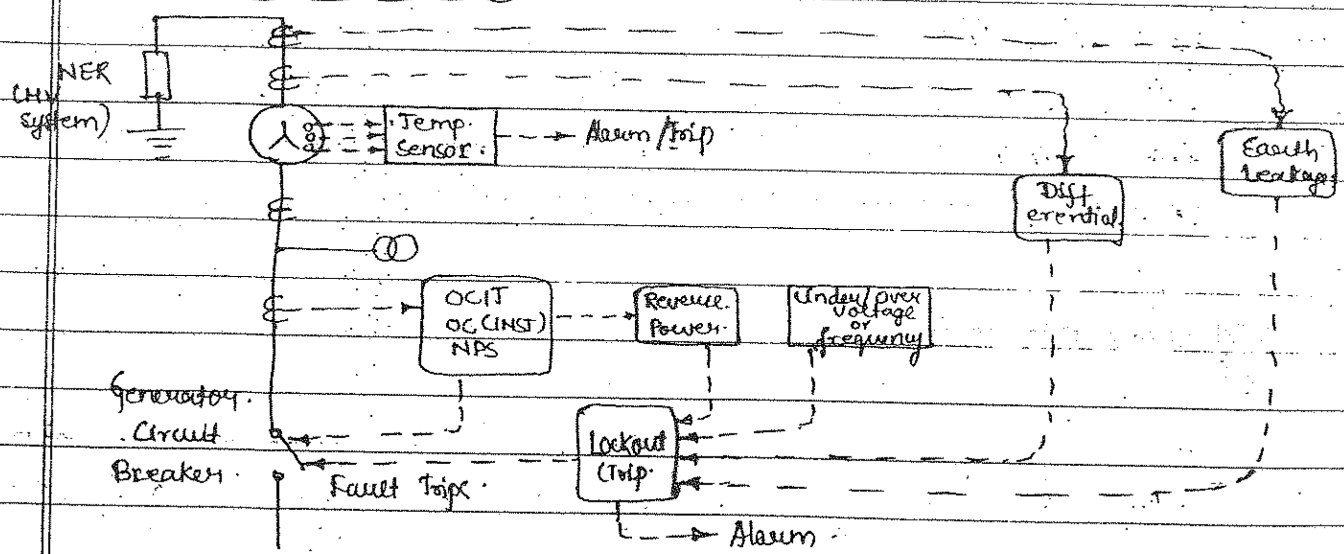
Both governor & AVR are equipped with "droop characteristics" for proper sharing.

Governor – KW load & AVR – KVAR load.

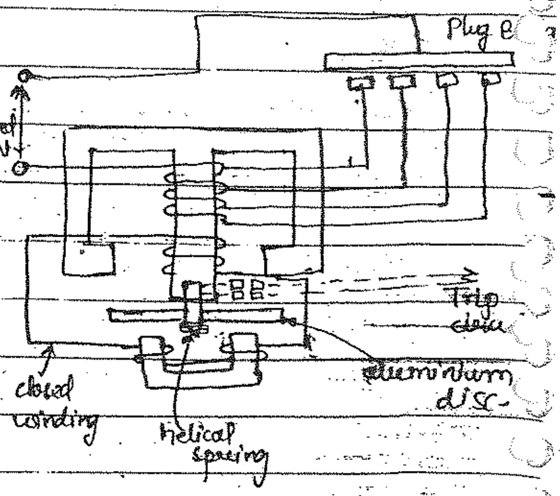


The two generators' governor & AVR characteristics should have a definite 'crossing' point to provide stable load sharing. If the characteristics are flat, load will swing b/w 2 m/c's repeatedly & load sharing is unstable. The amount of droop is a compromise b/w accuracy & stability in terms of frequency & voltage.

⇒ GENERATOR PROTECTION



1) Overcurrent inverse time relay [OCIT]



Current from main winding via a current transformer is fed to the winding on the centre leg of the laminated iron core. This produces magnetic flux & thus current is induced in the closed winding.

The magnetic field associated with the closed winding is displaced from the magnetic field of the main winding & the effect on the aluminium disc is to produce changing eddy-currents in it. A tendency of disc to rotate is prevented by a helical restraining spring when normal current is flowing. Excessive current causes rotation against the spring & a moving contact on the spindle comes in to bridge, after a half-turn, the 2 fixed contacts, so that the tripping circuit is closed.

~ This is for protection against over current more than 0.7 to 2 times the rated generated current & time is b/w 1-10 secs.

2) Overcurrent (Instantaneous) Trip.

- protect against very high overcurrent caused by a short circuit fault.

$I_{\triangleright}$ = 2 to 10 times normal generator current.

t = 0.1 to 1 sec.

3) Negative Phase Sequence Relay

determines the amount of unbalance in the stator current which is an indirect measure of generator ~~stator & rotor~~ temp.

A relatively small degree of unbalance cause significantly ↑ temp rise.

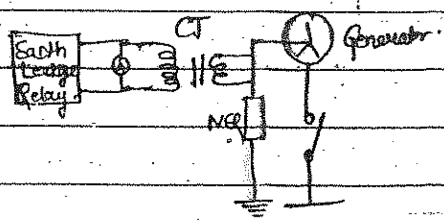
Setting $I \doteq 0.2$ times rated generated current.

4) Differential Relay

- measurement of current at each end of a stator phase winding to detect an internal fault in the stator winding which may be caused by partially short ~~cu~~ circuited coils turns and/or earth fault.

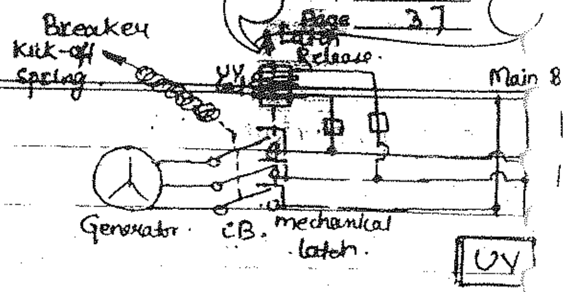
$I_{\triangleright} \doteq 0.1$ times rated generator current.

5) Earth Leakage Relay



detects an earth fault current returning back through the earthed neutral connection.

I = 1-5 A   time = 0.1 - 0.5 secs.



6) Under voltage / Over voltage

UV — 0.8 times of rated voltage.

OV — 1.2 times of rated voltage.

Time delay - 2secs

Provides back-up protection
short-circuit protection.
[The short circuit reduces the bar voltage to zero which cau... the UV release to trip the breaker

Suppose during generator paralleling procedure, an attempt was made to close the wrong circuit breaker i.e the breaker of stopped generator. If this circuit breaker was closed, the stopped generator would be equivalent to a short circuit fault on the bus-bars & cause a blackout. The UV relay preve... the closure of the CB of the dead generator.

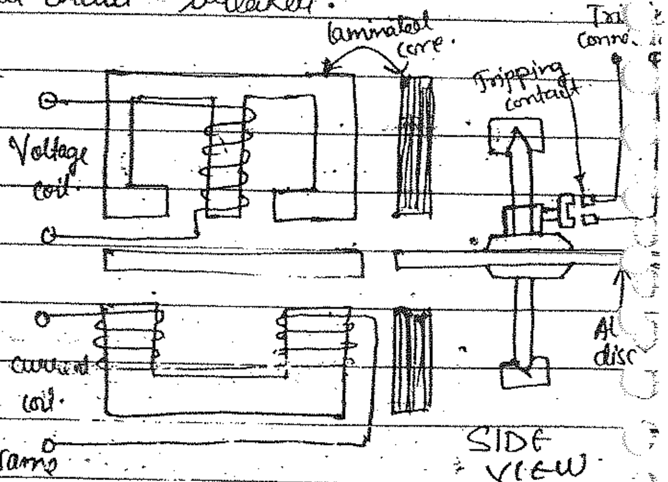
7) Under / Over Frequency.

UF - 58 Hz OF - 62 Hz for a 60 Hz system.

Steam turbine - 1.5 to 3%.

8) Reverse Power Trip. Time delay - 5secs.
Turbine - 2 to 6%. Diesel Engine - 5 to 15%.

to protect the generator from reversal of power flow. It monitors th... direction of power flowing from generator to load. If a prime mover fail... occurs, the generator could undergo a motoring effect. Reverse power ... detects the fault & trip the generator circuit breaker.



Al disc is placed in the gap b/w the two electromagnets.

Upper electromagnet has low voltage coil with inductance in it which causes a magnetic field produce by the current in it to lag voltage by 90°.

lower electomagnet is also connected to the same phase as the upper & is a current coil supplied from current transform...

Both field of upper & lower electromagnet passes through Al disc & induces ~~an eddy~~ current which brings torque to the spindle. With normal power flow, trip contacts on the disc spindle is open & disc bears against stop. when power reversed, disc ~~rotates~~ in other direction ... from stop & contacts are closed so that the ~~breaker trip~~ ...

Generator Maintenance

Always ensure that the generator prime-mover is shut down and locked off before you begin any maintenance. Also ensure that the generator circuit breaker is locked off, auto-start circuits disabled and electric heaters are switched off & isolated.

- Inspection & cleaning of rotor & stator winding with a dry lint-free cloth / low pr dry compressed air for heavier dust / Vacuum cleaner.
- Oily deposits to be cleaned using special degreasant liquids.
- check for visual signs of damages in the windings & terminals.
- Cooling air passages to be clean & clear.
- Terminal boxes free of dirt & moisture. Inspect tightness of terminal connections.
- Check bearing oil level & condition.
- Measure air gap using plastic feeler gauge (2 to 3 mm)
- Measure insulation resistance. Disconnect any electronic components which are likely to be damaged by a high voltage insulation test.
  Check insulation b/w Rotor & earth
  Stator & earth
  Phase to earth   Min^m 1 MΩ.
  Phase to phase
- Rotor slip rings & carbon brushes must be checked for uniform wear.
- Generator excitation transformer, AVR components, rotating diodes must be kept free of dirt, oil & dampness.
- Special contact grease is used b/w the diode connections to prevent electrolytic action occurring b/w dissimilar metals.
- Bake the windings at temp not more than 43°C to remove moisture.

★ Testing Reverse Power Protection:—

- Can be easily checked during a generator changeover. The outgoing generator is gradually throttled down so that it motors causing the reverse power relay to trip its generator circuit breaker.

A.C MOTORS

Classification

(I) AC motors (On principle of operation)

- Synchronous
- Asynchronous
  - Induction motor
    - Squirrel Cage
      - single cage
      - double cage
    - ~~Wound~~ Rotor (Slip Ring type)
  - Commutator Motor
    - Series
    - Compensated
    - Shunt
    - Repulsion
    - Repulsion-start in
    - Repulsion - indu

(II) On basis of current :- [A] Single ϕ and [B] 3 ϕ.

(III) On basis of speed :- [A] Constant Speed. [B] Variable Speed [C] Adjustable Speed.

(IV) On basis of structure :- (A) Open (B) Enclosed. (C) Semi-enclosed (D) Ventilated (E) Pipe-ventilated. (F) Riveted frame eye.

Induction motor

Electrical power is converted into mechanical power in the rotating parts of e electrical motor. Here rotor receives electrical power by induction, therefore as induction motor (ie in same way as secondary receives from primary in tran

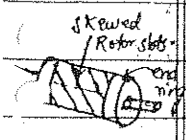
Construction:-

1) Stator : carries 3 phase windings separately insulated & spaced 120° apa They are placed in slots cut into laminated steel core. Ends the stator windings are terminated in the stator terminal box where they are connected to incoming 3 ϕ supply.

II) Rotor : consists of copper or aluminium conductor bars which are connected together.

→ Squirrel Cage :- The ~~rotor~~ consists of a cylindrical laminated core wit parallel slots for carrying the rotor conductors which are not wires but consists of heavy bars of copper, aluminium or alloys. One bar i placed in each slot & are brazed or electrically welded or bolted to two heavy & stout short-circuiting end-rings, thus forming a squirrel cage construction.

The rotor ~~cage~~ slots are usually not parallel to the shaft but are purposely given a slight skew bcoz:—



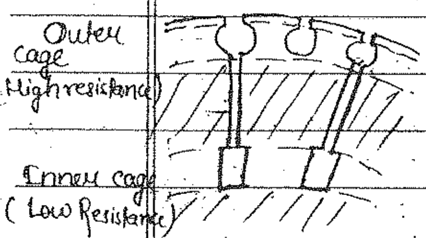
i) it helps to make the rotor run quietly by reducing the magnetic hum.

ii) it helps in reducing the locking tendency of rotor i.e tendency of rotor teeth to remain under the ~~stator~~ teeth due to direct magnetic attraction b/w the two.

iii) ↑ effective ratio of transformation b/w stator & rotor.

iv) ↑ rotor resistance due to ↑ in length of rotor bars.

Double cage:— for obtaining high torque for starting on load.

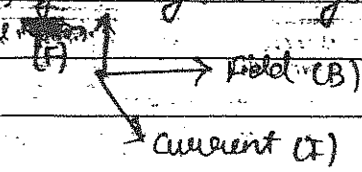


Inner bars are of large cross-section, low resistance copper, but bars in the outer cage are of small ~~size~~ size & have higher specific resistance.

(working explained later in pg. 41)

Operation:- when a 3ϕ ac supply is connected to the 3 stator phase windings, the resulting phase currents produces a multi-pole magnetic flux. This flux is physically rotated around the stator core by the switched sequence of the R-Y-B currents at a speed called synchronous speed (N_s). The stator rotating magnetic field cuts through the rotor conductors to induce an alternating emf in them. Since the rotor conductors are connected together at the ends, the induced emf's set up ~~rotor~~ currents. The rotor current also produces a magnetic flux which interacts with the stator rotating 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 the rotating magnetic field.

Direction of Rotation given by ~~Fleming's~~ Left Hand Rule.

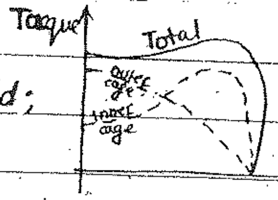


Torque $\propto \phi \, I_R \cos\phi$ ← angle b/w ϕ & I_R

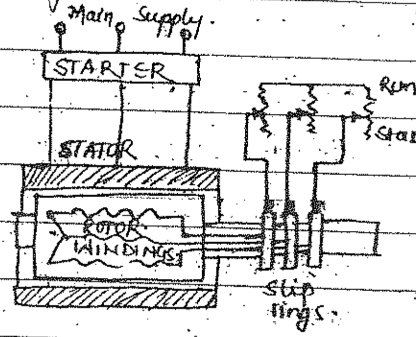
Stator flux ↑ (ϕ), Rotor current ↑ (I_R)

Date
Page

→ operation of double ~~go~~ cage induction motor :- The 3 ϕ supply to stator prod a rotating magnetic field which cuts both sets of conductor bars. Init current flow is induced mainly in the high-resistance outer cage inner conductor bars although having low resistance, impede current flow, making it lag the rotating field; this lag is due to high resistance developed as the result of the fast rate at which the magnetic field



cuts the stationary & then slow-moving rotor. As speed ↑ & slip is ↓, the rate of cutting drops & reactance of the inner cage lessens. The inner cage then becomes an easier current path & takes over as the means of produ producing torque. The characteristics of both high & low resistance cages combi to give good starting & running Torque.



Wound Rotor Motor

3 sets of windings on the rotor are connected together at one end, with the other ends brought out 3 separate slip-rings. At start, 3ϕ current applied to the stator from the mains create rotating magnetic field. Current flo induced in the rotor windings by the rotating field circulates through slip-ring brushes & external resistances so that high starting torque is developed. As the rotor runs up to the speed, resistances decrease & finally current is short-circuited by the common connecting wire. The ~~wo~~ rotor is wound only that it can be connected in series with external resistances to give hig starting torque. (Note :- slip-rings are automatically short-circuited by means a metal collar, which is pushed along the shaft & connects all the rings together. Brushes are automatically lifted from the slip-rings to reduce the frictional losses & wear & tear)

* An induction motor cannot ~~be~~ run at synchronous speed. This is because the rotor conductors would then be stationary w.r.t to the rotating magnetic ~~field~~. No emf would be induced in the rotor & there would be no rotor current & no torque developed. Even when the motor is on no-load the rotor speed has to

Ramesh.

be slightly less than the synchronous speed so that current can be induced into the rotor conductors to produce the torque to overcome the mechanical rotational losses of friction & windage.

※ Slip :- diff b/w the synchronous speed (N_S) of the rotating magnetic flux & actual rotor speed (N_R).

$$\text{Slip \%} = \left(\frac{N_S - N_R}{N_S}\right) \times 100\,\% . \qquad N_S = \frac{120f}{P}$$

If the load torque on the motor shaft is increased, the rotor will tend to slow down (↑ slip) which ~~will tend~~ allows rotor conductors to cut the flux at an increased rate. This causes more current 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 & full load is very small (b/w 1% to 5%) so induction motors are considered to be almost constant speed m/cs.

→ Rotor direction can be reversed simply by swapping over any two supply line connections at the stator terminal box. This reverses the direction of the rotating magnetic field.

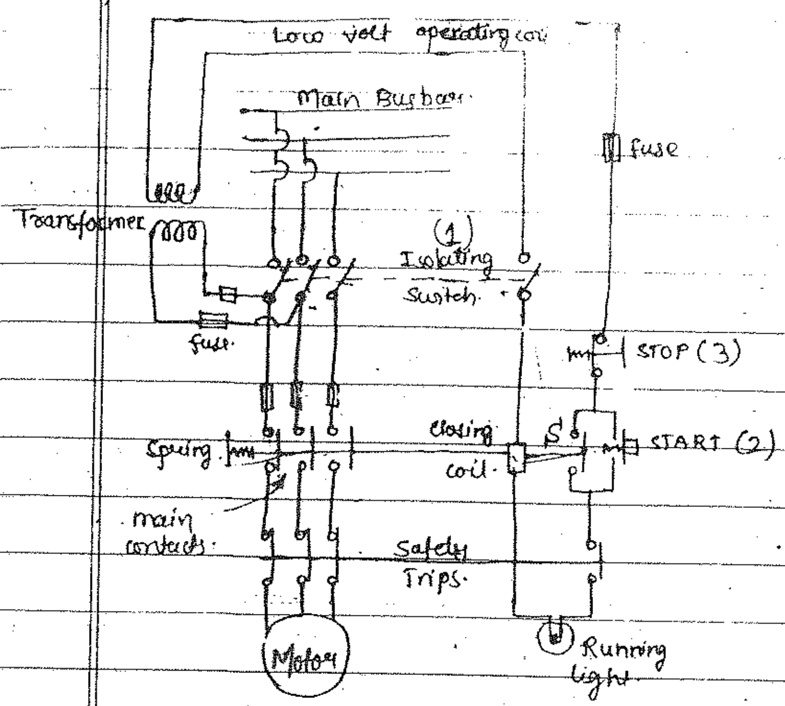
⇒ STARTERS :—

When an induction motor is connected directly to its 3ϕ a.c supply voltage, a very large ~~a.c~~ stator current of ~~5.8~~ 5–8 x full load current is taken. This is due to the maximum rate of flux cutting (s = 100 %) in the rotor, creating large induced rotor current. This starting surge current is very dangerous as it may destroy the armature winding.

To limit this starting current we use starters.

This sudden current loading may cause supply line & generator trip.

1) Direct-on-line Starter



Closing the isolating switch (1) m[ake] main power available to the main[s] & via the transformer & rectifier to [the] operating circuit. When the star[t] button (2) is pushed the closing coil gets energized & main contacts get closed and also the contact 6,5'. Release of start button will not inte[rrupt] the closing coil bcoz continuity is maintained through the retaining contacts (6,5'). The main contacts are closed against spring & de-energizing of the closing coil by opening the control circuit [by] STOP (3) button or operation of safety trips, will cause the contacts to ope[n] & motor stop.

[UPTO 10 HP MOTOR]:

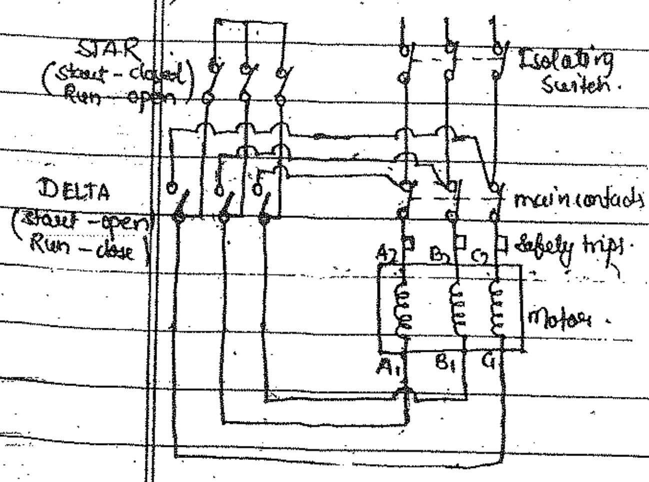
Advantage :-

I) Low cost.
II) Compact
III) Simple operation
IV) Fault finding easier.

Disadvantage :-

I) Starting current is high
II) Low starting torque
III) single speed operation.
IV) Repeated successive start will cause ↑ of winding temp.

2) STAR-DELTA Starter



:- It is a 2 step starter.

Step: 1 Start the motor with star connected winding.

Step: 2 change over to delta connected winding.

If star connection, $V_{ph} = 1/\sqrt{3}\, V_{line}$

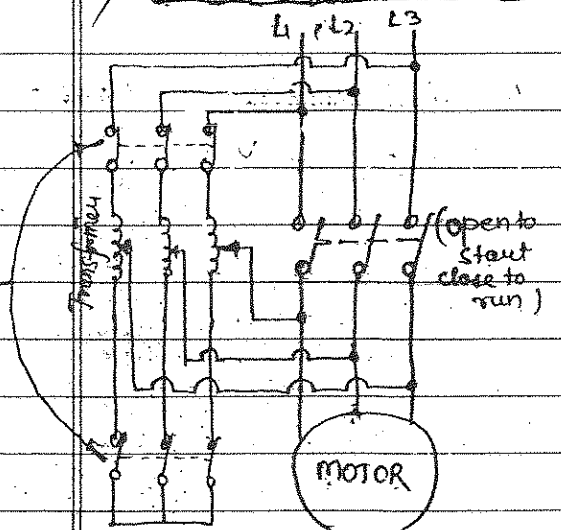
As $T \propto V^2$, starting torque produced is 1/3 times less. ~~the~~ Starting current is also reduced by ~~3~~ three times as in case of delta.

An induction motor runs at same speed whether in star or delta as rotating magnetic field produced is same as flux speed depends on supply frequency.

If star connection is used for running the motor, windings get overheated and may burn because the phase current is equal to line current in star connection.

Disadvantage :- initial torque is also reduced.
only for light starting loads.
surge current during changeover stage.

3) Auto-transformer Starter

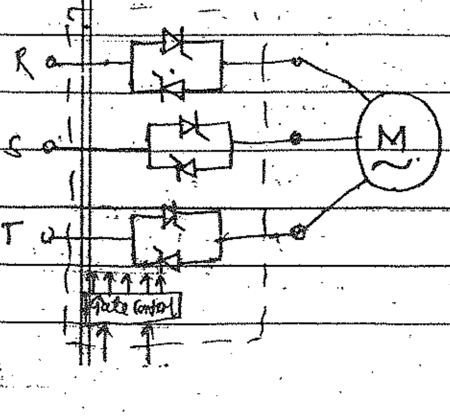


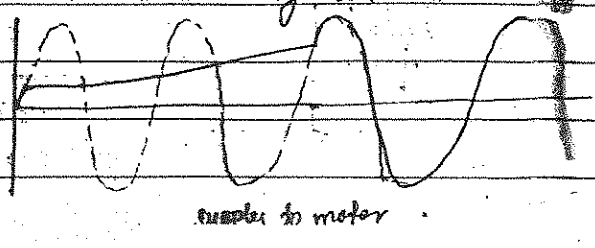
Auto transformer used hence has only one winding which can be used as both primary & secondary for changing voltage. Primary voltage of 440 V applied across a single coil can be tapped at some point ~~along~~ its length & at the end to give a secondary voltage with a value in proportion to the position of the tap.

Tappings are usually available on transformer winding giving voltage o/p ranging from 50 % to 80 %.

~~Used for~~ Disadvantage :- (i) expensive, hence used only for large motors.
(ii) max no. of consequtive starts limited as it may burn out auto-transformer.

4) Soft Starter - use thyristors in the supply line which reduces the average voltage. Applied voltage to motor is gradually increased by the gate control circuit. When motor gains speed, electronic switching circuit is bypassed.





supply to motor

⇒ Speed Control:-

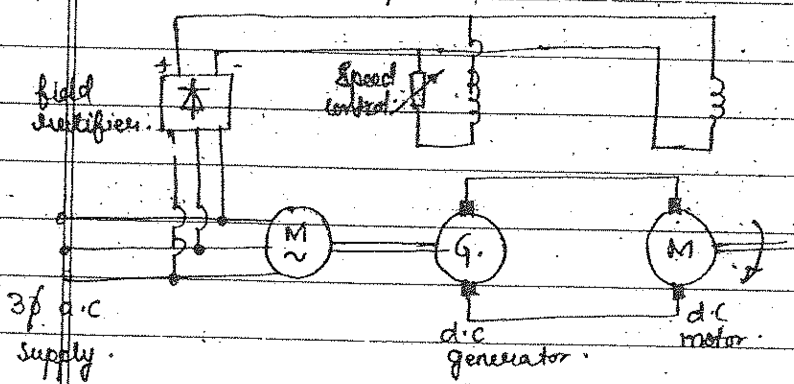
i) By changing rotor resistance

Rotor resistance can be ↑ by using external resistances via slip ring. ↑ value of external resistance, ↓ rotor speed.
[Wound Rotor]

ii) By changing pole $N_S = \frac{120f}{P}$ So ↑ no. of poles will ↓ speed.
No. of poles changed to obtain two or more fixed speed.
- useful in cranes, winches, windlass operation.

$p = 4$ then $N_1 = \frac{120 \times 60}{4} = 1800\ rpm$ Now if $p = 8$, $N_2 = \frac{120 \times 60}{8} = 900\ rpm$

iii) By changing supply voltage
Ward Leonard Speed Control: [FOR DC Motors]..



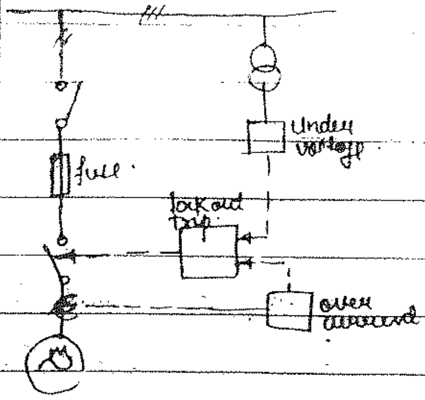
A constant speed induction motor drives a d.c generator which in turn supplies one or more d.c motors. The generator o/p voltage is controlled by adjusting its small excitation current via the speed regulator.

The d.c motor speed is directly controlled by the generator voltage i.e. voltage applied through armature winding of d.c motor is changed.

iv) By changing frequency
- very difficult.
- Electronic thyristor frequency converter is now used for frequency control & thereby speed.
- Variable DC o/p from a thyristor bridge rectifier is ~~fed to thyristor~~ inverter which gives controllable AC voltage & variable frequency o/p.

Fuse → 32 M63
32 A continuous rating
63 A starting period.

MOTOR Protection :-



mainly to prevent overheating ~~which~~ can cause deterioration of windings insulation & burnout of severe.

Overheating as ~~the~~ a result of :-

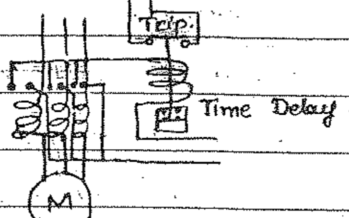
overload, stalling, single phasing or prolonged starting period

★ Fuse :- (i) break in event of short circuit.

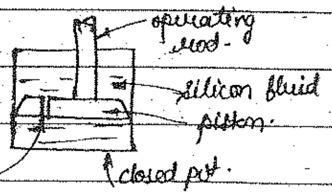
(ii) provide back-up for other protective devices.

★ Overcurrent / Overload protection

1) Electro-magnetic overload protection.

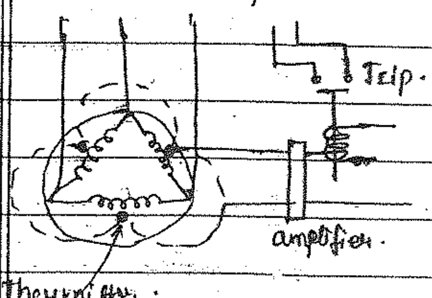


Each of 3 ϕ supply ~~ϕ~~ is fitted with an overload relay. Such arrangement should detect single-phasing. Operation of any of the relay will close the circuit to energize the time-delayed trip. They have a time delay dashpot for high starting current.



Time delay can be varied by size of orifice or viscosity of fluid.

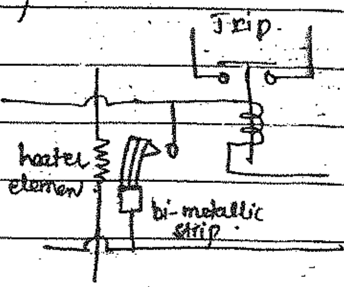
2) Thermistor protection



Thermistor is inserted in each of the three windings ~~which~~ to detect overheating from any cause. When a given temp. is exceeded the circuit is tripped via a relay & an amplifier.

- can be used in conjunction with electromagnetic overload trip.

3) Indirectly heated by metallic strip.

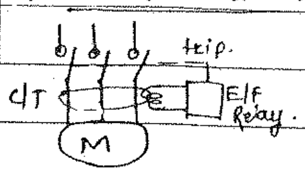


excessive current in any of the supply cables will cause deflection of bi-metal strip through temp. rise. This will activate the trip.

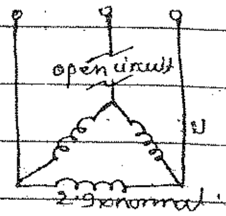
Thickness of strip is used for time delay when motor starts.

★ Undervoltage protection :- necessary for distribution system. ∵ In ca of blackout or voltage loss, all motors are disconnected from the sup, & this prevent all motors from restarting together.

★ Earth Fault monitor :- C/T measures phasor sum of 3 line current when circuit is healthy, phasor sum is zer. If earth fault occurs, phasor sum is not zero & this will energize the earth fault r to trip the circuit.



→ SINGLE PHASING :- Loss of current through one phase in a 3 ϕ supply is described as single phasing.



Open circuit in phase, often from a blown fuse, fault contact or broken wire, will prevent a motor from starti, but a running motor may continue to operate with fault.

The motor with single-phase fault will carry excess current in the remaining supply cables. Motor windings may have unequal distribution of curre

Effects :- overheating ; vibration ; burnout ; electric fire etc.

→ Motor Maintenance

- clean to remove dirt, dust, grease & oil. using dry air & cleaning liq. (Both interior & exterior).
- Keep insulation resistance high
- Lubricate correctly & maintain uniform air gap.

Stator :- (I) inspect windings [damage, discolouration,] signs of rubbing
Clean, dry, Revarnish. → (II) check insulation resistance b/w windings & earth.
(III) anticondensation/space heater (If provided) must be in good condi

Rotor :- (I) inspect for signs of damage & overheating.
(II) ensure ventilating ducts are clean & clear.

Bearing :- (I) change as per PMS.
(II) inspect for signs of damage.
(III) properly fitted & lubricated.

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[illegible] ...sure

IP (Ingress Protection) number.

[illegible] of protection against entry of solids & [illegible] protection of person against contacts [illegible] moving parts inside.
[illegible] degree of protection against entry of liquids [illegible] ...ing the equipment in various ways.

	[illegible] of Protection against contact with [illegible] moving parts inside the enclosure and protection of equipment against ingress of solid bodies	2nd Numeral	Degree of Protection against ingress of liquid.
0	No protection	0	No - protection.
1	Protection against solid objects > 50mm Eg. hand. [but no protection against deliberate access]	1.	Protection against dripping water (vertically falling drops).
2	Protection against solid objects > 12mm Eg: finger	2	Protection against dripping water when tilted upto 15° from its normal position.
3	Protection against solid objects > 2.5mm Eg:- tools, wires etc.	3	Protection again[st] spraying water [illegible] angle upto 60° fro[m] [illegible]

4	Protection against solid objects > 1 mm Eg:- wires or strips	4	Protection against splashing water from any direction.
5	Protection against harmful deposit of dust (dust does not enter in sufficient quantity to interfere with the satisfactory operation of the equipment).	5	Protection against water jets from any direction.
6	Total protection against ingress of dust and contact with moving / live parts.	6	Protection against water from heavy sea or water projected in powerful jets.
		7	Protection against the effects of immersion of water under defined conditions of pressure and time.
		8	Protection against indefinite immersion in water under specified pressure [No water ingress at all.]

Enclosure :- (I) check for accumulation of dirt - clean
(II) corroded part cleaned & repaired.

Contactors & relays :- (I) check for signs of overheating
(II) loose connections.
(III) clean contacts
(IV) Ensure free movement. Check spring pr.
(V) Check settings of relays.

Connections :- (I) tightness of connections
(II) signs of overheating.

⟹ MOTOR NAME PLATE.

(I) Rated full load current - ~~continuous~~ max^m current that the motor can continuously take from supply without exceeding temp limit of the insulating material used.

(II) Rated voltage - motor is designed to operate at this voltage.

(III) Power rating - motor shaft power o/p when connected to rated voltage & frequency.

(IV) Rated speed - full load speed when connected to rated voltage & frequency.

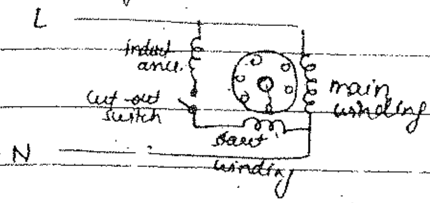
(V) Insulation class - max temp the insulating material can withstand.

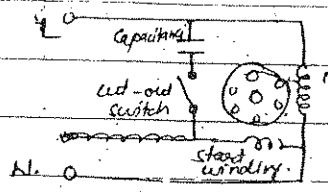
A	105°C	- cotton, silk
E	120°C	- wire enamels with base of epoxy, poly vinyl acetyl.
B	130°C	- mica products.
F	155°C	- glass fibre
H	180°C	- wire enamels with a base of pure polyimide

(VI) IP Number :- Degree of protection by the Motor enclosure.

3ϕ Induction Motor.		
Type: 112M 4	V: 440	KW: 4
Amp: 7.9	RPM: 1730	Hz: 60
Conn: Δ	Ins class: F	Kg: 50
Bearing :- Drive end: - -; N/Drive end: - -		
Sr. No :- - - - - - -		

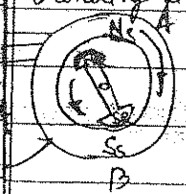
Single phase Induction Motor (washing m/c's, drilling m/c's etc.)
has 2 main windings in which single phase supply develop opposite poles that alternate only. This effect is sufficient to keep the rotor turning once it has started but an extra pair of winding with lagging or leading current is necessary to start the motor initially.





An alternating or pulsating flux acting on a stationary rotor cannot produce rotation. Therefore two windings are provided to create a revolving flux during starting & it is cut off a centrifugal switch when the rotor picks up speed.

Synchronous Motor
3 ϕ winding supplied by 3 ϕ supply, a magnetic flux of constant magnitude and rotating at synchronous speed is produced. Consider a two pole stator rotating at synchronous speed, say in clockwise direction.

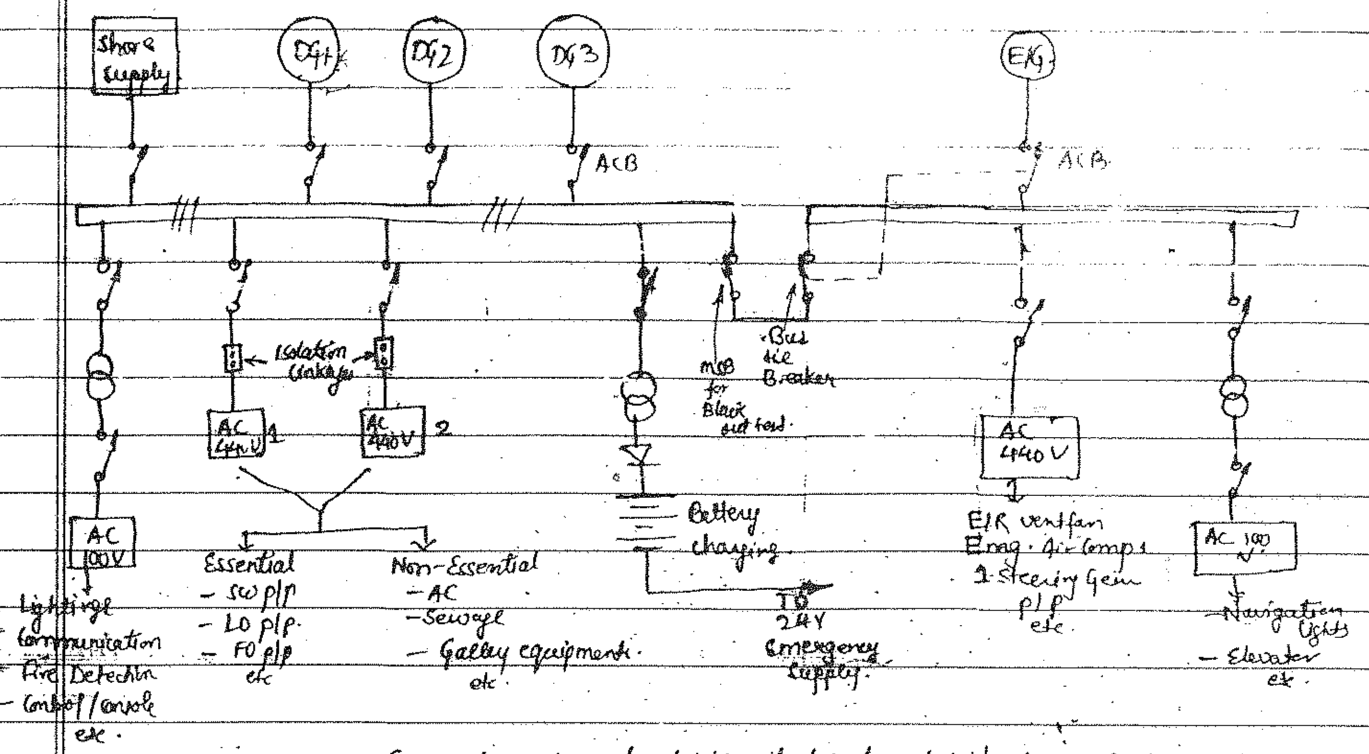


If N_s is at A & S_s is at B during first half cycle, Rotor will turn anticlockwise so that N_R is at B & S_R is at A.
But during next half cycle, stator poles have changed i.e. N_s is B & S_s is at A. Therefore now rotor will turn clockwise so that N_R is at A & S_R is at B.

So we that rotor is subjected to torque which is continuously reversing. Owing to its large inertia, rotor cannot instantaneously respond to such quick-reversing torque, with the result that it remains stationary.

Rotor will rotate only if it rotate with such a speed that it turns through one pole-pitch by the time the stator poles interchange their position ~~then~~ they will continuously experience a unidirectional torque.
~~i.e.~~ Rotor speed is equal to the synchronous speed of the rotating field.
~~Not self starting~~ ~ has to be run upto synchronous speed by some means.

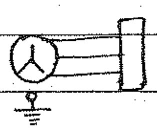
Electrical Power Distribution

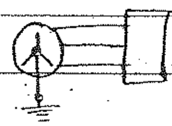


General view of ship's electrical distribution system

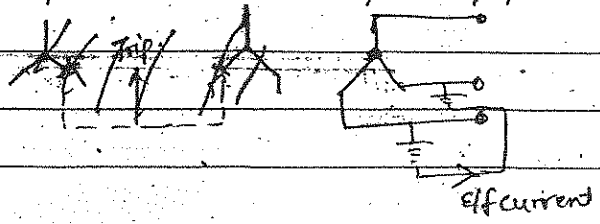
Majority of ships have 3-ϕ ac, 3 wire, 440 V insulated-neutral system.

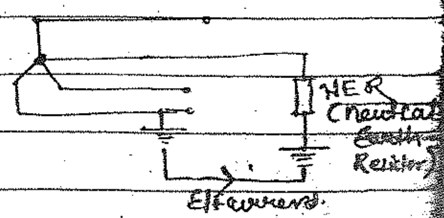
Insulated Neutral System	Earthed Neutral System
More effective in maintaining continuity of supply to essential services	
- electrically insulated from earth.	- supply neutral point connected to earth.



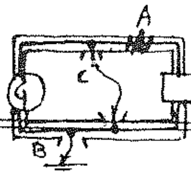


Insulated Neutral System	Earthed Neutral System
- LV system 440 V ac.	- HV system > 1000 V ac.
- single earth fault will not operate any trip & m/c will function normally. If 2nd earth fault occurs then the 2 earth fault together would be equivalent to a short-circuit fault & would operate the protection devices to trip the equipments.	- Single earth fault would be equivalent to a short-circuit fault across the generator through the ship's hull. Faulty equipment is immediately tripped & isolated.





Ohmic value of NER is usually chosen so as to limit the earth fault current not to go more than ... full load current ...



Basic faults in a circuit

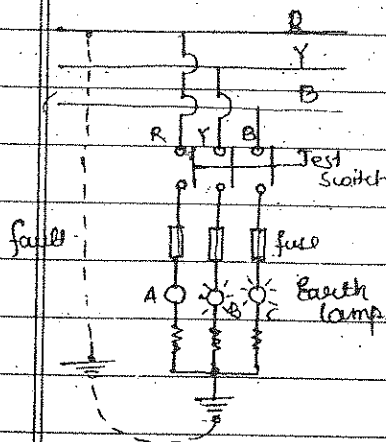
1) Open-circuit fault (A) :- due to a break in conductor so that current cannot fl...

II) Earth fault (B) :- break in insulation allowing conductor to touch the hull or earthed metal enclosure.

III) Short circuit fault (C) :- due to double break in insulation allowing both conductors to be connected so that very large current by passes or "short-circuits" the load

~ To protect against dangers of electric shock & fire that may result from earth faults, the metal enclosures & other non-current carrying metal parts of the elec equipment must be earthed. The earthing conductor connects the metal enclosure to earth to prevent it from attaining a dangerous voltage wrt earth. Such earth bonding of equipment ensures that it always remains at zero voltage.

Earth fault Monitoring.



Regulation requires that an earth fault monitor fitted to the main switchboard to indicate the presence of an earth fault on each isolation section of a distribution system eg on 440V & 220V sections.

It can either be a set of indication lamps or an instrument (calibrated in KΩ or MΩ).

If there is an earth fault in one phase (say ...) then the current will take an easier path & the lamp A will go dim or extinguish depending on severity of earth fault.

Earth fault 220/110V

- Switch off & on the switches from 220V feeder panel to check the earth fault. When a switch is off & the earth fault indication shows fault is cleared we come to know the distribution board which is having earth fault. Now switch on & off at that distribution board to locate the actual earth fault equipment / circuit.

Earth Fault 440V

- If 440V down comes, look for any m/c which has been started
- If any m/c started, shut down the m/c to see if the earth fault indication is clear.

→ Start the standby machineries first before testing in case of 440V / ~~ME LO. PP~~.

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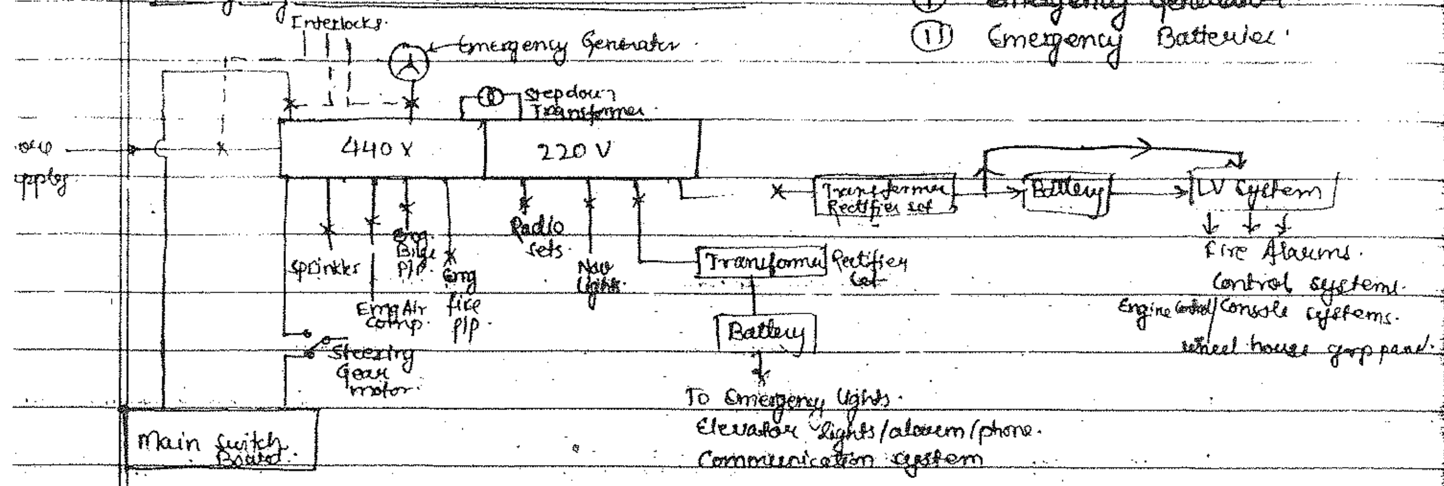
Emergency Switchboard distribution.

Emergency Power Source
(I) Emergency Generator.
(II) Emergency Batteries.



Emergency Generator SOLAS

- should be capable of starting automatically & supplying required load as quickly as possible & in time not more than 45 seconds.
- arranged to be automatically started with starting devices with a stored capacity of at least 3 consecutive starts. A ~~sec~~ 2nd source of energy shall be provided for additional 3 starts within 30 minutes unless manual starting can be demonstrated to be effective.
- capable of starting in cold condition at a temp of 0°C. If ~~not~~ then Provided with heating arrangements to ensure starting of generator.
- fuel flash point not less than 43°C.
- function at full rated power when the ship is upright & when inclined at any angle of list upto 22.5° or when inclined upto 10° either in fore or aft direction. or is in any combination of angle within those limits.
- location :- uppermost continuous deck above waterline.
  b/w forward & aft collision bulkhead.
  away from E/R & dangerous cargo spaces.
- for a period of ~~18~~ hours, supply to — 3hrs.
  (I) emergency lighting's :- $\boxed{\text{muster station, embarkation station}}$ alleyways, stairways, m/c spaces & main generating stations, control stations, ECR, stowage position of fireman's outfit, steering gear, fire P/P, sprinkler p/p & emergency bilge p/p.
  (II) Navigation lights & other lights required by International Regulations for preventing collisions at sea & VHF radio Installation.

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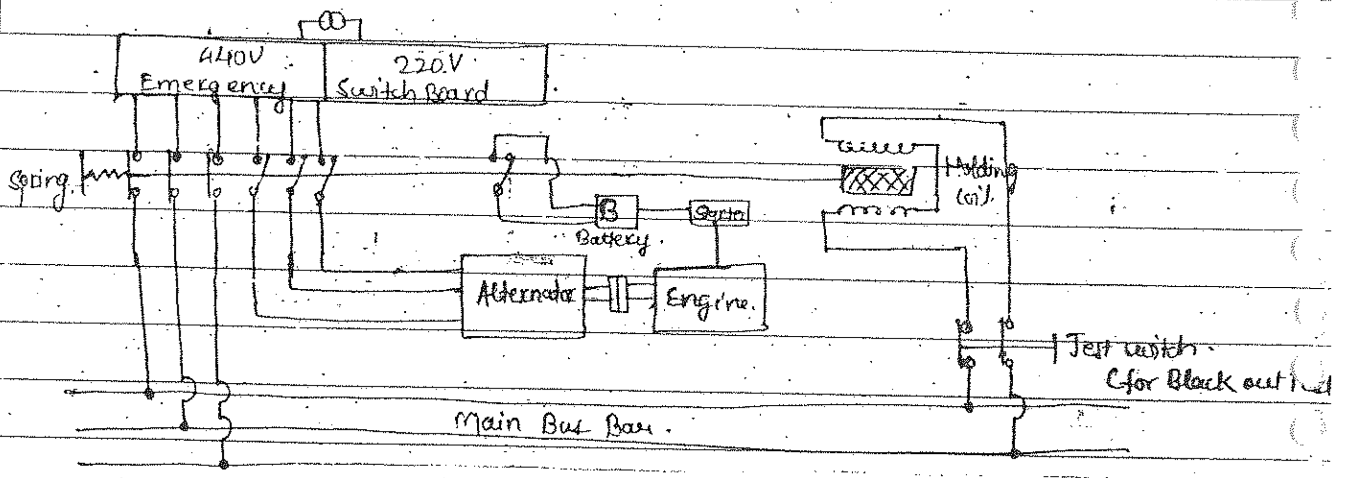
(iii) internal commn equipment, shipboard navigation equipment, fire detection & [illegible] system, ship's whistle, daylight signalling lamp, manually operated call [illegible] & fire p/p; automatic sprinkler p/p; emergency bilge p/p & all the equipments essential for the operation of electrically powered remote controlled bilge v/vs.

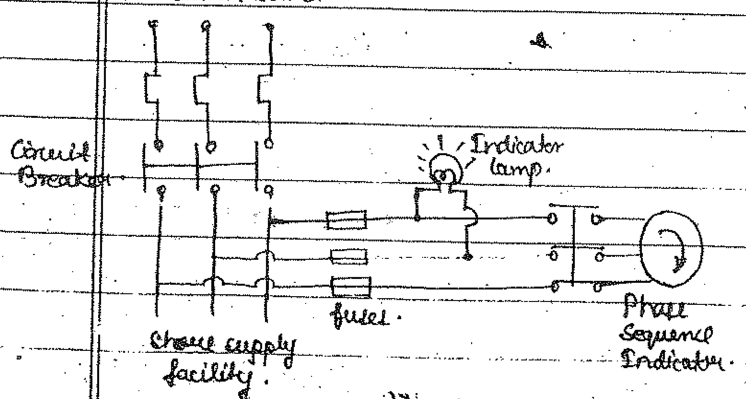
(iv) 1 steering gear p/p

* for a period of half an hr, supply for operating water tight doors together with their indications & warning signals.



AUTO Starting of ~~gen~~ Emergency Generator on Loss of "Main Power"

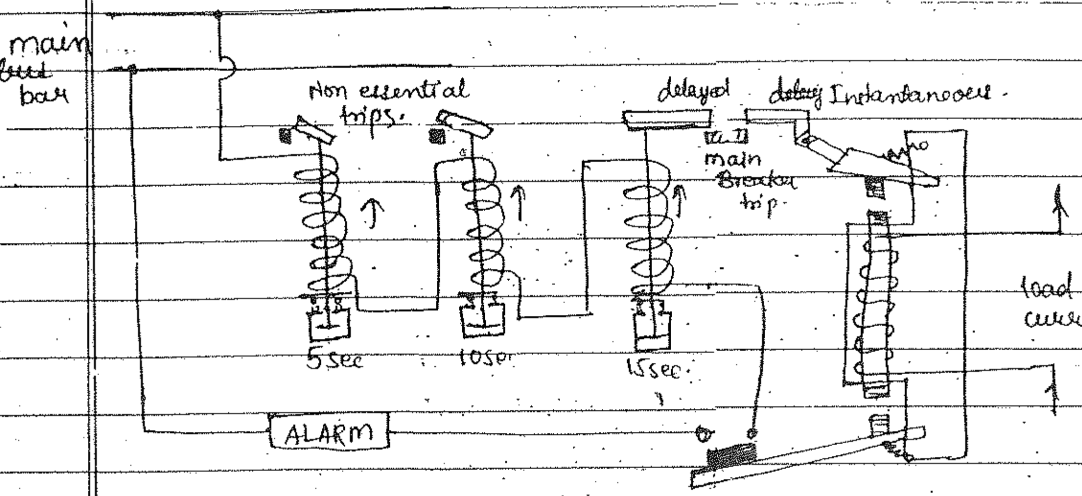
→ Shore Supply Connection :— Connection box located at the entrance of accomod. or in emergency Generator Room.



Safeties :- (i) connect earth i.e ship's hull to shore's earth point.
(ii) interlock b/w shore supply switch in MSB & generator supply breaker.
(iii) phase sequence indicator.
(iv) indicator lamp to indicate shore supply is available.
(v) Check load not to exceed the capacity of shore connection in MCB.
(vi) Check insulation condition of shore supply cable.

- V & f should be same.
- phase sequence should be correct.

⇒ Preferential Tripping :- essential to prevent interruption of services necessary to maintain propulsion & navigation.
They are designed to disconnect non essential circuits in the event of partial overload or partial failure of supply with the aim of preventing operation of the main breaker trip & complete loss of power.



Generator overload condition will energize the timing relay of the preferential overload trip. The timing relay then operates to disconnect the non-essential services in a definite order at set time interval.
1st trip - AC & ventilation - 5 secs.
2nd trip - Ref. cargo plant - 10secs.
3rd trip - deck equipment - 15 secs.
when sufficient non-essential load has been disconnected, the preferential overload trip resets & no further load is disconnected.

⇒ Sequential Start :- Under all normal conditions, the 1st standby generator will start & come on load after black out [within 15.32 sec on ~~my~~ ship]. If for some reason, 1st standby generator fail to start or fail to come on load, the 2nd standby generator will come on load [max 25.27 secs on my ship] to start the vital pumps & systems to regain the essential services in sequence. This is called sequential starting.

→ Main Switch Board Safeties & Protection

1) Circuit breakers – auto shut down device which activates during an abnormalities (overloading, short-circuit etc.) in the electrical circuit.

2) Fuses – for short circuit protection. If current passing through the circuit exceeds the safe value, the fuse material melts & isolates MSB from an default system.

3) Overcurrent Relay – mainly on local panel & MSB for protection from high curr

4) Dead front panel – on MSB individual panel wherein you cannot op the panel until the power of the panel is switched off.

5) No water or all pipes above MSB.

6) Location :- good ventilation; illumination; minimum vibration & temp.

0.6m 7) Insulated Rubber mats minm 15mm thickness on operating floor space front & behind.

8) Enclosure should be dip proof.

9) Panel doors opening mechanism should be interlocked with power supply.

10) MSB should be properly earthed.

11) Insulation Resistance Meter / Earth fault Indicator must be provided.

12) Red tag / Name plate including high voltage & danger sign should be fitted

13) Appropriate fire extinguisher (CO_2) should be positioned near by.

14) Wiring diagram indicating supply system must be displayed nearby.

→ Circuit protection :-

From Generator to Bus Bar :- Overcurrent, undervoltage, reverse power, earth leak

At Bus bar :- Overcurrent, over/under frequency, undervoltage.

Bus bar to transformer :- Overcurrent, Earth leakage, over temp.

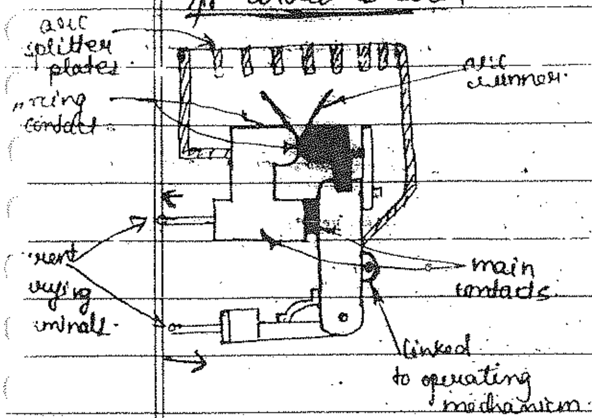
Before starter or motor :- over current, thermal overload, earth leakage, under voltage, locked rotor.

→ Protective Discrimination Scheme :- ability of the protection system to disconnect only the faulty circuit & maintain the supply to healthy circuit.

Eg. If a short-circuit fault occurs at lamp holder, the fault current is high enough to trip all the protective devices from generator to lamp. But as the fuse at lamp holder has lowest current rating & shortest operating time, it will be quickest to operate & clear quickly leaving all healthy circuit still connected.

→ Circuit Breaker :- switching device which can be operated manually or automatically to make or break the electrical power system.

Air Circuit Breaker [Rating 400 - 2000 Amps]



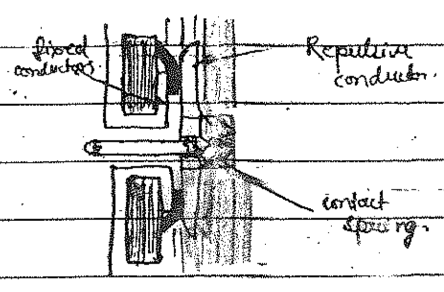
- circuit breaker contacts separate in air.
- main & arcing contacts are of copper & usually silver-alloy coated.
- arc chutes or splitter boxes confine & control the inevitable arc to rapidly accelerate to extinction.

Closing of CB → independent manual spring
motor driven stored charge spring.
Solenoid closed.

Opening /Tripping — manual mechanical linkage.
undervoltage trip coil or relay.
overcurrent / short-circuit trip device or relay.
Solenoid trip coil.

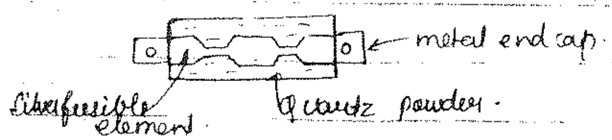
Moulded case circuit Breaker (MCCB) [50 - 1500 Amp]
- very small & compact fitted in moulded plastic case.
- have thermal overcurrent setting & adjustable overcurrent ~~trip~~ for short-circuit protection.
- Operation to close is by hand operated lever
- Reliable, trouble free & negligible maintenance.

Miniature Circuit breaker (MCB) [5 - 100 Amp]
- very small in moulded plastic case.
- thermal overcurrent & magnetic short circuit protection.
- no maintenance possible.
- set to a pre-determined rating at the factory. No adjustment can be made.



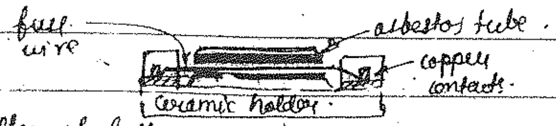
→ Fuses :- ↑ current through fuse ↑ the temp & cause it to melt & break the circuit.

cartridge fuse:



- High Rupture capacity fuse (HRC), has silver wire enclosed in quartz powder filled in ceramic tube with metal end caps.

Semi-enclosed fuse



- wire of lead or tin or alloy of both.
- wire is contained in an asbestos lined tube.

→ Electric Cables :- electrical conductors used for transferring power or signals.
- need to withstand a wide variety of environmental conditions, eg extreme temp, humidity, etc. thus, they are insulated throughout their length.

Insulation class :- See pg. 48.

- the core of marine cables should not be affected by sea atmosphere.
- Insulation Resistance :- LV - > 1MΩ   HV - > 10 MΩ
- High dielectric strength.
- non hygroscopic / dampness resistant.
- Flame / fire resistant (not propagate or transmit fire)

ACB safeties :- (I) Arc Runner & Arc chutes
(II) Breaker open first before taking out ACB
(III) Simultaneous closing of all 3 units of each phase.
(IV) Arcing contact close before & open after
(V) Breaking speed as high as possible

Safe Electrical Equipment for Hazardous Area.

→ Hazardous Zones :- indicates the possibility of an explosive gas-air mixture being present & therefore, the likelihood of an explosion to occur.

Zone 0 : explosive gas-air mix continuously present or present for a long time.

Zone 1 : explosive gas-air mix likely to occur in normal operation.

Zone 2 : explosive gas-air mix not likely to occur in normal operation & if it occurs, will exist for only a short time.

→ Protection against sparks is necessary whenever flammable gas & air mixtures are present. Hot surfaces, however, will not cause combustion unless their temp reaches the ignition temp of gas. Therefore there is a table for the max^m surface temp of electrical equipments & their temp class.

Temp. class	Max surface Temp.
T_1	450°C
T_2	300°C
T_3	200°C
T_4	135°C
T_5	100°C
T_6	85°C

→ Explosion Protection :- there are a no. of diff. constructional techniques employed in preventing electrical equipment causing explosions in hazardous area.

Symbol	Type of protection
Exd	flameproof enclosure ← prevent transmission of flame & hot gases. must withstand an internal explosion.
Exi	intrinsic safety ← designed for power so low that any spark or thermal effect produced by it is incapable of igniting the surrounding flammable gas.
Exe	increased safety ← elimination of open sparking during operation & or close control of surface temp.
Exn	non-sparking ← equipment which has no arcing contacts or hot surfaces.
Exp	pressurization ← clean, dry air or an inert gas is supplied to the equipment slightly above atm pr. to prevent entry of any external flammable gas.
Exs	special protection.

↑ precautions taken to prevent explosions which are not specifically covered by the previous designations.

Electrical Equipments Survey.

1) Generators & Governors

- Generator enclosure clean [dust free, no oil & moisture]
- Windings condition [deterioration, abrasion, heating], ~~insulation~~
- Insulation Test to earth & b/w phase windings.
- Rotating diode stack condition.
- Carbon brush (length & spring pr.) & slip rings
- Running test on load & proper operation of AVR & governor.

2) Circuit Breakers

- condition of main, arcing & aux. contacts for signs of wear, misalignment & overheat.
- arc chutes clean & free of arc debris.
- internal wire in good conditions & end connections tight.
- Test include close & trip operation
- Undervoltage release & overcurrent trip settings.

3) Switch Board & Fittings

- all internal & external surfaces of panel to be clean.
- bus bar & aux connections checked for tightness, overheating signs etc. [during dead period]
- damage to insulation material
- earth bar secured properly.
- Earth fault indicator operation.

4) Cables

- Insulation Resistance Test Report
- Condition of wiring & enclosures

5) Motors & Starters

- enclosure clean & intact.
- winding condition.
- Insulation Test
- Starters condition.
- Operation of all safety alarms & trips.

6> Emergency Power & Associated Equipments.
- manual & auto start of emergency generator & coming on load as per regulations.
- emergency generator condition.
- emergency supply to various equipments.
- Electrical interlock b/w main & emergency switchboard.
- Emergency battery condition
- Battery charging equipment

7> Parts of Steering Gear
- Correct functioning of Electrohydraulic steering gear
  (i) Power Unit (ii) Control Unit (iii) Indications & alarms.

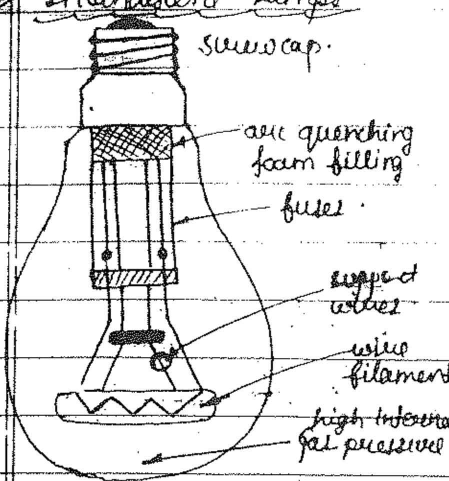
8> Navigation Light Indicators
- must operate correctly & give appropriate alarms

9> UMS operation.
- alarms, fire detection, controls & fail safe features of such installation.

Miscellaneous Items.

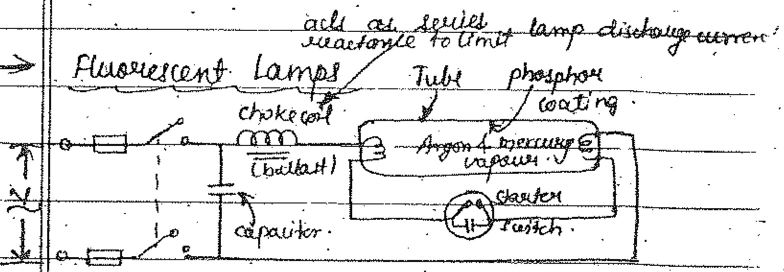
Incandescent Lamps :- A current is passed through the thin tungsten wire filament which raises its temp to around 3000° C when it becomes incandescent (it glows).

The glass bulb is filled with an inert gas such as nitrogen or argon which helps to reduce filament evaporation & allows an operating life expectancy of about 1000 hrs.



Power Rating :- 15 W to 1000 W.

Fluorescent Lamps

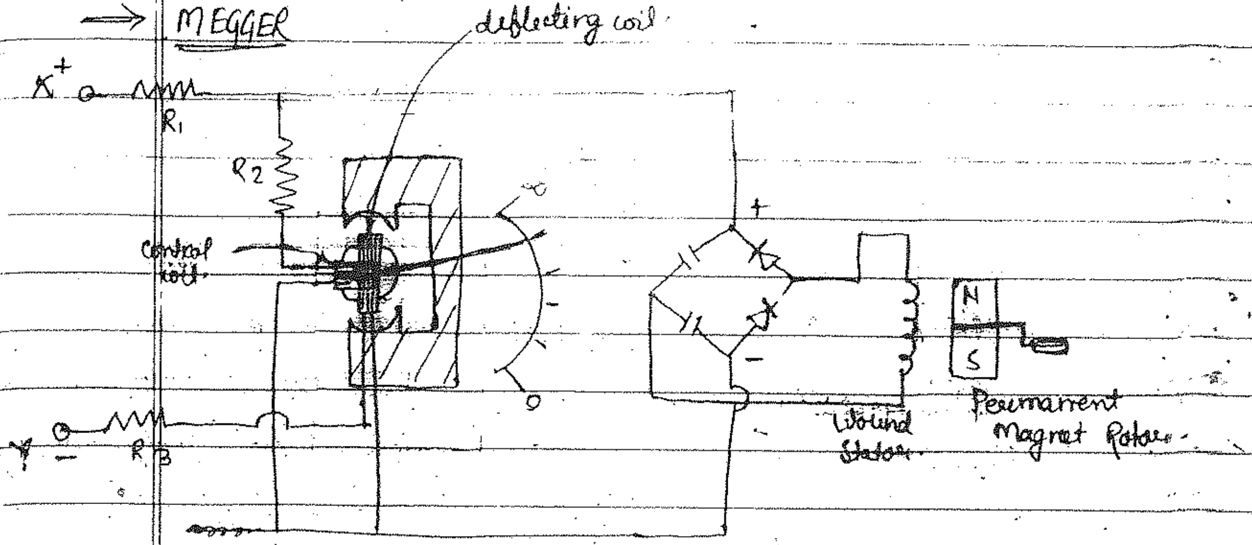


Starting action is initiated by glow type starter which is connected b/w the opposite ends of the tube. When supply voltage is applied to the circuit, full main voltage appears across the starter switch & glow discharge occurs b/w the starter contacts which quickly heat up, bend & touch together. This allows current to flow through the lamp cathodes which will cause the tube ends to heat up & glow before the tube actually strikes. The tube strikes when the starter switch re-opens as it cools down during its closed (non-glow period). When the starter switch opens it interrupts an inductive coil (choke) circuit which produces a surge voltage across the tube which then strikes. The tube is now ~~fully glown~~ full-away & the reduced arc voltage across it not sufficient to restart the starter so its contacts remain open.

Capacitor - for power factor correction.

used to raise the supply p.f to around 0.9 lagging [without this capacitor the p.f may be as low as 0.5 lagging due to the choke-coil inductance to cause supply current to be 4 to 5 times larger than normal].

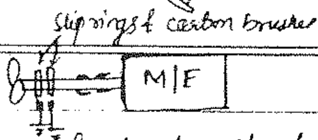
→ MEGGER



- Voltage required for testing is produced by the hand driven d.c generator which has a permanent magnet. [500 V]
- Deflecting coil or current coil connected in series & allows flowing the current taken by the circuit being tested
- Control coil also known as pressure coil is connected across ~~the~~ circuit.
- As the voltage increases in the external circuit, the ~~deflection~~ of pointer ↑ & deflection of pointer ↓ with increase in current.
- When electrical circuit being tested is open, torque due to voltage coil will be max^m & pointer shows 'infinity' means no shorting throughout the circuit & has max^m resistance within the circuit under test.
- If there is short circuit, pointer shows zero which means 'No' resistance within circuit being tested.
- Torque of megger varies with V/I.
- If R is ↑ — no current in deflecting coil — pointer infinity.
  If R is ↓ — high current — pointer zero.

⇒ Electrical safeties on E/R crane.

(I) Electromagnetic fail safe brakes which do not allow the ~~crane~~ to fall with the load even when there is failure of power.
(II) Emergency Stop.
(III) Distance limit switch in both transverse & longitudinal ~~direction~~.
(IV) Load limit switch.
(V) Push button type control switches.



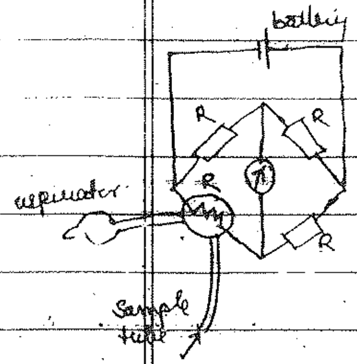
Shaft earthing.

A turning shaft is electrically insulated from the hull by the lub oil film on bearings & the shaft. There is a possibility that the turning shaft get magnetized & produce stray voltage which may lead to
(i) spark erosion resulting in damage to bearings.
(ii) Cavitation damage to the tips of the propeller.
In order to avoid this, the stray current has to be grounded using slipring & brushes arrangement.

TESTING

1. Diodes :- Connect multimeter across the diode.
In forward volt drop across diode is shown b/w 500 mV to 900 mV.
In Reverse it should indicate over-range
If it displays over range in both direction, the diode is open-circuit.
If it shows less than 1V in both direction, it may be short-circuit

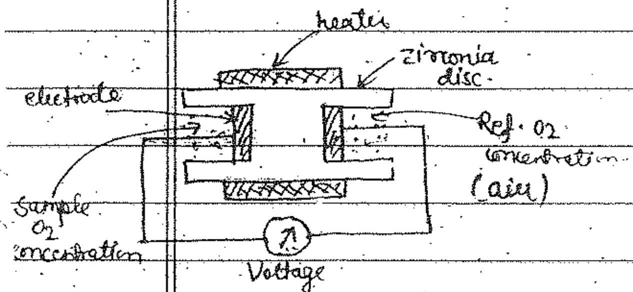
⇒ Explosion meter



Wheat stone bridge.

Scale – % LEL or ppm.

⇒ Oxygen analyser



Zerconia – ceramic which conducts ~~heat~~ electricity at high temp.

Voltage – diff in O_2 concentration b/w the 2 sides of disc.

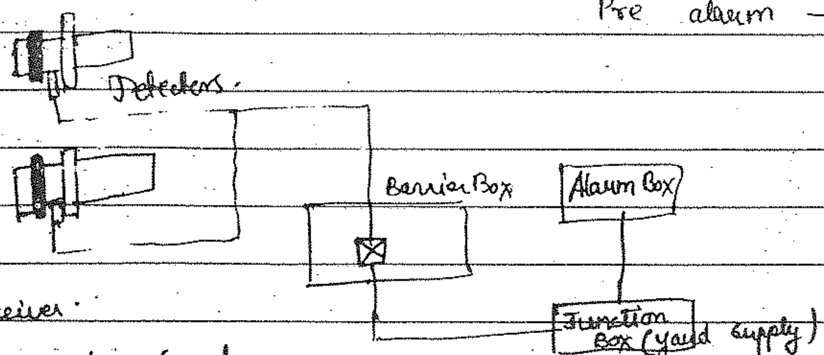
⇒ Salinity indicator.

detects the electric conductivity in the liquid & its conductivity is ~~to~~ converted to NaCl (salt) ratio in the seawater and it is indicated as ppm.

⇒ Water Ingress Alarm System

Main alarm – 2.0 m from hold bottom

Pre alarm – 0.5 m from hold bottom



Ultrasonic will show individual natural ~~according to its~~ frequency of sound ~~transmitting~~ environment.

Oscillator ⟷ Receiver.

water → freq ↓ → Sensed & send to signal alarm