Electrical Written Notes

for

MEO Class 4 COC

– Clyde

Big Thanks To All The Faculty To Impart Their Knowledge With Me.

DC Machines

CLYDE

* Faraday's Law:

When a conductor experiences a varying magnetic field, an emf is induced in conductor.

Now a magnetic field can be established either by → permanent magnet
→ electro magnet

If mag. field is produced by AC current, it will produce varying magnetic field.

If mag. field is produced by DC current, it will produce static magnetic field.

So in order to produce an emf, there should be relative motion bet^n
* conductor w r t magnetic field
* magnetic field w r t conducto

* Maxwell's Law:

Time varying magnetic field will create time varying electric field & vice verca.

So time varying electric field means A.C

Now magnitude of the induced emf is directly proportional to
→ No of turns in conductor
→ Rate of change of flux through conductor.

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

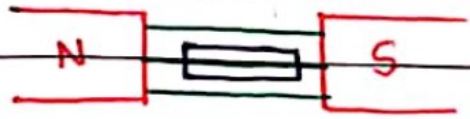
CLYDE

3 magnetic lines of force
So flux = 3

Unit of flux = Weber
1 Wb = 10^8 mag lines of force

Now, consider 2 permanent magnets & a conductor bet^n them

@ t = 0 sec
Initial flux = 3 lines



No emf generated due to no movement in conductor.

@ t=2 sec when conductor rotates
Final flux = 1 line

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

$= -1$

Now, if you want to increase $\frac{d\phi}{dt}$, you either
→ increase magnetic lines of flux
→ increase speed of rotation of conductor

* **Lenz Law:** CLYDE
Direction of induced emf is such that it opposes the cause that produced it.

$\therefore E_{induced} \propto N_T \times \frac{d\phi}{dt}$ → Cause

So in any case

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

* **Lorentz Law:**
A current carrying conductor when placed in a magnetic field experiences a force.
This force is Lorentz force.

Magnitude of this force given by:

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

where i = current
$\vec{l}$ = length of conductor
$\vec{B}$ = magnetic field

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

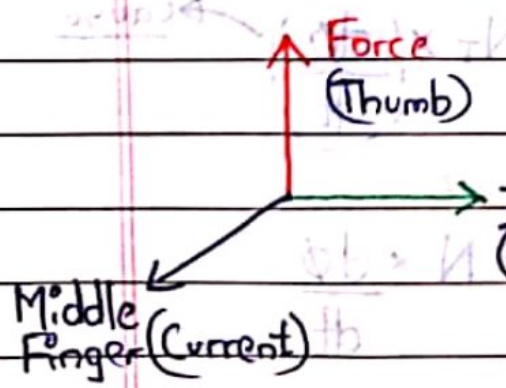
where B = flux density

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

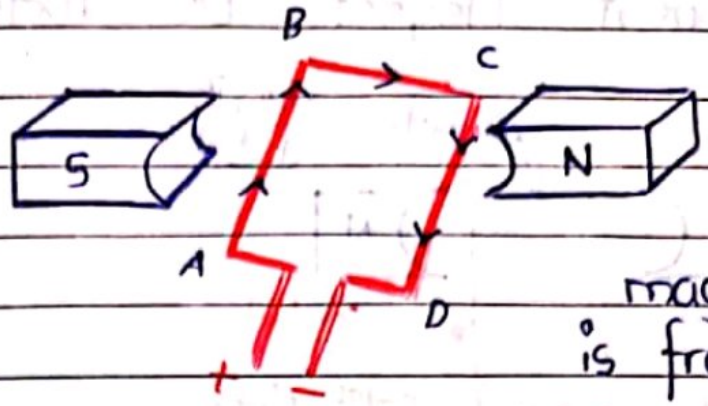
Now how to know the direction of force?

So Flemings Left Hand Rule gives the direction of force

CLYDE



→ Flemings left hand rule is for motors



Consider 2 permanent magnets where magnetic field is from N to S & current is supplied +ve to -ve

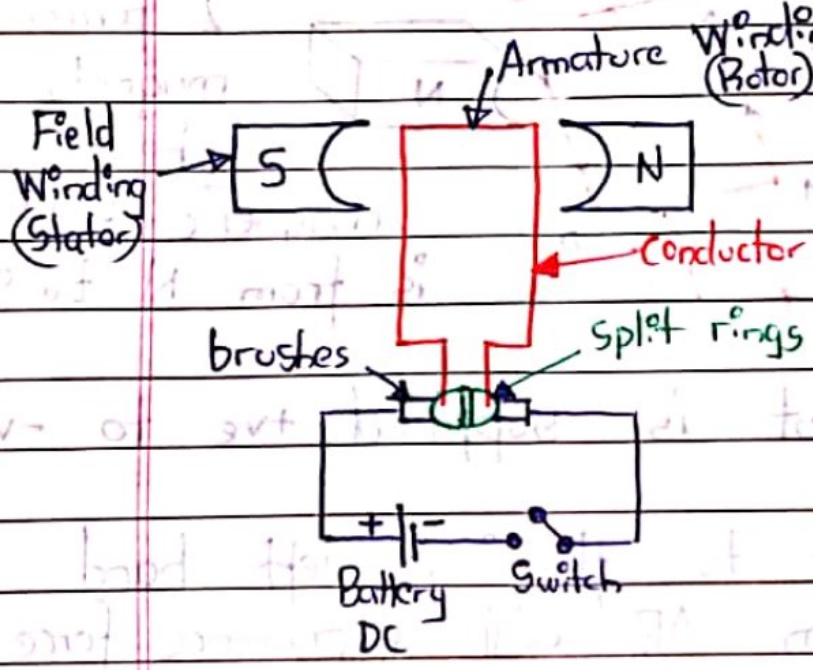
Now acc to flemings left hand rule, arm AB will experience force up & arm CD will experience force down

This will cause a couple & motor will rotate clockwise

Now as soon as 180° completes, the motor will tend to come back to initial rotate anticlockwise

So by putting split rings or commutator & brushes, current will keep flowing in only 1 direction & motor will keep rotating.

① Permanent Magnet DC motor



* So just by using split rings which rotate & brushes which help to keep terminals the same we can avoid bi-directional rotation

* We can say that, commutator/ Split rings help the motor to have unidirectional torque

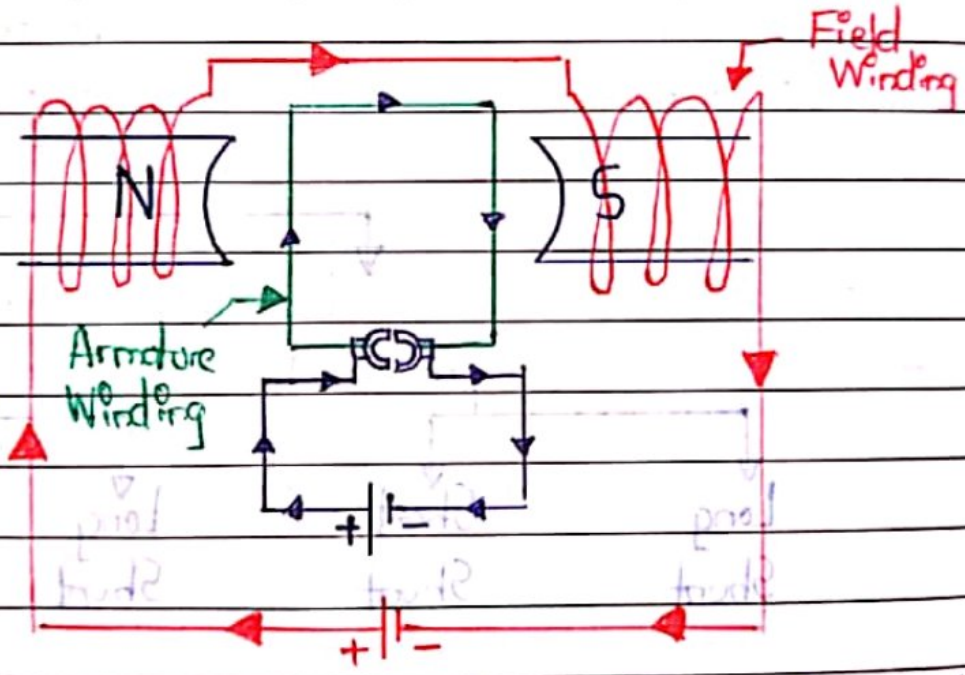
Electromagnet :

* When we supply electric current to a magnet, we call it electromagnet.

As we know, magnetic field can be produced by either
permanent magnet
electro magnet

CLYDE

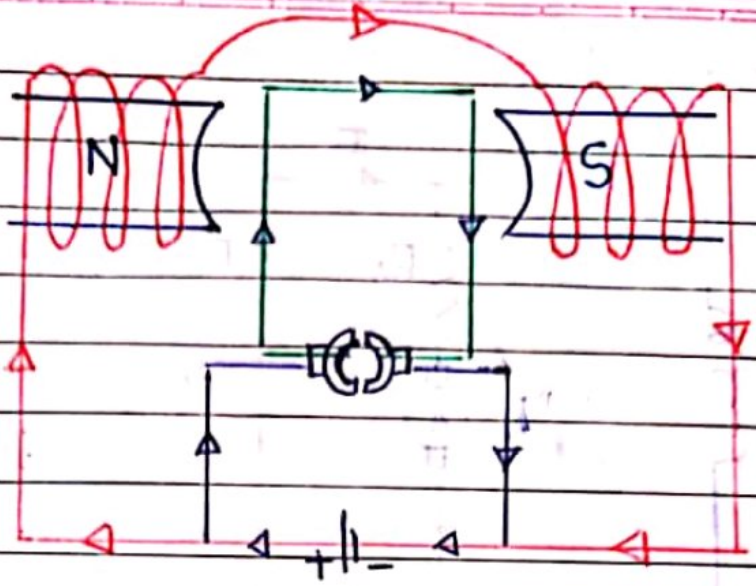
② Seperately Excited DC Motor



- when both field winding & armature winding are connected to seperate DC sources, it is called seperately excited DC motor.

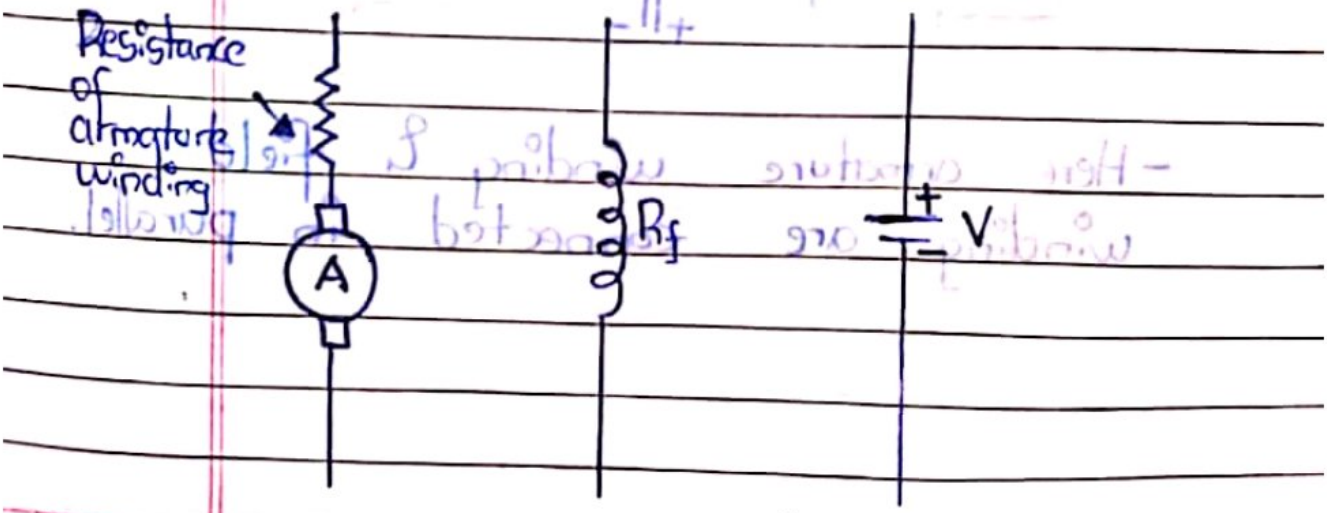
③

Self Excited DC Motor

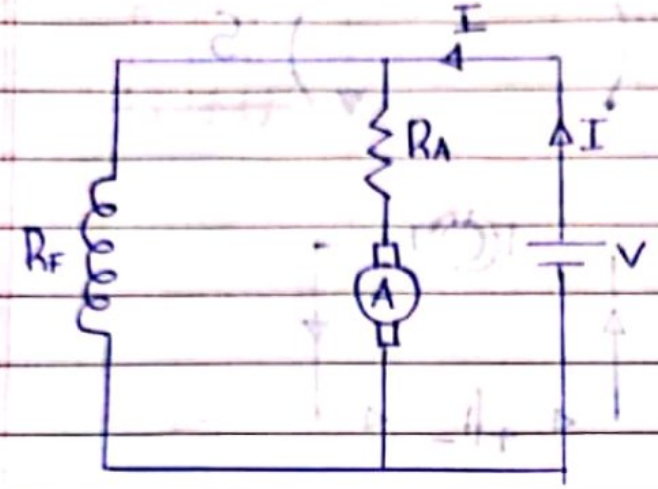


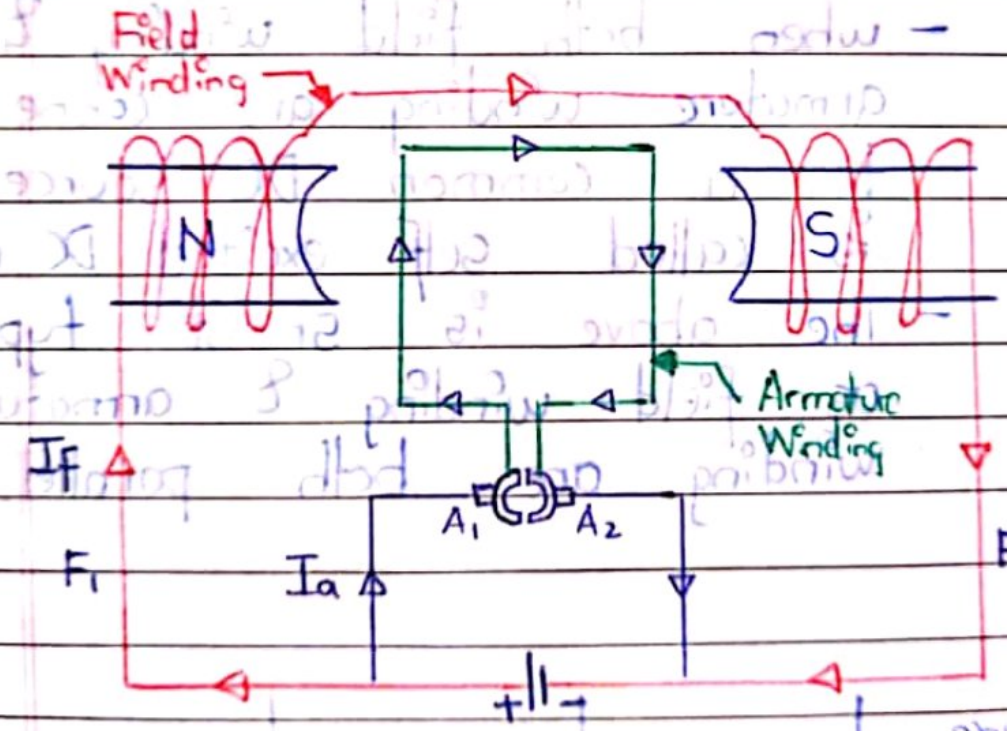
CLYDE

- when both field winding & armature winding are connected to a common DC source, it is called self excited DC motor
- The above is shunt type as field winding & armature winding are both parallel

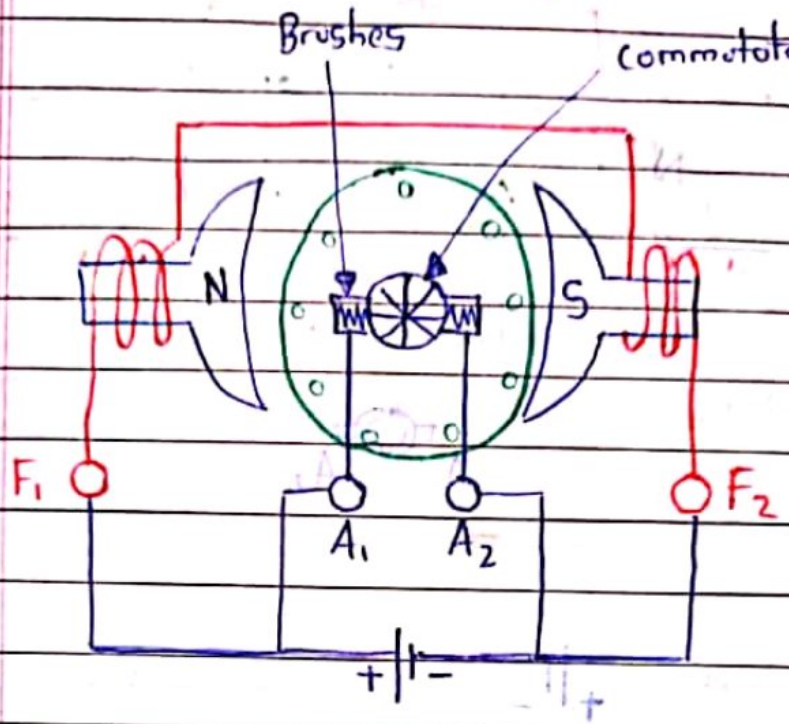


Shunt Motor

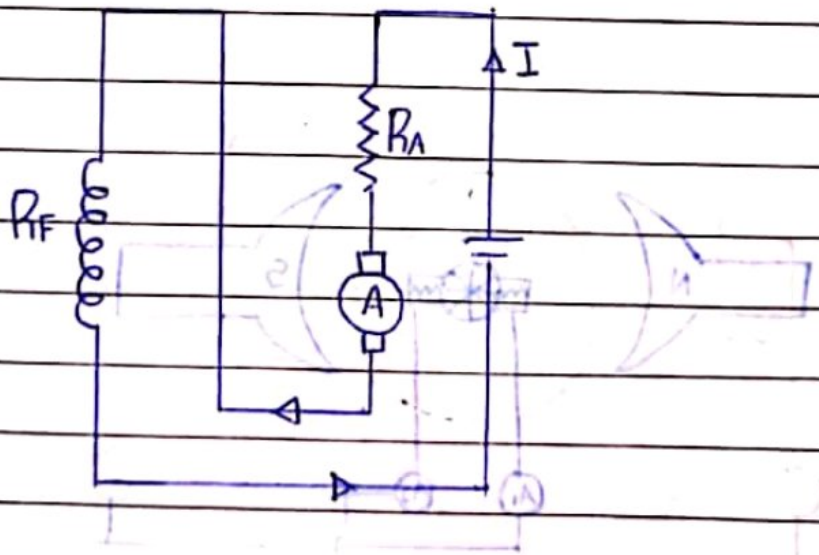




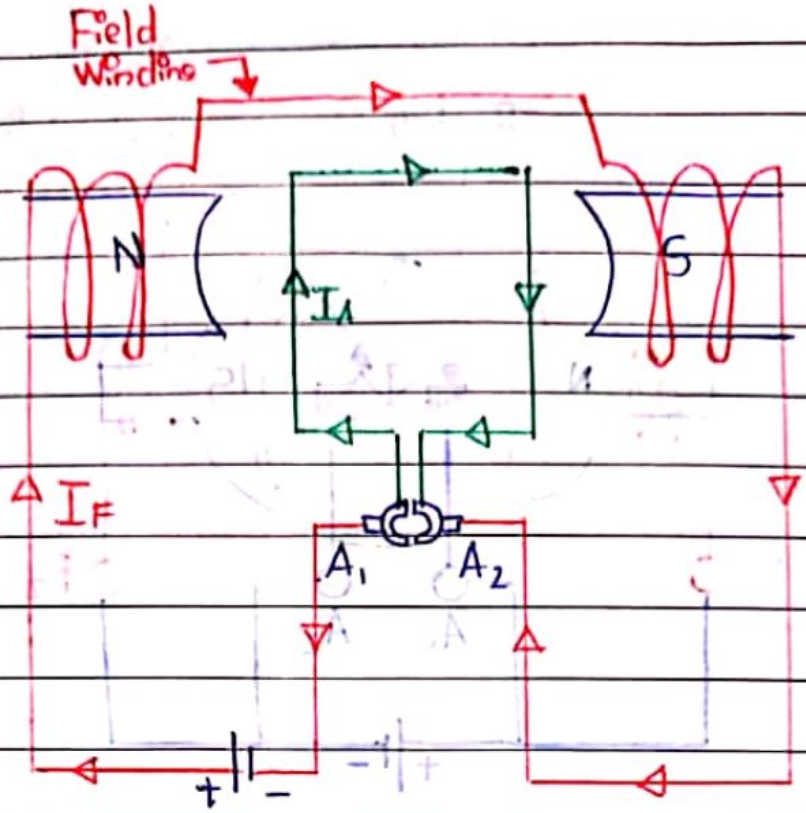
- Here armature winding & field winding are connected in parallel.



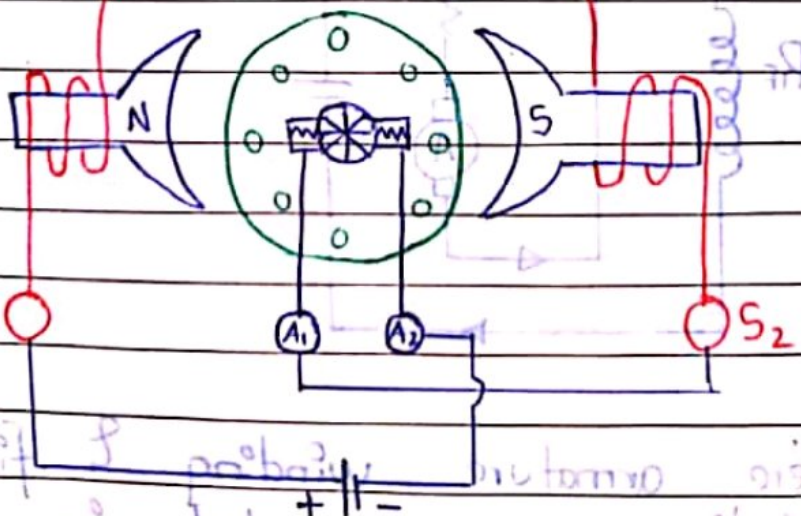
Series Motor



- Here armature winding & field winding are connected in series.



CLYDE



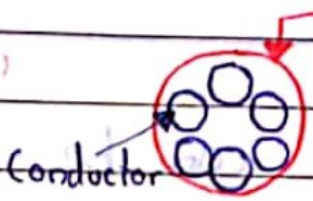
* Armature is current carrying conductor. so it will start rotating
* So acc to faraday law, when a conductor experience a varying mag. field, an emf is induced in conductor

* Emf is given by

$$E_{back} = \frac{N.d\phi_t}{dt} = \frac{P\phi N}{60} \times \frac{Z}{A}$$

where
P = No of poles
ϕ = Flux per pole
Total flux (ϕ_t) = P x ϕ
N = Speed of motor
Z = Total no. of armature conductor
A = No of parallel paths.

CLYDE



Each conductor has 4 slots
So 6 x 4 = 24

Difference bet^n DC Series & DC Shunt motor

	DC Shunt Motor	DC Series Motor
①	Field winding & armature winding are connected in parallel	Field winding & armature winding are connected in series.
②	3 pt starter is used	4 pt starter is used.
③	Torque developed is low	Torque developed is high
④	Used on machine tool, printing, pumps	Used in electric trains, crains, conveyors.

CLYDE

Now the armature can be connected in 2 ways :-

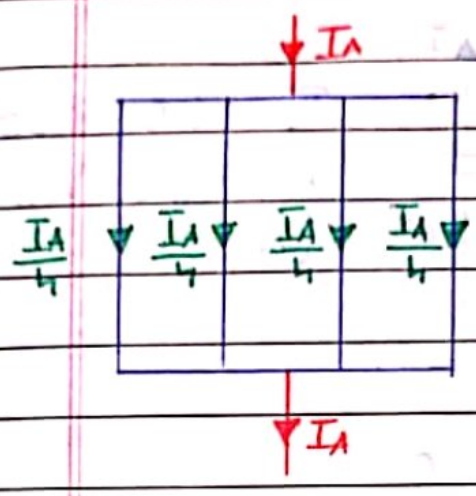
① Lap connected

here A=P

A → No of parallel paths

P → No of poles

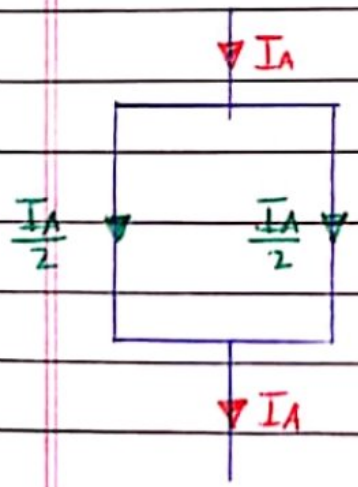
In lap connected winding, no of parallel path equal to no. of poles



* So basically it reduces current rating flowing to all parallel paths
* Hence we can use thin conductor.
* So in case of big motor, cost of winding reduces.

(2) Wave connected

here $A = 2$



* No of parallel paths is always 2.
* So for required current rating, a thick conductor will be needed.

→ For AC motors,

$T_{ac} \propto \phi . I_2 \cos\theta_2$

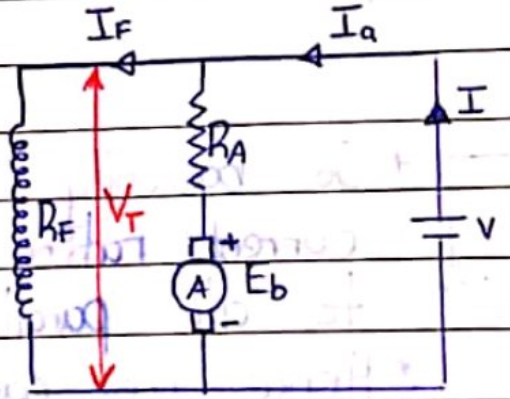
I_2 = rotor current

$\cos\theta_2$ = rotor power factor

→ For DC motors

$T_{dc} \propto \phi . I_A$

In Shunt Motor



If we apply Kirchoff's Voltage Law

$$+V - I_a R_A - E_b = 0$$

$$V = E_b + I_A R_A$$

but $V_T = V$

$$\therefore V_T = E_b + I_A R_A$$

PAGE No.

DATE / /

Resistance
Reactance
Impedance
} All are opposition to flow of current.

NEXT TOPIC

→ STARTERS

value of overload current is 125% rated current

PAGE No.
DATE / /

* Induction motor (3ϕ) is a self starting motor

So why we require starters?

* Starters are used to reduce starting current as IM draws high starting current

CLYDE

* It draws 5~8 times full load current for 5 seconds

* Starters also used to provide thermal overload protection to protect windings from v high temp.

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

* Y-Δ, autotransformers, soft starters help to reduce starting voltage which reduce starting current but their starting torques reduces.

TM MOTOR STARTERS

* When induction motor is connected directly to 3Ø AC supply voltage, a very large stator current (5~8 times FLC) is drawn.

Q Why start current is high in IM?

rotor speed at starting

@ starting, rotor speed $N_r = 0$

So relative speed = $N_{stator} - N_{rotor}$
= $N_s - 0$

That means relative speed = N_s
(i.e speed of mag field which is max)

This is max value of relative speed because once rotor starts rotating, it will try to oppose this mag. field & hence relative speed decreases.

So relative speed is max at start.

Now since $\frac{d\phi}{dt} \propto$ relative speed

CLYDE $\frac{d\phi}{dt}$ also max

* We reduce start current to protect alternator from overload trip.

We also know, induced emf $\propto \frac{d\phi}{dt}$

So emf also max.

CLYDE

Also rotor current $\propto$ emf

So rotor current also max.

Stator behaving as primary winding

Now because of transformer action stator current also becomes max.

Rotor behaving as secondary winding

Hence we get Start Current 5~8 time of rated current.

Rated current = Full load current

↓

Value of current at which motor operates at rated load.

Starting period is the period the IM takes to reach 85% of FLS

* High start current causes significant I^2R losses (copper losses)
* The only way is to reduce supply voltage so that start current is reduced.
* This voltage reduction is done by Reduced Voltage Starters.

In DOL, we do not reduce starting current. We only use to start motor & provide Thermal Overload Protection

PAGE No. 23
DATE / /

JCW plp
SW plp
Compressor
FO supply
FO circulating
ER fan

① DOL Starter

* For most I.M., high start current surge will not cause serious heating damage to motor unless the motor is repeatedly started & stopped in short period of time

* So Direct On Line starter can be used for such motors

* But when large motors are started on DOL, the cause significant disturbance of voltage (voltage dip)

* If voltage dip for AE is 10~15%, then it is acceptable

* But for large motors, it is unacceptable. So it may cause flikering of lights

* If voltage dip increases further when other large motors are connected, it can cause AE to trip.

{when alternator goes from NL to FL there is a voltage dip}

* On ship, slight voltage dip can be compensated easily by Brushless Excitation.

* DOL used mainly 65 ~ 75 KW motors

ADVANTAGES :-

① High starting torque (as we dont reduce phase voltage)
② Simple circuit (which helps in easy trouble shooting)
③ Only 1 contactor used (which means less maintenance)
④ Economical.

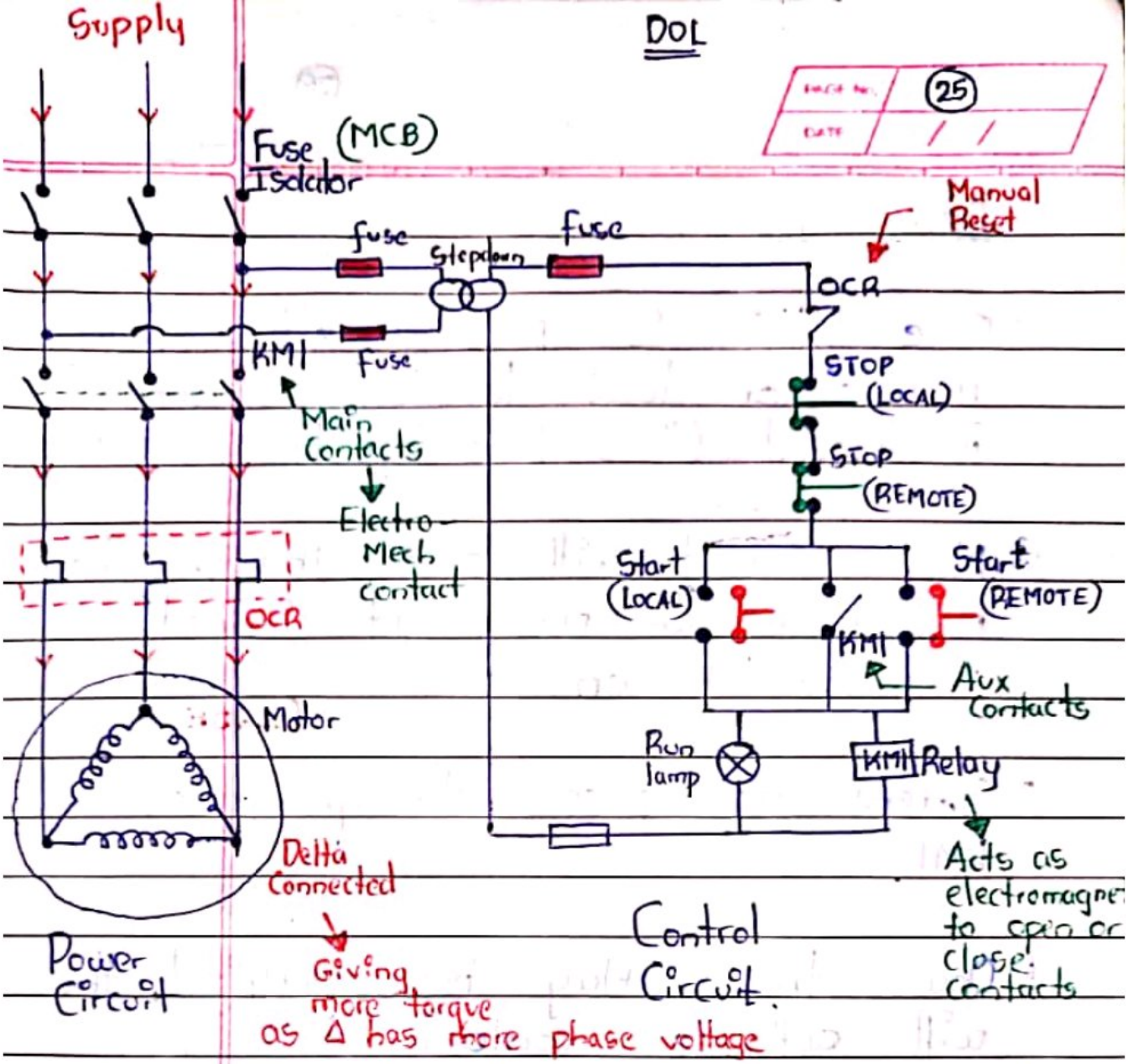
CLYDE

DIS-ADVANTAGES :-

① High start current affecting lifespan of motor.
② Does not support multiple starts as winding may heat up
③ Causes voltage dip so only suitable for small motors

Even though DOL & starting current is high, voltage dip definately happens but our AVR will bring back in 0.6sec back to ruted voltage.

DOL



Giving more torque as Δ has more phase voltage

* Stop is always having NC contacts
* Start is having NO contacts.
* In this circuit, we can START & STOP from local & remote locations
* OCR is a thermal overload protection in circuit which consists of bimetallic strips
* When motor receives 125% of FLC, the OCR will activate & circuit will trip.

Operation :

① Once start is pressed, either from remote or local location, the contact is closed (∵ start always has NO contacts)

② Now current will pass through the ron. lamp & run light indication will switch on

CLYDE

③ Current also passes through relay KM1.

④ Once this relay is energized, the will activate contact KM1 & 3ϕ supply will be available to motor to start.

⑤ Once start is pressed, the latching contact will hold start in NC position unit stop is pressed.

Main contacts – have higher current rating
Aux contacts – have lower current rating

⑥ OCR are bimetallic contacts

Connected in Star – for 5sec
Connected in Delta – afte. 5sec

$V_{ph} = \frac{V_{line}}{\sqrt{3}}$ ②

Star - Delta Starter (Reduced Voltage Starters)

We are reducing phase voltage before starting

* In this type of starter, motor is first connected in star (to reduce start current) & then runs on delta.

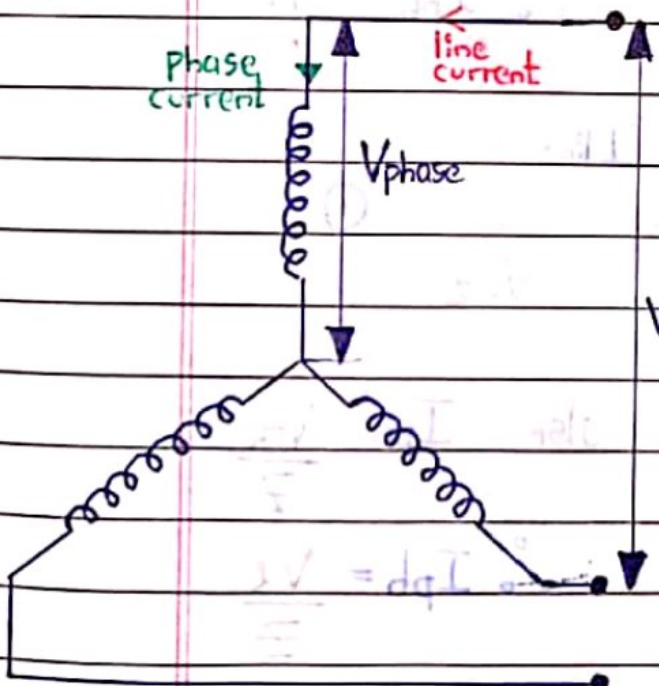
Due to the $I_{line\,\lambda} = \frac{1}{3} I_{line\,\Delta}$

* This is because

$$I_{line}\,(Star) = \frac{1}{3} I_{line}\,(Delta)$$ for same power rating

But here torque will also be reduced

* So when motor connected in star, it draws $\frac{1}{3}$ times line current in delta



STAR Connection

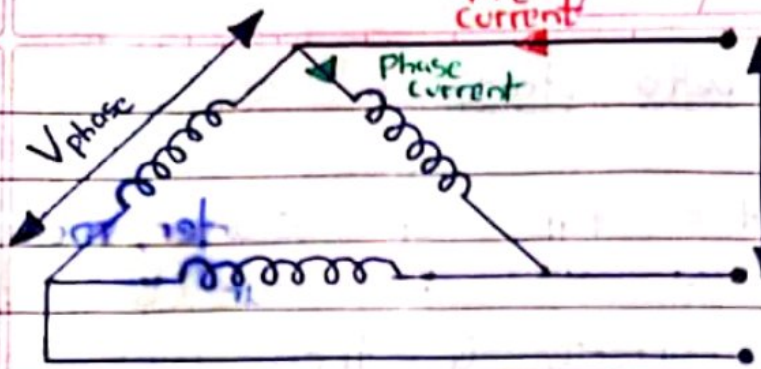
* Voltage across each phase winding = Phase Voltage

* Voltage bet^n any 2 phases = Line Voltage

Here $V_{phase} = \frac{V_{line}}{\sqrt{3}}$

$I_{line} = I_{phase}$

line voltage is voltage measured across 2 phase wires.



Phase Voltage is voltage across phase winding

DELTA Connection

Here $V_{phase} = V_{line}$

$$I_{phase} = \frac{I_{line}}{\sqrt{3}}$$

How?

CLYDE

$V_{ph} = \frac{V_l}{\sqrt{3}}$ & also $I_{ph} = \frac{V_{ph}}{Z}$

$\therefore I_{ph} = \frac{V_l}{\sqrt{3}Z}$

Star

Now $I_{phase} = I_{line}$

$$I_{line} = \frac{V_l}{\sqrt{3}Z} \quad (1)$$

$V_{ph} = V_{line}$ & also $I_{ph} = \frac{V_{ph}}{Z}$

$\therefore I_{ph} = \frac{V_l}{Z}$

Now we know $I_{line} = \sqrt{3}\, I_{phase}$

$$I_{line} = \frac{\sqrt{3}\, V_l}{Z} \quad (2)$$

Divide eq ① by ②

$$\frac{I_{line}(Y)}{I_{line}(\Delta)} = \frac{V_\ell}{\sqrt{3}Z} \times \frac{\sqrt{3}V_\ell}{Z} = \frac{1}{3}$$

$$\therefore I_{line}(Y) = \frac{1}{3} I_{line}(\Delta)$$

* Star - Delta starter is a reduced voltage starter or a open transition starter

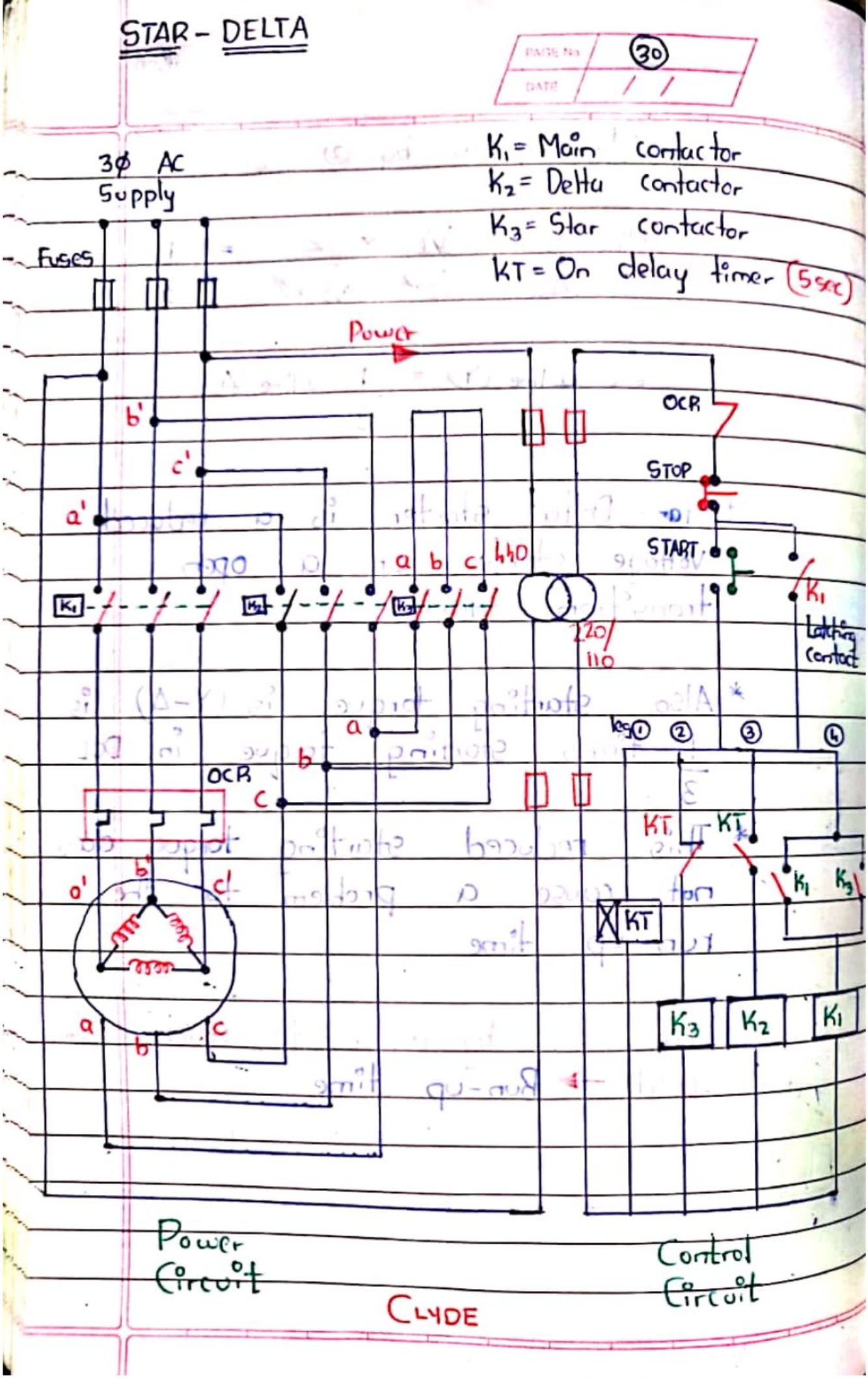
* Also starting torque is (Y-Δ) is $\frac{1}{3}$ times starting torque in DOL

* This reduced starting torque does not cause a problem to the run-up time

Time taken by motor to reach 80% speed → Run-up time

STAR - DELTA

PAGE No. 30
DATE / /



PAGE NO. (31)
DATE / /

CLYDE

Operation :

① Power is available upto main contactor (K_1) in power circuit & upto start push button in control circuit.

② Latching contact of (K_1) is given for start push button

③ On pressing START, power is available to on-delay timer KT & also star contactor (K_3) as KT in that leg is closed

④ Once relay contactor (K_3) is energized, K_3 contacts in power circuit closes & motor connected in STAR

⑤ Also contacts K_3 in leg ④ closes giving supply to relay contactor (K_1).

⑥ Once relay contactor (K_1) is energized, K_1 contacts in power circuit closes & now supply will be available to motor to run in star.

⑦ Once on-delay timer deenergizes i.e after 5 sec KT in leg ② opens & KT in leg ③ closes.

CLYDE

⑧ That means relay contactor (K_3) gets de-energized & opens all [K_3] contacts in power circuit.

⑨ Now as relay contactor (K_2) is energized, contacts [K_2] in power circuit closes & thus motor is connected in delta.

⑩ While shifting from K_3 to K_1, both contactors are open called Open Transition

Open Transition :

* There is some time delay bet^n opening of star connection contactor (K_3) & closing of delta connection contactor (K_2) of about 20~30 millisecond.
* This period of time, stator winding deenergizes means no supply available but rotor still rotates @ 95% full load speed as rotor now has residual magnetism.

⑪ Open transition can cause a rapid current spike & motor will tend to accelerate at dangerous speed causing winding to burn or mechanical damage.

⑫ Contact K_1 will remain closed during open transition.

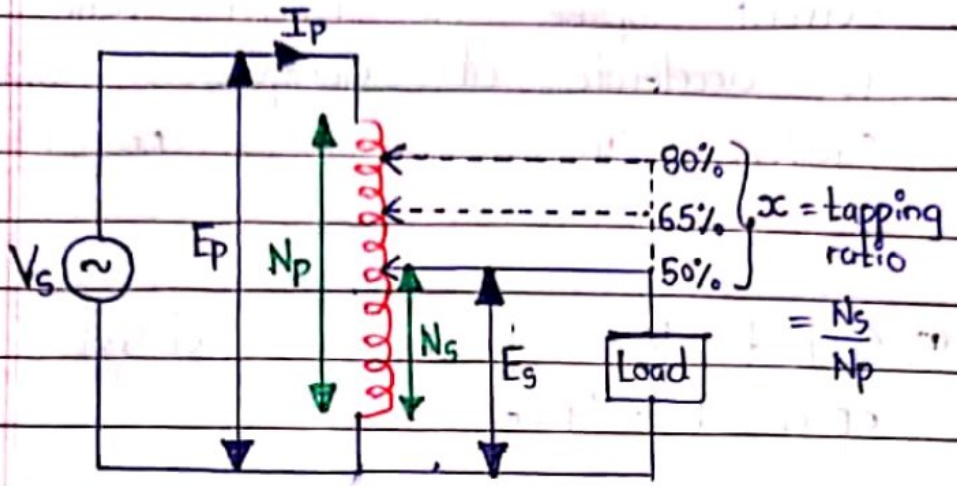
ADVANTAGES :-

① Multiple starts are possible
② Low starting current while starting.
③ Can be used for high capacity motors

DISADVANTAGES :-

① Low starting torque
② Possible damage to motor due to open transition
③ Complicated circuit
④ More contactors used so costly.
⑤ Requires more maintenance.

③ Auto-transformer starter. (Reduced Voltage Starters)



- Np = No of turns in primary winding
- Ns = No of turns in secondary winding

But Ns is variable according to tapping

* In normal transformer, primary & sec windings are seperate, but in auto-transformer, winding is common. Only no. of turns in secoundary winding can change by tapping.

CLYDE

* Generally tapping x = 50%
  65%
  80%
* Depending upon req. starting torque, the x changes
* For high starting torque, we req x = 80%

The tapping or the no. of turns decides voltage in sec coil

∴ We know $\frac{E_p}{E_s} = \frac{N_p}{N_s}$

$\therefore E_s = \frac{N_s}{N_p} \times E_p$

$E_s = x \times E_p$ $\left\{\because \frac{N_s}{N_p} = x\right\}$

Center tap →

* If $x = 50\%$, means $N_s/N_p = 50\%$ means secondary winding is half of primary winding.

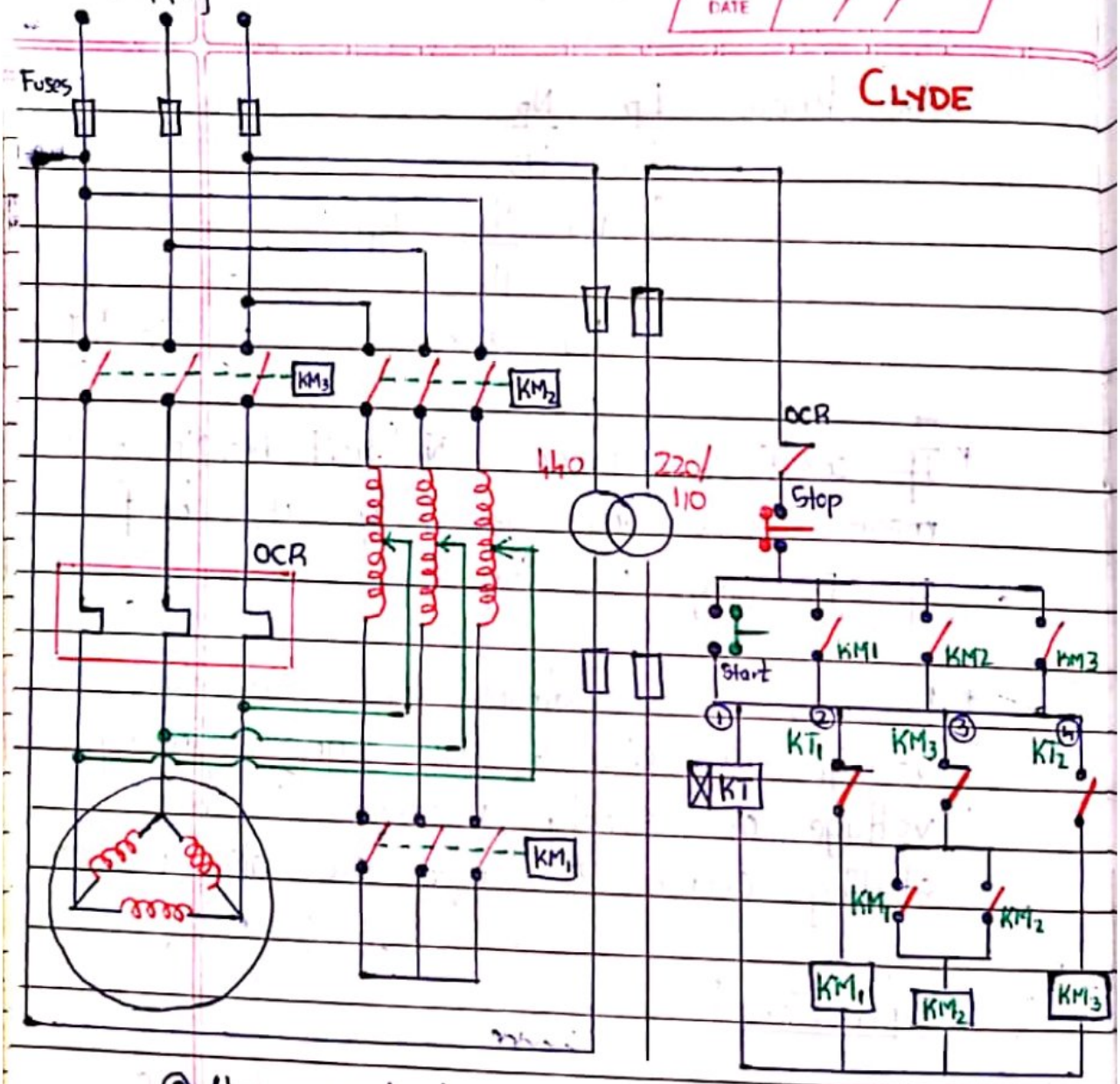
* Basically in autotransformer, secondary voltage is always less than primary voltage or supply voltage & hence starting current & torque are also reduced

Operation :

① 3 latching contacts are provided for start button. KM1, KM2, KM3 so that if any relay contactor energizes, then latching contact also closes ensuring supply

② On pressing start, supply will be available to time delay & also relay contactor KM1 energizes & KM1 contacts in power supply closes

CLYDE



③ Also contact KM1 in leg ② closes, allowing power to flow through relay contactor KM_2

④ This will cause contactor KM_2 in power circuit to close.

⑤ Now motor is connected to power supply & voltage is induced in primary coil & depending on tapping

Some voltage is induced sec winding.

⑥ Time delay is for about 5~6 seconds after which motor has reached its rated full load speed.

⑦ After 5~6 seconds, contact KT_1 will open & KT_2 will close but there is a period of 20 micro sec. where KT_1 & KT_2 are in open condition & this is Open Transition Period.

⑧ Now as relay contactor [KM3] is energized, contacts [KM3] in power circuit will close & motor can now run at high torque.

* 50% tapping gives low starting current & low torque during starting

* 80% tapping gives high starting current & high torque during starting

$I_{starting\ in\ Autotransformer} = x^2 \times I_{start\ in\ DOL}$

$I_{starting\ in\ Autotransformer} = x^2 \times I_{start\ in\ DOL}$

Self Induction :-

It is a phenomenon in which emf is induced in a coil because of current flowing in same coil

Mutual Induction :-

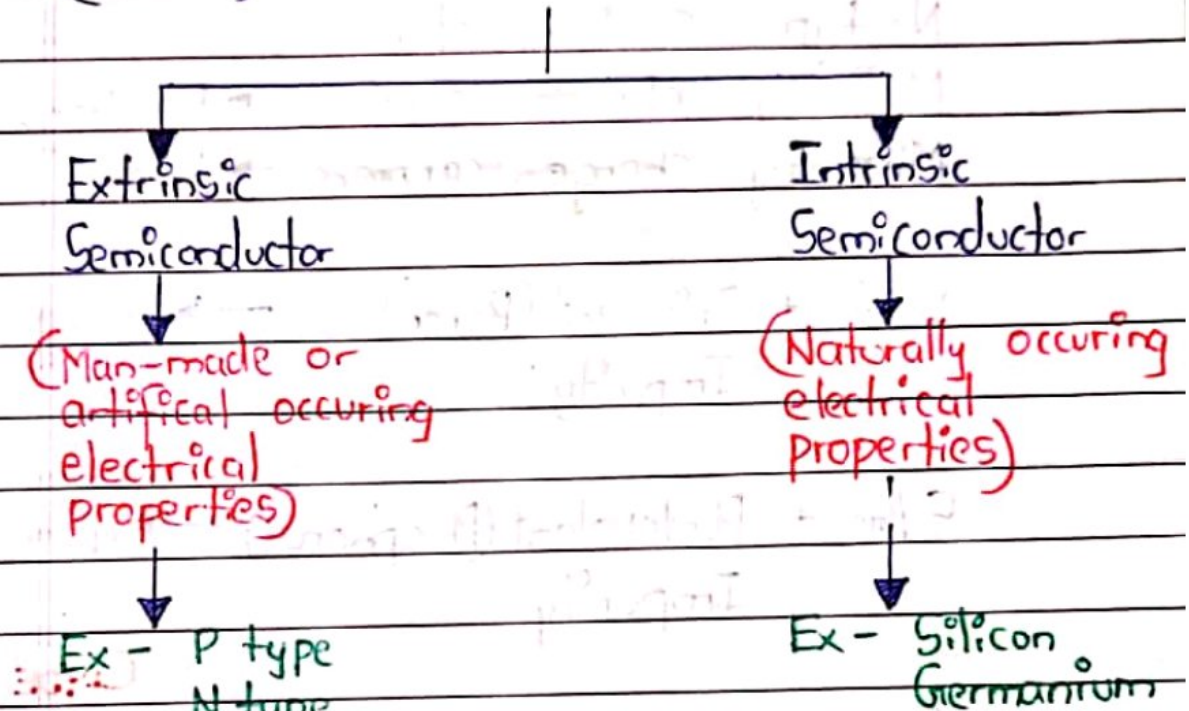
It is a phenomenon in which emf is induced in a coil because of current flowing in another coil

Auto-transformer works on principle of mutual inductance.

CLYDE

SEMICONDUCTOR :-

* It is a device whose conductivity lies bet" conductor & non-conductor (insulator)



Doping :-

* It is a process of adding impurities to intrinsic semi-conductor to improve its properties/performance & use it as extrinsic semi-conductor

CLYDE

Semiconductor Devices

1. Diodes
2. Thyristor (PNPN)
3. BJT (NPN/PNP)
4. MOSFET
5. IGBT

P-type semiconductor :-
Majority charge carriers → Holes
Minority charge carriers → Electrons

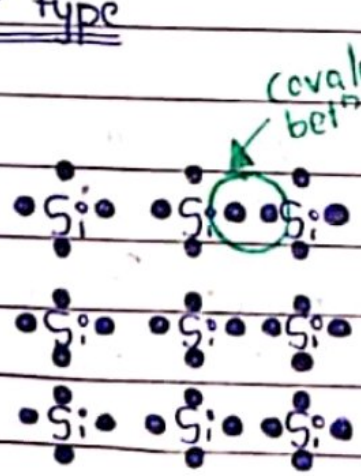
N-type semiconductor :-
Majority charge carriers → Electrons
Minority charge carriers → Holes

Si/Ge + Trivalent (Boron) Impurity → P type

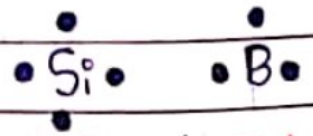
Si/Ge + Pentavalent (Phosphorus) Impurity → N type

CLYDE

P type

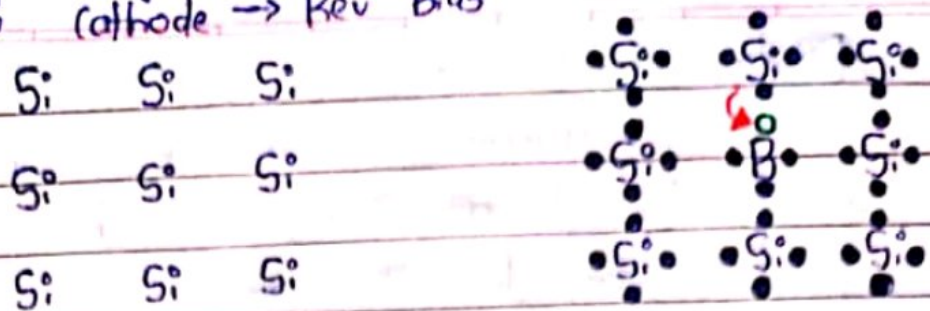


*Silicon has 4 valence electrons in outermost shell



Now if we replace 1 Si atom with Boron then

If positive terminal given to anode → Fwd Bias
If negative terminal give to cathode → Rev Bias



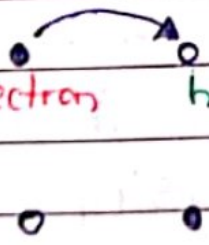
o hole
• electron

* Now due to the hole created by adding (Boron) é from silicon will tend to jump to hole.

* This will cause conduction to begin

CLYDE

* Hence boron is called acceptor atom



* If é has energy, it will jump to hole

* This will again leave a hole in its place

Hence, é are negative charge carriers & holes are positive charge carriers

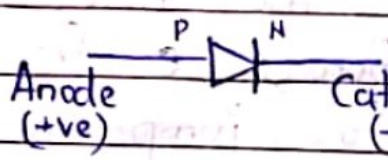
Diode is 2 layer
2 terminal
1 Junction
Uncontrolled semiconductor devices

PAGE No. 42
DATE / /

Diode - It is a device that allows flow of current in only 1 direction. It has 2 leads cathode & anode.

* Generally cathode is marked by silver or coloured band

CLYDE



PN Junction Diode

Working of diode in Fwd & Reverse bias

Diodes used in rectifiers

AVR ICCP VFD

If anode voltage > cathode voltage

Forward Bias :-
Here voltage potential is connected +ve to P-type material & -ve to N-type material. This has an effect of decreasing width of depletion layer

If anode voltage < cathode voltage

Reverse Bias :-
Here voltage potential is connected -ve to P-type material & +ve to N-type material. This has an effect of increasing width of depletion layer.

So Diode will conduct only in fwd bias after crossing barrier potential.

So basically when depletion layer decreases in fwd bias, é will be able to recombine with holes & conduct in fwd bias

Acceleration of minority charge carriers causes Avalanche Breakdown

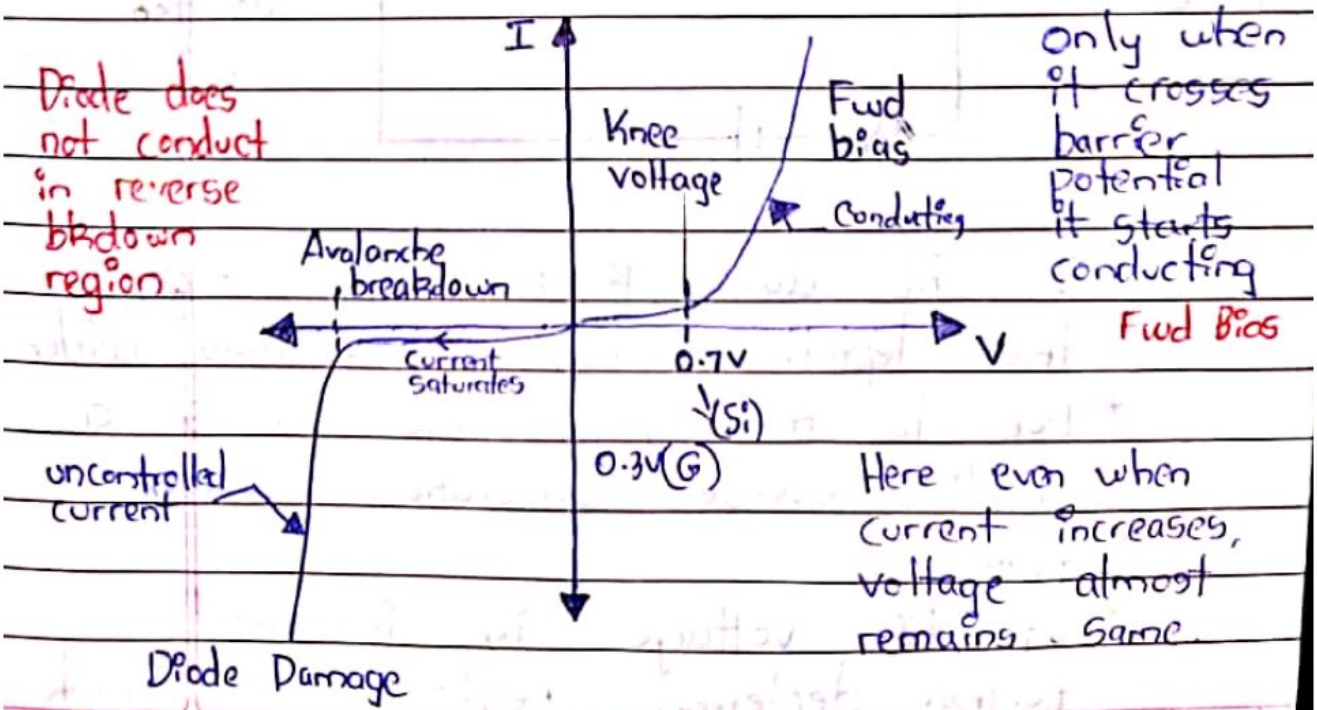
But in reverse bias, conduction won't take place

In fwd bias, current will flow only when voltage applied is greater than barrier potential

0.7V → silicon

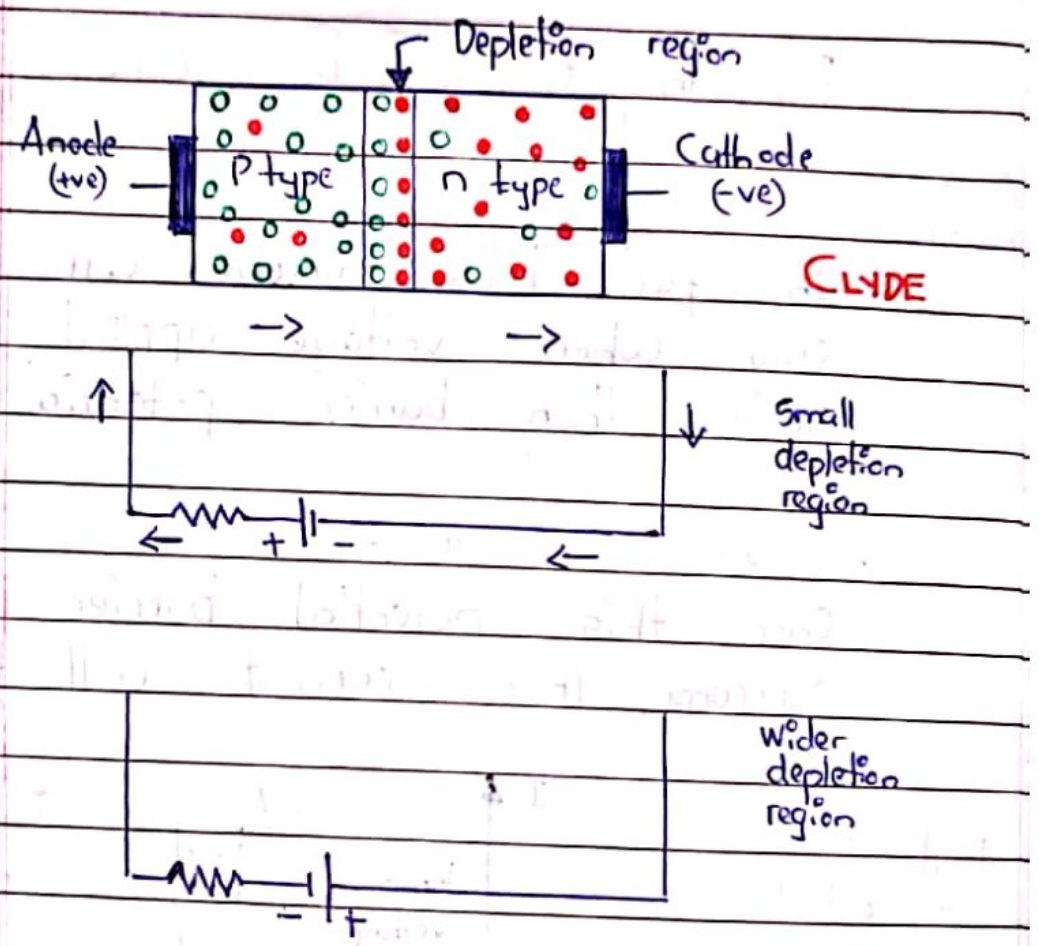
0.3V → germanium

Once this potential barrier is overcome, then current will flow



Uses of diode -

used as rectifier, voltage regulator, switch, oscillators etc.



* In RB, due to RB. voltage, the depletion region becomes wider
* Due to minority charge carries a small reverse saturation current flows
* If RB voltage is increased further, depletion region will break & huge current will flow.

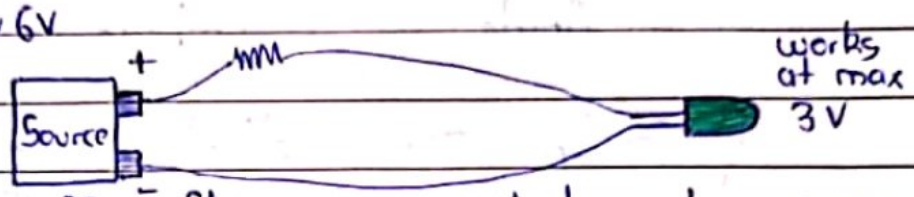
used in intrinsically safe equip & voltage regulator circuits

(45)

Zener Diode

It is a heavily doped PN Junction Diode

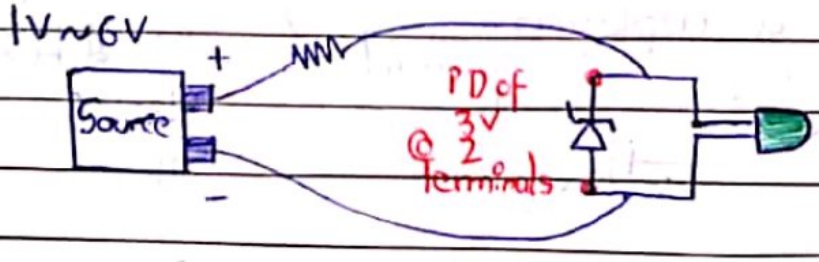
* If suppose we have a DC source from 1~6V which keeps fluctuating.



* Now if its connected to LED & voltage goes above 3V, LED will destroy

* So in such cases we use of zener diode.

* In similar situation, if voltage goes above 3V it wont allow this voltage to be passed to LED



* Hence a zener diode is used in reverse bias

Only when voltage = Zener voltage then

Zener diode will work like normal diode in fwd bias condition.

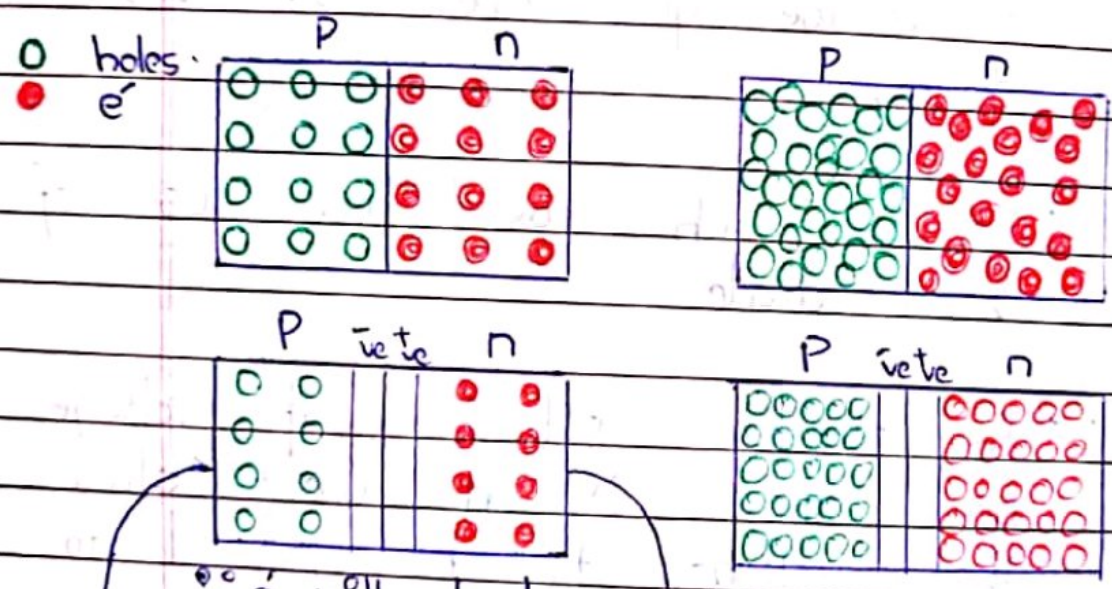
PAGE NO. 46
DATE / /

Hence we can use a zener diode as a voltage regulator

CLYDE

Zener Diode.

Basically zener diode is a heavily doped PN junction diode.



∴ é will tend to move to holes, a depletion region is formed

Here also the same happens but as heavily doped, depletion region is thin

Because of RB, depletion region becomes thicker

Because of RB depletion region becomes thinner.

but potential of depletion region is same

Here a controlled breakdown happens called zener breakdown caused by thin depletion region.

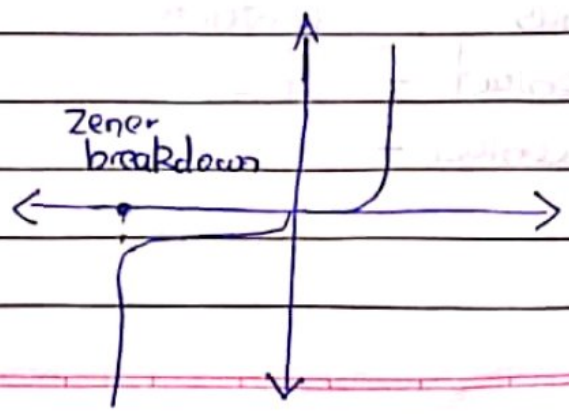
but in normal PN junction diode, eventhough depletion layer is wider, the electric field is less.

So when free electrons come from P region, it will knock of the silicon atoms and huge heat energy is generated.

But in zener diode, eventhough depletion layer is thin, the electric field is large.

So when free electrons come from P region, it will have less possibility to knock off silicon atoms and energy of electric field is large collision of atoms in depletion region is avoided. Hence heat not generated.

Zener Diodes usually used in reverse bias region



Air Circuit Breaker

* ACB is an electrical device used to provide overcurrent & short-circuit protection for electric circuits.

CLYDE

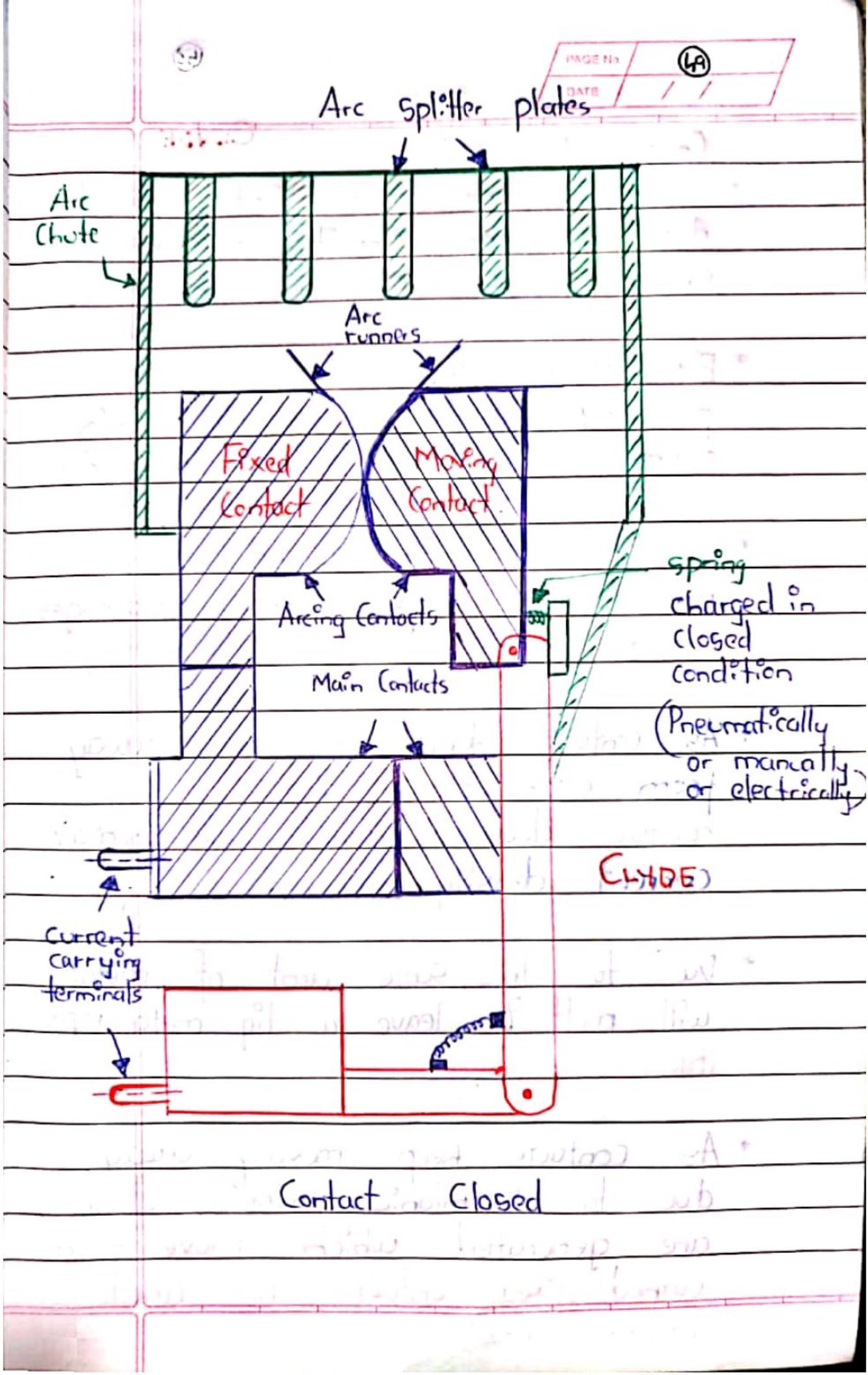
* Used in applicated where voltage is or less than 440V

* ACB are found on distribution panels.

* ACB basically operates as an arc extinguishing medium

* Unlike a fuse which operates & must be replaced, a circuit breaker can be reset to normal operation.

ACB has 2 contacts
Main contact - Copper
Arcing contact - Carbon



Contact Closed

CLYDE

Concept :-

* when contacts are just opened due to open circuit, no current should flow.

* But during this time, a arc is produced which causes a v high current to flow through this arc

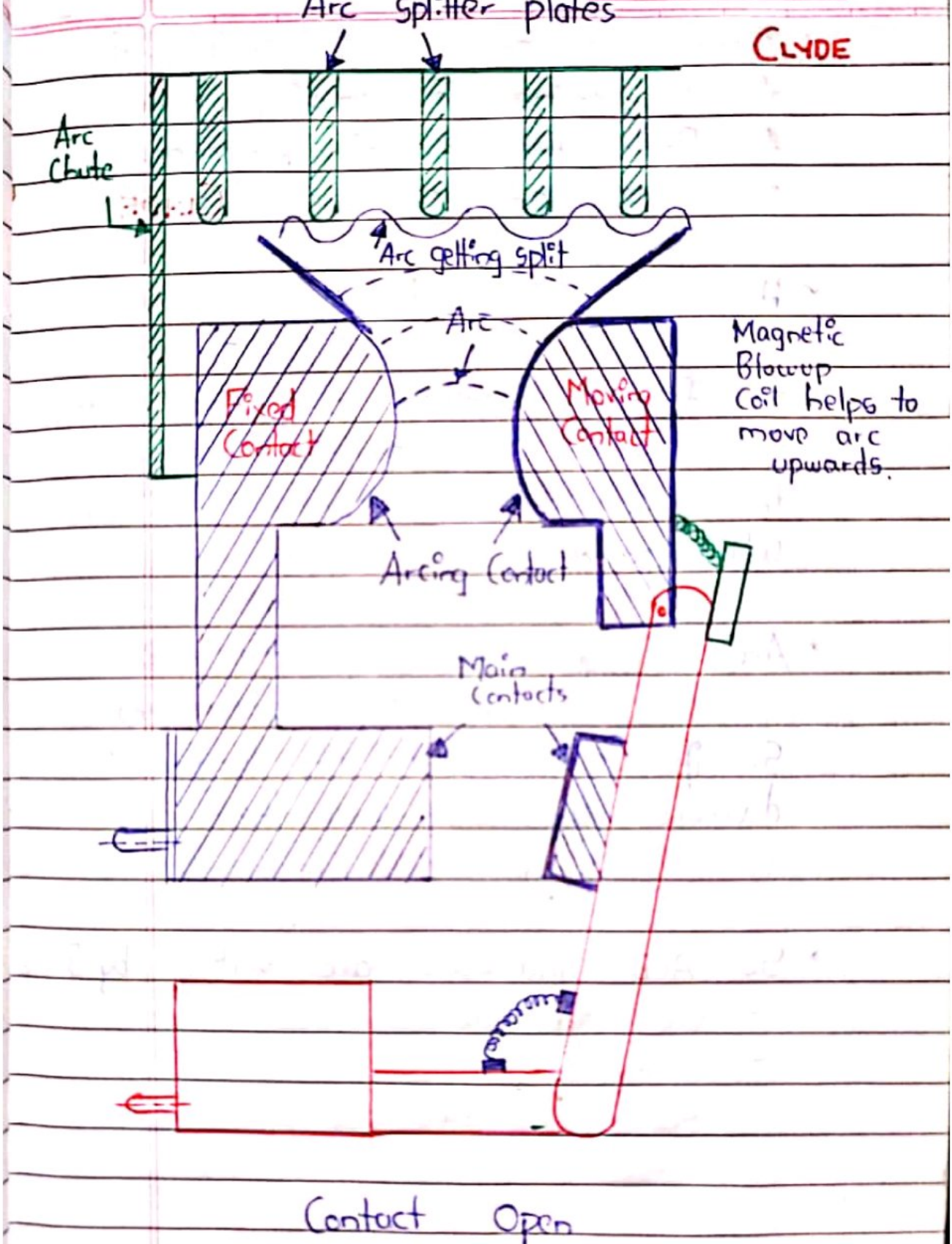
* So its imp to quench this arc before this high current damages circuit.

* As contacts tend to move away from each other, the area of contact decreases which will increase current density

* Due to this, some amt of metal will melt & leave a liq metal vapour (plasma state)

* As contacts keep moving away, due to thermionic emission, electrons are generated which move from cathode (fixed contact) to anode (moving contact)

CLYDE



Contact Open

∴ * These electrons will strike the air & ionize it causing current to flow through air. This can be seen as an arc CLYDE

* Hence we need to quench this arc.

* So if we increase the arc voltage Varc equal to supply voltage V_s, then current will be 0 & arc will quench

* Arc voltage $\propto \frac{\text{Arc length} \rightarrow \text{(increase)}}{\text{Arc c/s area} \rightarrow \text{(decrease)}}$

So if we increase arc length & decrease arc c/s area then Arc Voltage will increase

* So ACB increases arc voltage by 3 ways
  - → cools the arc
  - → lengthens the arc
  - → splits the arc

→ When field is charged, the fixed & moving contacts are held together.

* When spring is actuated, the main contacts open first & then arcing contacts open.

* The arc moves up due to thermal & electromagnetic effect

* The arc enters arc chute where it becomes colder & also arc splits. Hence Arc Voltage becomes high & finally arc extinguished

* A current transformer or voltage transformer is used to activate the trip coil for ACB to open

CT → steps down current (current transformer)
PT → steps down voltage (voltage transformer)

* Other circuit breakers are
  → Miniature circuit breaker
  → Vaccum circuit breaker
  → Oil circuit breaker

PAGE No. 54
DATE / /

Variable Freq Drive

- It is used to run a 3ϕ AC motor at various speeds
- This is done by adjusting the freq of motor to vary rpm
- It consists of 3 main components

CLYDE

① Diode
- It works like a check vlv allowing water to flow in only 1 direction
- It converts AC → DC

② Capacitor
- It works like a water filter to keep everything clean which smoothens ripples

③ Transistors
- They act as valves turn the flow on & off when needed which again converts DC → AC

- VFD can be control & monitor by PLC

- VFD also helps to ramp up speed of motor at start

- So basically $N_s = \frac{120f}{P}$ where P is fixed.

- So synchronous speed of motor can be varied by varying frequency.

- But as we know synchronous motor runs at speed lesser than this we call rotor speed due to slip.

Synchronous speed = speed at which rotating magnetic field rotates

$$\text{Slip} = \frac{N_s - N_r}{N_s}$$

CLYDE

$$s = 1 - \frac{N_r}{N_s}$$

$$N_r = N_s(1-s)$$

$$N_r = \frac{120f}{P}(1-s)$$

So to control speed we can vary 3 factors only

But slip $\propto$ loading.
as we go from no load to full load, the slip increases.

Means if we increase load, slip will increase but N_r will decrease.

But we dont want to change load to vary N_r

Also we can change poles only once.
So we only remain with frequency

$$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + (2\pi f L)^2}}$$

CLYDE

∴ So magnitude of current depends on voltage & frequency

* So if we only increase freq. the current will decrease
If current decreases flux decrease
also torque decrease
& as torque decreases, we won't be able to match load.

∴ if we increase frequency, we also need to increase voltage by same value.

* Also if we only decrease freq. the current will increase.
If current increases flux increase & flux will saturate a behard a certain value.

* So basically, if we want to control rotor speed (N_r). we need to increase/decrease freq & voltage by same value

Working

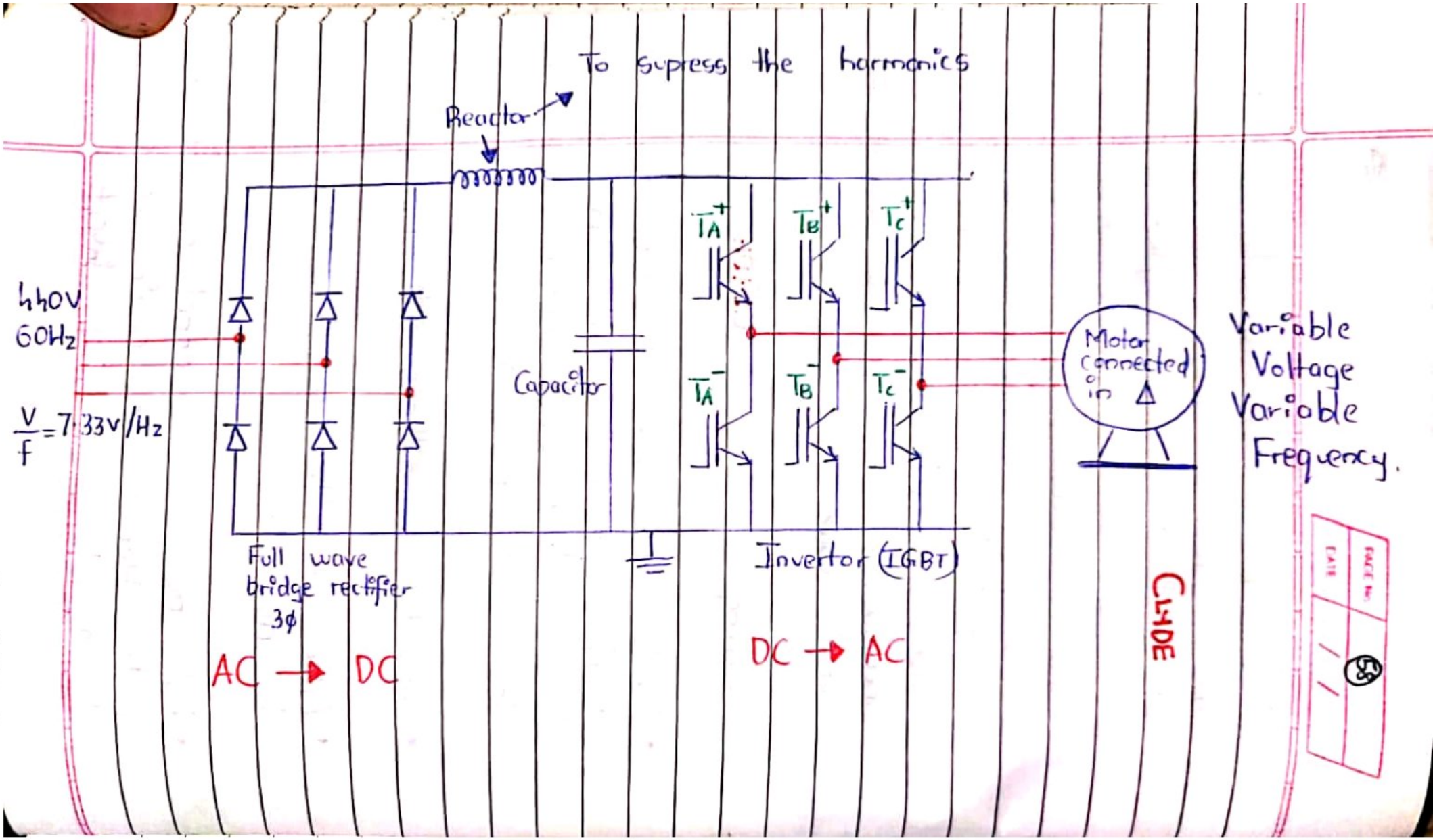
CLYDE

* Reactor is used as due to rectifier harmonics will be produced & we don't want harmonics to go in circuit of VFD

* Capacitor smoothens all ripples

* After capacitor, a fixed DC voltage is available

* But now we cannot give DC to motor. Hence we again convert it to AC by use of invertor.



* We require a gate trigger control which will control the switches of IGBT.

* At gate control speed is varied.

* Gate signals are varied using a pulse width modulator.

Zener Barrier

- used in intrinsically safe equipments
  ex i(a) } can be used
  ex i(b)] in hazardous zone

Energy = Power × Time
= V × I × t

- In any electric or electronic equipment, a spark produced can cause an explosion.
- In intrinsically safe equipments also a spark is produced but there wont be any explosion
  → low power equip (intrinsically safe)
  → high power equip (explosion proof)

If we regulate V × I we can control energy

Shore Supply

CLYDE

Q Precautions before connecting shore supply to ship?

- Check the condition of cable through which ship will receive supply from shore
- Check IR of cable
- Check IR of shore supply box.
- Check polarity of shore supply using voltmeter.
- Chek & ensure freq & voltage of shore supply are matching with specification req by ship.
- Check the phase sequence of shore supply using phase sequence tester.
- Check tightness of shore cable connector clamp to ensure not loose
- Display notice near ships vicinity receiving high power in use.
- Check & ensure ships generators are disconnected from MSB
- Officer must check & record energy meter reading
- Ensure ships hull is earthed to shore before supply of power.

Cold Ironing :- Shutting down generators & connecting ship to shore power supply in order to decrease noise, emissions like NO_x, SO_x, VOC, particulate matter, carbon monoxide & HC.

Now while take shore supply, various concerns are there.
- Voltage
- Frequency

CLYDE

* If voltage is less than rated voltage then :

$T \propto V_{ph}^2$

① So starting & max torque will be low. Thus longer acceleration period will be needed resulting in overheating.
② Current will be higher in order to maintain same power o/p. So heat will increase
③ Ageing of insulation will be accelerated due to heating.

* If voltage is more than rated voltage then : CLYDE

① Increased voltage drop while starting making lights flicker.
② Starting & max torque will be increased resulting in shearing of coupling
③ Starting current will be high
④ Increased motor current causing overheating
⑤ Ageing of insulation will be accelerated due to heating.
⑥ Power factor will be low.

* If freq is less than rated freq then :

① Current must be increased to generate same torque

$$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + (2\pi fL)^2}}$$

② To avoid excessive current, voltage must be reduced.
③ Motor runs 20% slower
④ Motor cooling by its own fan slower hence overheating.

* If freq is more than rated freq then :

① Motor runs 20% faster.
② Starting torque is reduced

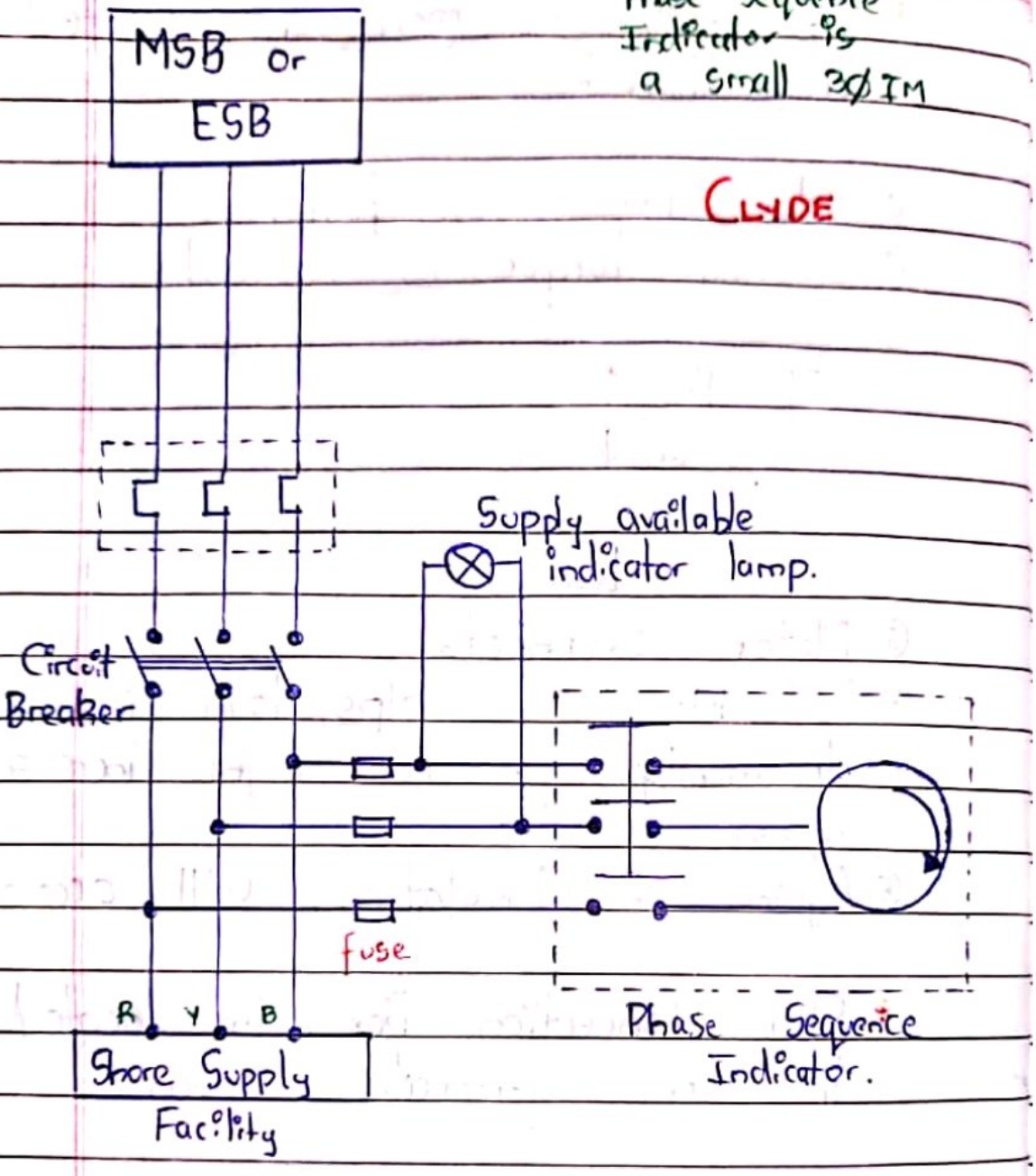
If freq ↑
current ↓
then flux ↓
torque ↓

③ Motor overheats
④ For blowers & pips, load increases drastically for a slight increase in speed
⑤ Ageing of insulation will accelerate.

* Shore Connection Box is located in eme generator room

Phase sequence Indicator is a small 3ϕ IM

CLYDE



- If phase sequence is wrong, motor will run in opposite direction
- So phase seq indicator is given which is a 3ϕ IM.
- Once switch is closed, indicator lamp will show green or red

depending on phase sequence
- Voltage & frequency meter shows value for voltage & freq.
- Under any condition $\frac{V}{f}$ ratio should be appropriate to match with flux

$$\frac{V}{f} \propto \phi \quad \& \quad I \propto \phi$$

CLYDE

— x — x — x —

* Before starting shore supply, eme gen should be put in manual & other gen off.

* Once blackout happens, then only shore supply to be made ON.

* An interlock is provided which do not let shore supply come on load if main power or eme power is ON.

* Bet^n shore & ship there is an Isolation transformer.

CLYDE

Isolation Transformer :- electrically isolates the AC shore power from ships AC power system. There is no direct ele connection bet^n earths grounded AC power & onboard electrical system. The shore ground is connected to shield that is wound bet^n primary (shore) & secondary (ship) transformer winding.

* The ~~shore~~ connection ~~ground~~ of this grounding wire to shield of transformer is called faraday shield isolates ships AC electrical sys from shore.

* This eliminates the stray galvanic currents from ship to shore.

* This means the sacrificial zinc anodes won't get damaged

* There is no ele continuity bet^n ship earth & shore earth.

* So if any electrical gets started on ship, no current will flow to shore as a faraday shield is there in between.

* Isolation transformer are also used in welding m/c. CLYDE

→ EARTHING :- Physically connecting wire to ground
This acts as 0V potential

→ GROUNDING :- Not physically connecting wire to ground
We create a equi-potential surface & connect wire to it.

On ships, we have grounding not earthing as there is no earth.

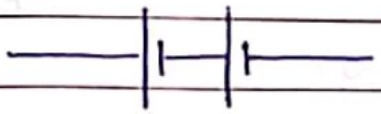
A series combination of 2 or more cells are called **battery**

PAGE No. 68
DATE / /

Battery

* Cell :- It is where chemical energy is converted into electrical energy.
* No of cells connected in series is called "Battery".

CLYDE



This is represented of battery with 2 cells.

* Cell can be of 2 types
  - ↳ Primary
  - ↳ Secondary

TYPE 1

* Primary cells are 1 time use cells means it cannot be recharged

TYPE 2

* Secondary cells are also called storage cell can be used again & again as recharging is possible.
* Secondary cells are of mainly 2 types
  - ↳ Lead Acid Cell
  - ↳ Alkaline Cell (Ni-Cd)

Other secondary batteries are
- Deepcycle battery :- battery meant for deep discharges
- SLI battery :- battery used for cranking of small engines & not meant for deep discharges

CLYDE

Q. Requirement & Use of Battery on ship?

SOLAS req : Reserve source of energy to supply radio installation must be provided on every vessel for purpose of conducting distress & safety radio communication in event of failure of vessels emergency source of power

Reserve source of energy must be capable of simultanously operating VHF radio installations & either MF/HF radio installations or the INMARSAT ships earth station

* The capacity of reserve source of energy should be sufficient to operate the particular installation with highest power consumption for appropriate period specified below: CLYDE

* Vessels with eme generator – 1 hr
* Vessels with no eme generator – 6 hrs

Primary Cells are used
1. EPIRB
2. SART
3. Torch
4. TV remotes
5. Temp. sensor gun

Secondary Cells are used
1. Bridge navigational instruments
2. Eme lighting
3. GMDSS
4. Radio communications

Oxidation → Loss of electron
Reduction → Gain of electron

PAGE NO. 71
DATE / /

LEAD ACID CELL :- CLYDE

* Anode & Cathode are 2 electrodes placed in an electrolyte.
* This will cause some chemical reaction to take place & produce a voltage.

Anode : Anode is that electrode where oxidation takes place

Discharge rxn when connected to load

$$Pb + SO_4^{-} \xrightarrow{\text{discharge}} PbSO_4 + 2e^{-}$$

(lead) (sulphate ions) (lead sulphate)

Cathode : Cathode is that electrode where reduction takes place.

$$PbO_2 + 4H^{+} + SO_4^{-} + 2e^{-} \xrightarrow[\text{discharge}]{} PbSO_4 + 2H_2O$$

(lead dioxide)

* Electrolyte used is aqueous solution of sulphuric acid (H_2SO_4)
  35% concentrated H_2SO_4
  65% water
* If load is not connected, the above rxn won't take place

Overall Rxn

$$Pb + PbO_2 + 4H^+ + 2SO_4^- \longrightarrow 2PbSO_4 + 2H_2O$$

* Voltage developed when cell rxn takes place is 2V @ 25°C

- If temp changes, voltage will change
- If concentration of electrolyte, voltage will change

CLYDE

* For a 12V battery, we need to take 6 cells & connect in series

* Once discharging happens, conc of H_2SO_4 decreases. So with help of hydrometer we test sp. gravity of electrolyte.

* We can also use voltmeter to check how much the battery has discharged.

ALKALINE CELL :-

* Electrolyte used is aqueous solution of potassium ~~hydroxide~~ hydroxide (KOH)

CLYDE

Anode :

Sponge Cadmium

$$Cd + 2OH^- \longrightarrow Cd(OH)_2 + 2e^-$$

(Cadmium) (Cadmium Hydroxide)

Cathode :

Nickel Hydrate

$$2NiO(OH) + 2H_2O + 2e^- \longrightarrow 2Ni(OH)_2 + 2OH^-$$

$$Cd + 2NiO(OH) + 2H_2O \longrightarrow 2Ni(OH)_2 + Cd(OH)$$

Overall Rxn

* Voltage developed when cell rxn takes place is 1.2V @ 25°C

* Here we cannot use hydrometer as concentration of KOH sol^n does not decrease

* For a 12v battery, we need to take 10 cells & connect in series

* We can only use voltmeter to check how much the battery has discharged : CLYDE

Q What is Ah of a battery?

Capacity of battery : It is the quantity of electricity that you can extract out of a battery from 1 cycle of fully charged to fully discharged

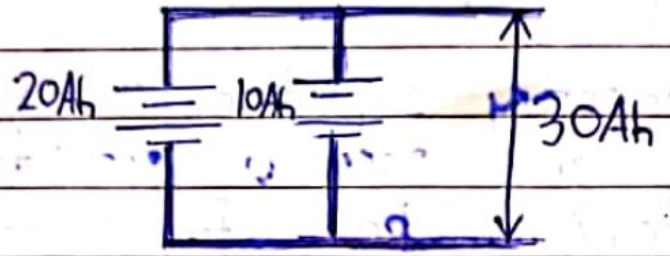
1 Ah battery means electricity of 1 Ampere current for 1 hr.

Difference bet^n 20 Ah & 200 Ah

20 Amps for 1 hr.
& 200 Amps for 1 hr
but it can also be used as 20 Amps for 10 hrs

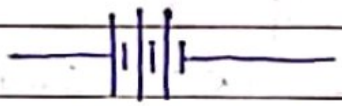
It mainly depends on load & how much current it draws

~~If cells ar~~
If you want to increase the ampere rating :
- put 2 batteries in parallel



CLYDE

If you want to increase the voltage rating :
- put 2 batteries in series



24 x 3batteries = 72 Volts

Sulphation :-

* The lead sulphate formed is amorphous in nature (powder)
* If we do not charge battery, this lead sulphate in powder form will become into crystalline form
* This will get coated on electrode & performance of battery will reduce.

* Sulphation can be 2 types
  ↳ Permanent / hard sulphation
  ↳ Temporary / soft sulphation

CLYDE

* Once battery has undergone permanent sulphation, it cannot be used again
* If temporary sulphation, overcharge the battery and pass a regulated current of 200mA & keep for some time.

Local Action :-

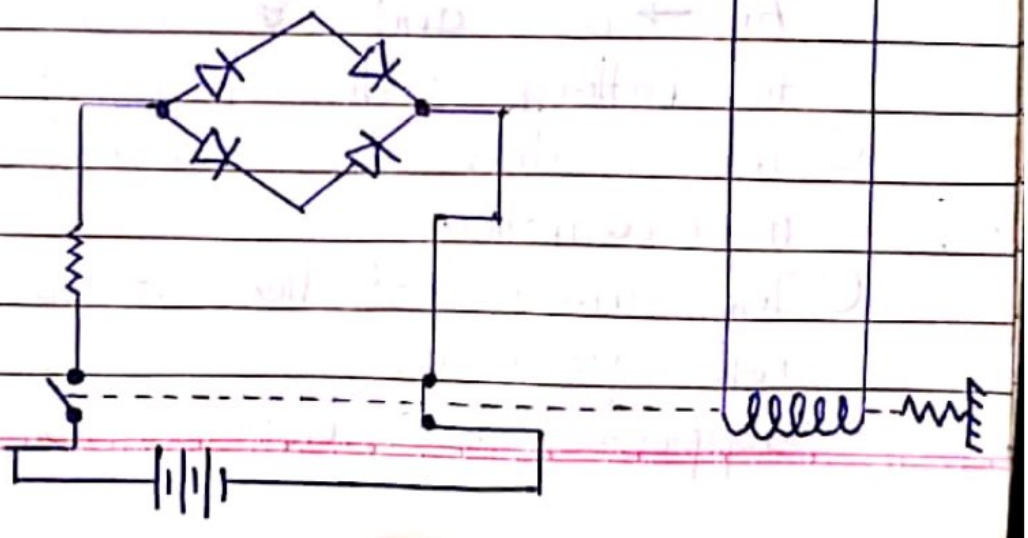
* It is a process where a battery discharges itself even when not connected to load over a period of time
* [illegible]
* If the electrode is not in pure form (ex - pure lead) and impurities are there on electrode then due to potential difference bet^n these 2 metals electrolytic action takes place & the battery will be self discharged.
* To compensate for this self discharge, we give trickle charge.

* If enough bubbles remain on surface of anode, they form a barrier that increases the internal resistance of battery.

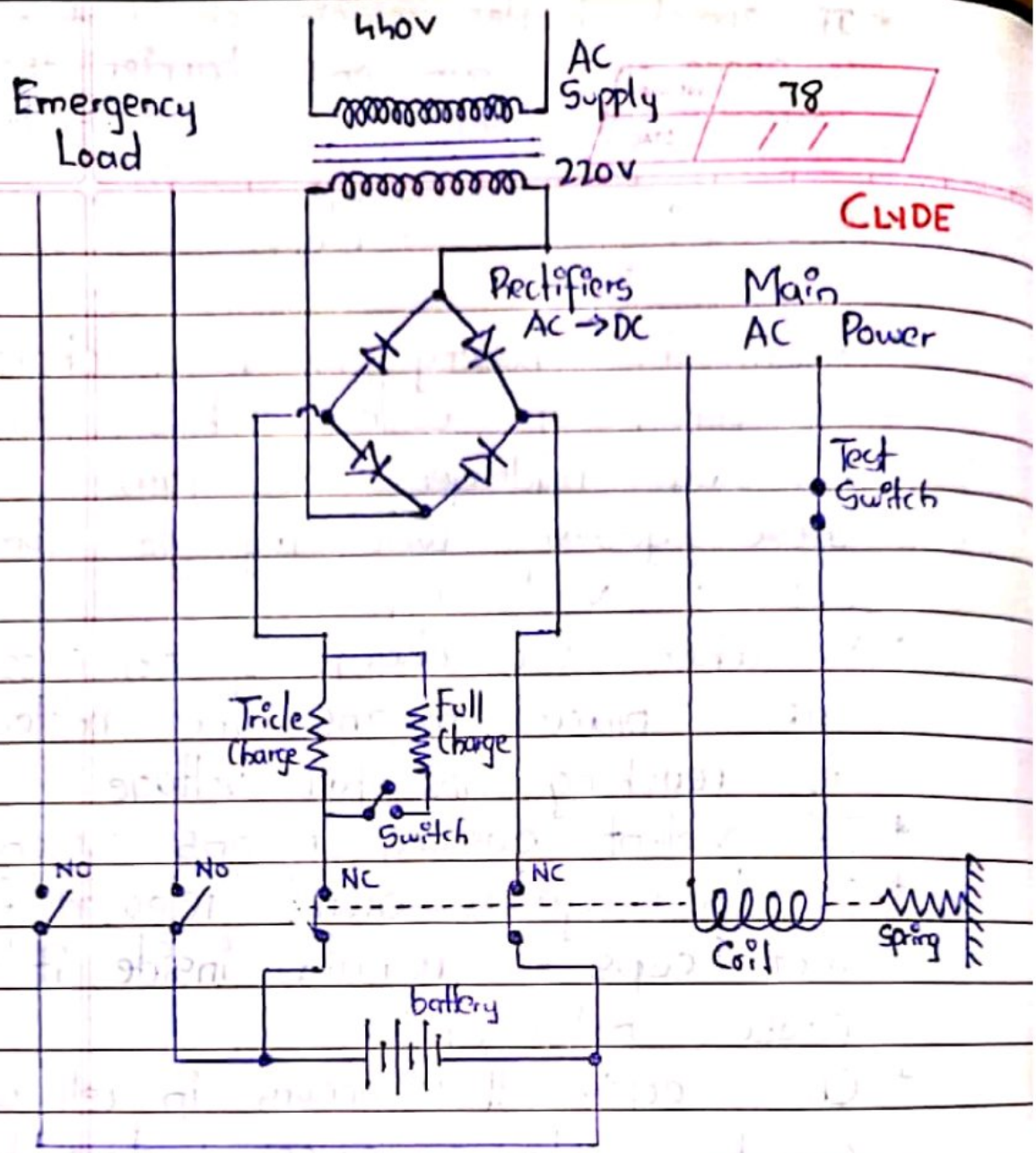
Gassing :-

- Hydrogen
- Oxygen

* When the battery is being charged electrolysis of water takes place releasing hydrogen & oxygen.
* These gases will try to come out of vent caps
* So when we charge & gassing takes place means the battery is reaching its full voltage
* If violent gassing means overcharging
* If these gases aren't released from vent caps & remain inside, it will cause polarization
* Chem action that occurs in cell while current is flowing causes hydrogen bubbles to form on surface of anode.
* This action is called polarization



CLYDE



① A 440V AC power is stepped down to 220V by a transformer

② Now the rectifiers convert the AC → DC and this is connected to battery with help of a circuit

③ The switch is controlled by a microcontroller.

④ The micro-controller measures the cell potential.
Suppose the battery is 12V,

& cell potential falls, the micro-controller will close the switch & battery will be charged faster

⑤ Once battery potential of 12V is achieved, the switch will open

TRICLE CHARGE :-

* It is the process of continously supplying a small current to battery so that local action does not take place & self discharge
* Tricle charge compensates for the self discharge
* Tricle charge will still be given even when battery is fully charged

⑥ Once main AC power is off, the coil will be de-energized. NC contacts will open & NO contacts will close

⑦ Now battery is disconnected from charging unit & connected to eme load

⑧ The test switch is to check if battery gets connected to eme load or not.

CLYDE

* State Of Charge :
* Depth Of Discharge :

Suppose a battery is 80% charged
So SOC will be 80%
DOD will be 100 - 80 = 20 %

* SLI batteries -
- Starting, lighting & ignition
- Used in lifeboat & automobiles

* Deepcycle batteries -
- used in radio installation
- meant for deep discharge
- Here these battries solid lead plates & thick.

* SLI battery cannot be used for deepcycle → battry will fail after v short while

Battery rating :

① CCA (Cold Cranking Amps) - It is a measurement of current a fully charged battery can deliver for 30 sec & maintains

a voltage of 7.2 Volts (12V battery) at temp of −18°C.
- Best used to start automobiles in cold countries

② MCA (Marine Cranking Amps) - It is a measurement of current a fully charged battery can deliver for 30sec & maintain a voltage of 7.2 Volts (12V battery) at temp of 0°C

③ RC (Reserve Capacity) - It refers to length of time in minutes that a battery at 25°C can deliver a current of 25 Amps until voltage drops to 10.5V

my self

Name: CLYDE

Class: 4 COC

School / College:

Email:

Index

Effect of temp on battery performance.

* If temp increases, the rate of rxn increases giving more current in less time. Also self discharge characteristic will increase.

* If temp decreases, the rate of rxn decreases Also self discharge characteristic will also decrease

CLYDE

* In extreme low temperatures, chances are electrolyte can freeze. Hence to avoid this, this is always recommended that batteries are kept at full charge.

Batteries can be

① Maintenance type batteries → Flooded type
② Maintenance free batteries → Sealed type

* Flooded type batteries have electrolyte in liquid state
* Sealed type batteries have electrolyte in gell state or AGM type (absorbant glass mat)

* AGM type batteries have a feature where the sulphuric acid is absorbed by fibre glass mat making battery spill proof
* While charging hydrogen & O_2 recombine to form water again & hence no loss of water.

* AGM has very low self discharge & can sustain even in freezing temperatures.

CLYDE

Ni:MH v/s NiCd

① Nickel metal hallide batteries have higher capacity, env friendly & no memory effect.

Memory Effect:
If NiCd battery has not been completely discharged before the next charge then battery charge won't be complete & will be set at lower energy potential.

② NiMH runs longer than NiCd
③ NiMH have no cadmium as cadmium is hazardous to env.

Battery Specification

① Purpose → Deepcycle battery
→ SLI battery
② Voltage rating
③ Amp Hour rating
④ Size & dimension of battery
⑤ Battery life cycle
⑥ Maintenance type or maintenance free.

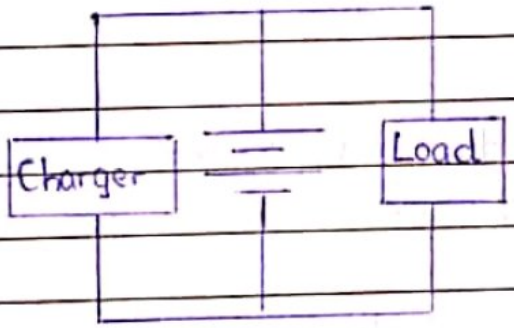
TRICLE CHARGE : It is the continous charging of battery after the battery has attained full charge.

* It is a small charging current to compensate for self discharge.

CLYDE

* Only when battery is fully charged, we go for trickle charge

FLOAT CHARGE : It is a type of intermittent charging where charging is not continous.



* Here battery, charger & load all are connected in parallel

* Battery supplies power to load. As battery voltage goes below a threshold value, the charger switches ON.

* When battery is fully charged & voltage increases, the charger switches OFF.

Battery Maintenance :

CLYDE

① The battery terminals must be kept clean & petroleum jelly to be applied to prevent corrosion. We cannot use grease as it will start melting at high temp and cause an insulation barrier.

② Battery vent should be checked & cleared so that the gases developed during charging escape

③ Battery connections should be tightened with correct torque.

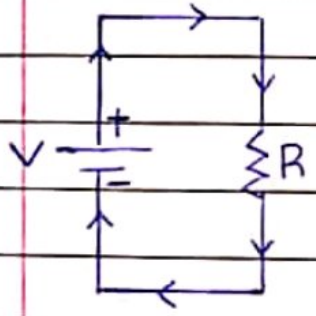
④ Top off the electrolyte in battery to correct level due to loss of water due to electrolysis. Electrolyte should cover the electrodes & be below the vent cap.

⑤ Check sp. gravity to check conc of electrolyte
Ni:Cd battery → Voltmeter test
Lead Acid battery → Hydrometer test & Voltmeter test.

Terminal Voltage of fully charged 12V battery is 12.7 or 12.8V

Power flow in AC & DC circuit

DC	AC
① It has uni-directional current	It has bi-directional current & the current alternates from 1 direction to another



CLYDE

ACTIVE POWER :-

* Whenever electric energy is converted in any other form of energy (useful work), the nature of current will always be inphase with voltage.

* That current is called Active Current & electric power responsible for this useful work is called Active Power.

REACTIVE POWER :-

* Whenever flux is produced by electric circuit, the inductive component is responsible. Because of this flux current will always lag the voltage by 90°

* This current does not do any useful work as it simply produces a flux.

* This current is called Reactive Current & electric power responsible for this is called Reactive Power.

* The unit of active power → Watts
* The unit of reactive power → VAR

* The total power (active & reactive) which produces a flux but also does useful work is called Total Power

CLYDE

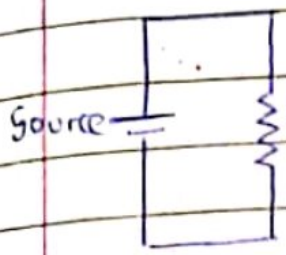
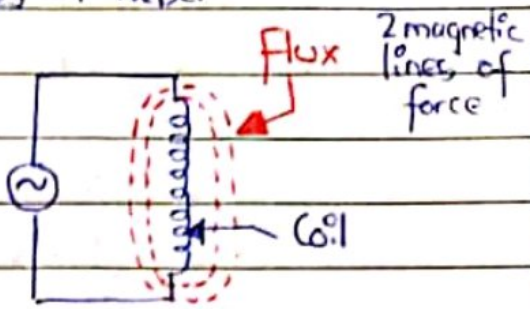
* Unit of total power → VA

* Generator produces VA
* Motor utilizes VAR & KW

Power Factor

* It is the cosine of the angle between active power & reactive power.

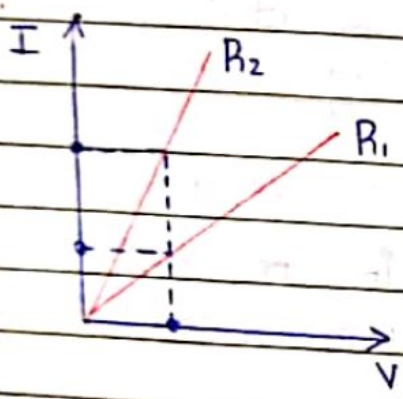
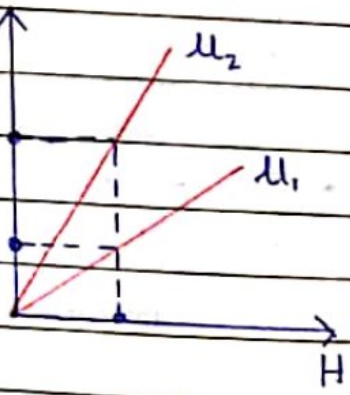
- Low PF causes loss of power.
- Increased fuel consumption

Electrical Circuit	Magnetic Circuit
	10^8 lines = 1 Weber
	
* It has a source & a load & a closed path for current to flow	It has a source & a coil & flux is generated in a closed loop around the coil
* To produce a current in electric circuit, we need emf	To produce a flux in magnetic circuit we need mmf
CLYDE	MMF = N x I No of turns, Current
Unit of emf = Volts	Unit of mmf = Ampere turns
* Resistance opposes current in electrical circuit.	Reluctance opposes flux in magnetic circuit.
Resistance = $\frac{V}{I}$	Reluctance = $\frac{\text{Ampere turns}}{Wb}$
Unit is Ω	

Flux density = $\frac{\phi}{A} = \frac{Wb}{m^2}$ = Tesla

Page No. 90

Permeability - Ability to allow flux to flow

* In electrical circuit, current is proportional to voltage	In magnetic circuit, Flux density (ϕ/A) is proportional to magnetising force (H)
$I \propto V$	$B \propto H$
$I = \frac{1}{R} \times V$	$B = \mu H$ (permeability)
More the resistance Less the current.	More permeability More the flux density
	
Here instead of flux we have flux density (B)	
Permeability is opposite of reluctance	
Iron has more permeability Plastic has more reluctance	
Here wattage will decide max current to flow through circuit	Here flux saturation will decide max current to flow through coil.

Page No. 91
Date / /

ELECTRICAL MACHINES

CLYDE

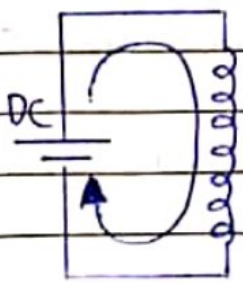
- Transformer.
- AC machine
  - Induction machine (Asynchronous) → Motor / Gen
  - Synchronous machine → Motor / Gen
- DC machine
  - DC motor
  - DC generator

CLYDE

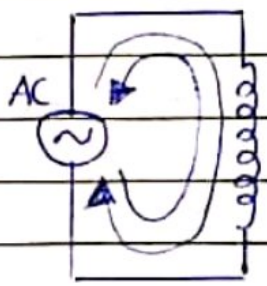
* Induction gen not found on ship
* Synchronous gen is used on ship which we also call alternator.

* But motor or generator both these machines cannot operate without magnetic field.
* This can be either produced by permanent magnet or electromagnet.

Electromagnet is the one where we use electric current to produce flux



DC excitation



AC excitation.

* Now in DC excitation, the current used to produce flux is constant
* ∴ flux is also constant & that is why this is Static Magnetic Field
* SMF means no change in flux wrt time

CLYDE

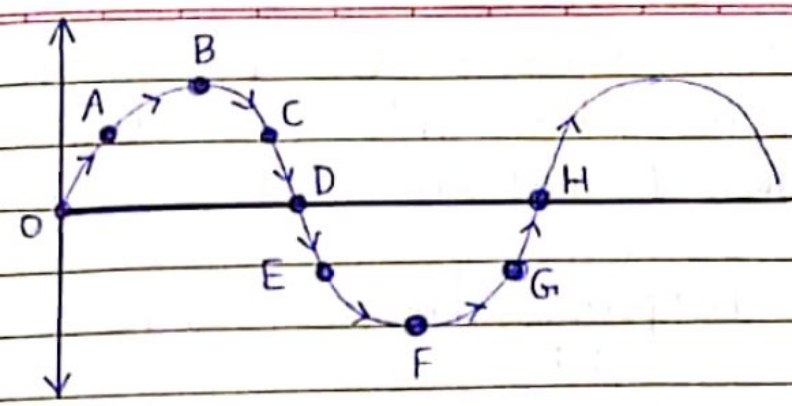
ex @ t = 2sec, flux is 2 lines
@ t = 8sec, flux is 2 lines

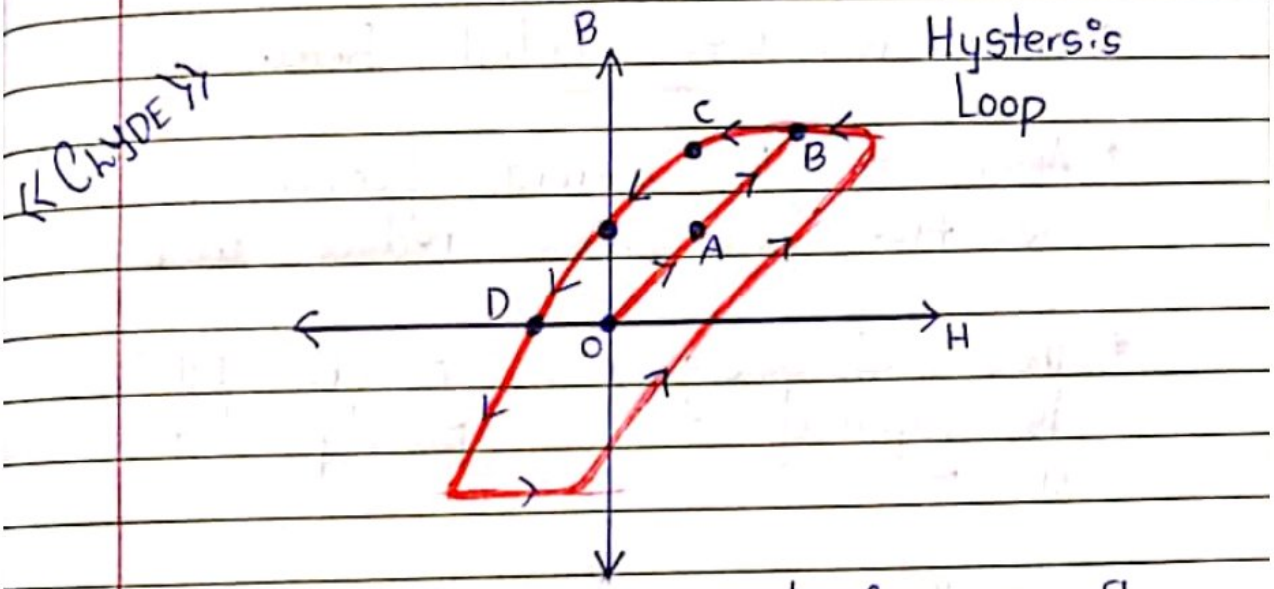
* Now in AC excitation, the current used to produce flux is alternating due to sinusoidal characteristic.
* So as current increases, flux also increased & vice versa & that is why this is Varying Magnetic Field

HYSTERSIS LOSS

* Happens in all machines AC or DC or transformer.
* It is one of the core losses

Page No. 93
Date / /





* From O to A, as current increases, flux also increases. As current increases to pt B, flux will further increase

* After B, current starts decreasing, so flux also decreases and does not follow same path to decrease.

* Further where current decreases, flux also decreases but doesn't become O. Still flux has some value. This is called residual magnetism or residual flux density.

Alternator producing low voltage
- REASON - ∴ Low remanence
- SOLUTION - ∴ Field flashing

Page No. 94
Date

* If MMF becomes 0 but still there is some flux, this is called Residual Magnetism

→ Means lag

* This happens due to hysteresis bet^n flux & MMF

* This is also called Remanence

* After pt D, current further reduces. So flux will also reduce & become 0.

* This tells us how much MMF is required to completely demagnetize a material

* So this constant magnetization & demagnetization causes the dipoles to align, re-align and misalign. This increases KE & heats up the material

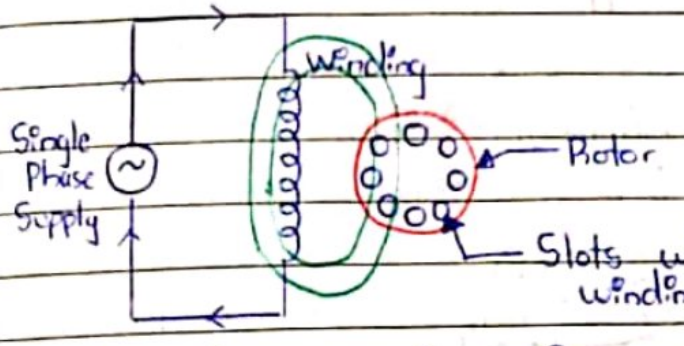
* ∴ this hysteresis loss appears as heating loss due to continous magnetization & demagnetization due to varying magnetic field.

* The hysteresis loss can be reduced by selecting a proper material where hysteresis loop area is smaller.

Page No. 95
Date

Single Phase IM

CLYDE



* Now in this current, as current flows, flux is produced

* Flux is varying in nature due to AC
* EMF will be in rotor, it experiences a force & torque is produced.

But, rotor won't be able to START

Why ?

$\phi \propto NI$

* As I alternates, flux also alternates

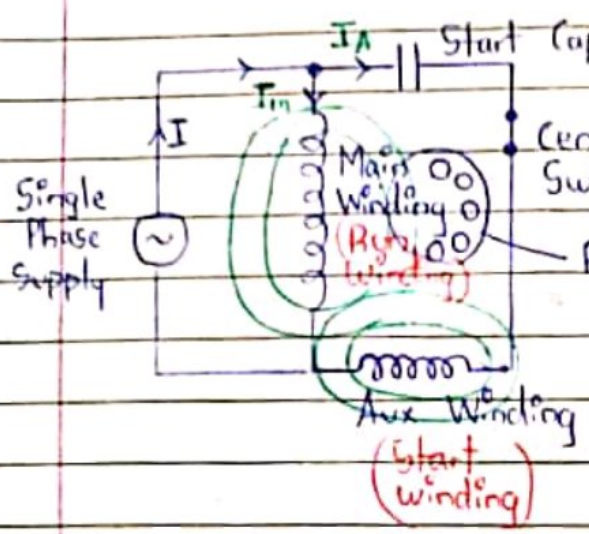
* Due to this, torque will be clockwise as well as anti-clockwise due to alternating flux

* This causes the net torque to be 0 & rotor won't rotate

* So we go for split face IM

we need 2 fluxes to produce phase shift 90°
Because only 1 flux will produce alternating current & torque will be 0

(i) Capacitor Start motors



* Centrifugal Switch opens & disconnects the aux windings when motor has reached rated speed

* Due to single phase supply current (I_m) will flow in main winding & (I_A) will flow in aux winding.

* Thus 2 fluxes will be produced

* This causes rotor to rotate in 1 direction due to torque

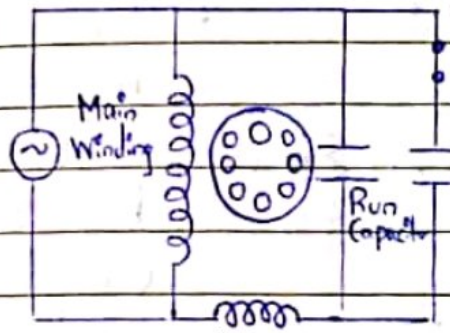
* Once rotor has attained its rated rpm, the centrifugal switch opens

* This happens because the aux winding flux leads the main winding flux. So at any pt of time there a 2 fluxes. The resulting flux makes rotor rotate in 1 direction

Hence we use main & aux winding 2 produce 2 phases These 2 phase produces a resultant BMF

Page No. 97
Date

(ii) Capacitor Start, Capacitor Run motors



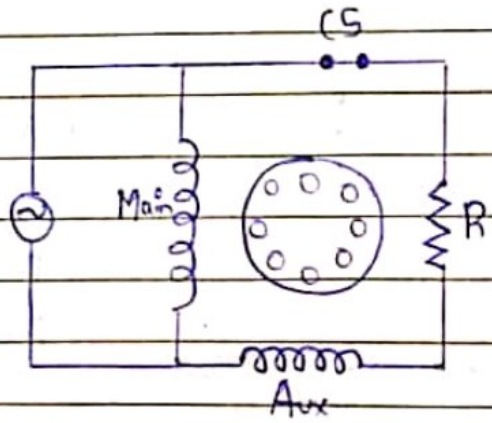
* Here 2 capacitors are placed in parallel

* Run capacitor is less value to start capacitor value.

* Once motor started we can disconnect bigger capacitor by opening centrifugal switch.

* These motors have higher value of running torque

(iii) Resistive Start motors



* Here due to resistor, main winding will be inductive circuit & aux winding resistive circuit

* Again there is a phase shift, causing a resulting flux.

* This will rotate motor in 1 direction

(iv) Shaded Pole motors

* Used in tape recorders
* These motors cannot take any load

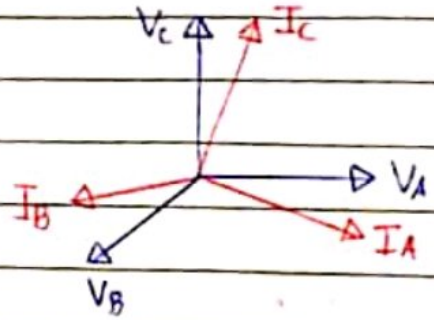
* Basically in a single phase IM, you need atleast 2 flux to produce RMF to rotate the rotor

3ϕ IM = FW, SW, JCW, LO
3ϕ SM = BT, Main ele propulsion motor
Synchronous condenser
for shaft generator

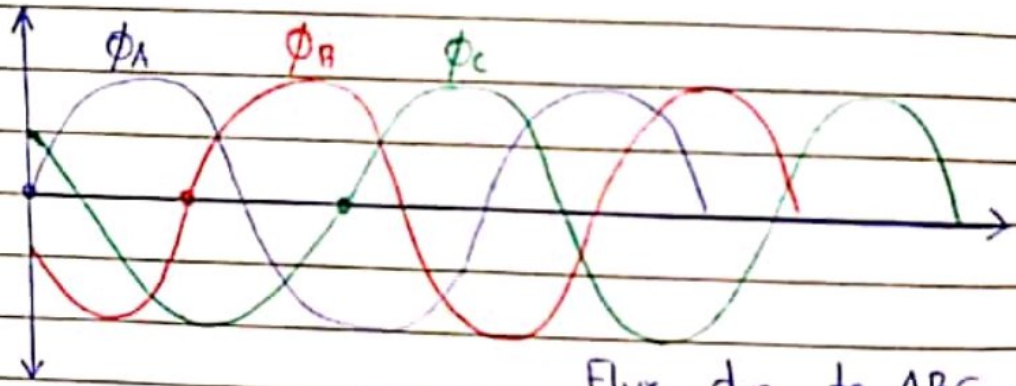
Page No. 100
Date

3 Phase IM

* The 3 voltages & current will be 120° apart



* So flux due to A B & C will also be 120° apart



Flux due to ABC

* The resultant flux produces a BMF with constant magnitude.

We can say $N_S = \frac{120f}{P}$ (rpm)

where N_S = Speed of BMF
f = frequency
P = no. of poles

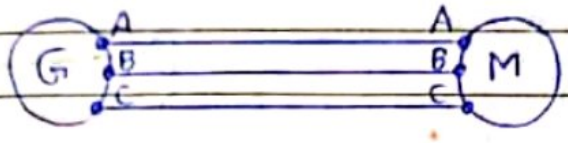
* The resultant flux produces a BMF in clockwise direction causing rotor to also move in clockwise direction.

1ϕ IM = Exh fan, galley
1ϕ SM = Viscotherm, Gyrocompass, Radar motor

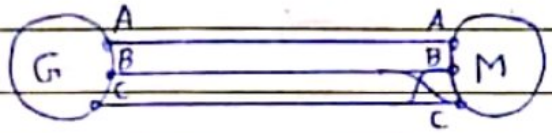
Can We Change Direction Of Rotation?

- Yes

* By interchanging any 2 phases, we can change direction of BMF

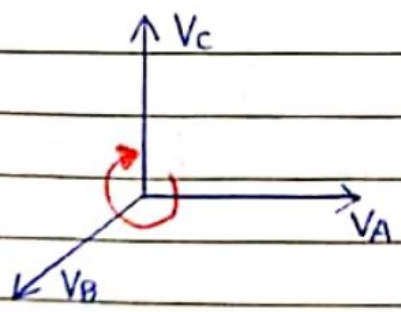


Phase sequence - ABC

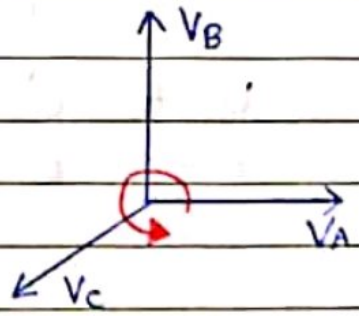


Phase sequence - ACB

* This will change direction of BMF if phase sequence is changed.



+ve phase sequence



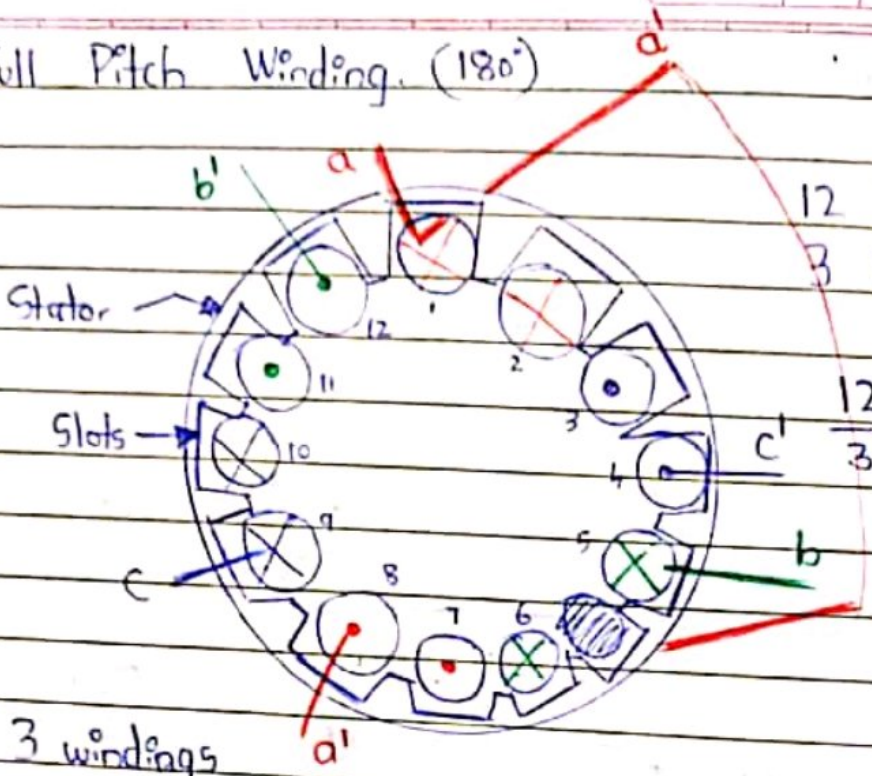
-ve phase Sequence

Phase Sequence :- The sequence or order in which the phase voltage reaches peak value

- ER Crane = 3Ø IM with VFD
- Turning Gear motor = Double cage IM.

Page No. 102
Date

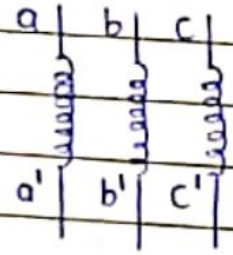
Full Pitch Winding. (180°)



12 Slots
3 Phases

$\frac{12}{3} = 4$ slots / phase winding

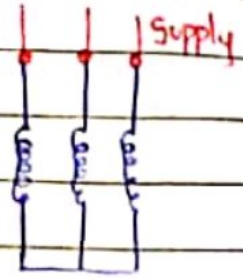
3 windings



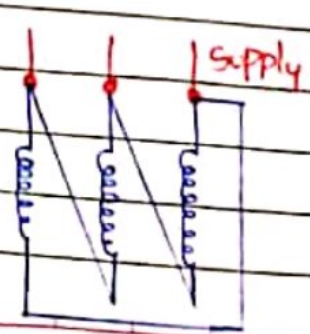
When these winding & put in slots, they should be 120° apart

a to a' → 4 slots
b to b' → 4 slots
c to c' → 4 slots
} 120° apart

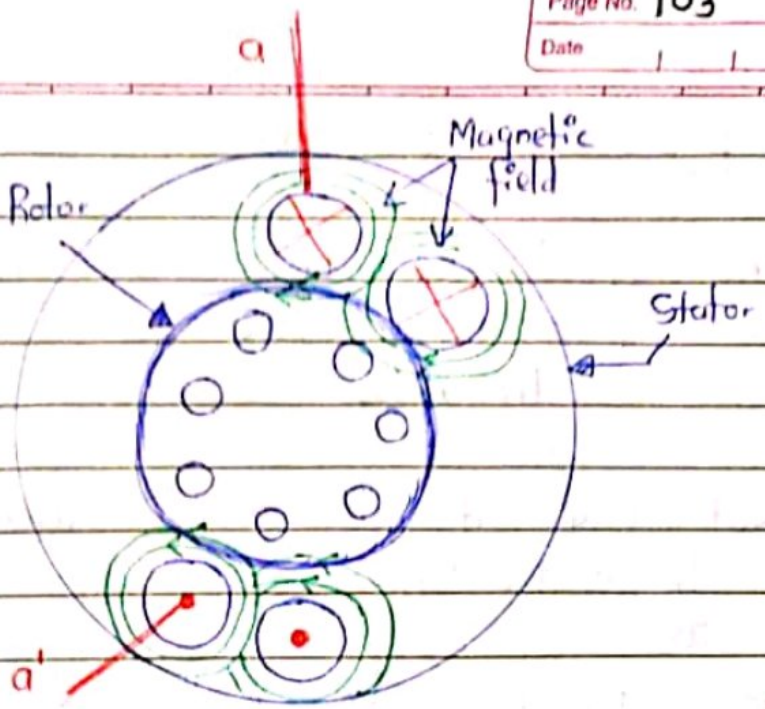
Motor can be connected in either
↳ Star
↳ Delta



STAR



DELTA



* Due to the magnetic field, stator produces an illusion that magnetic force (N-S) are ⊥ to winding axis

* The remaining windings will also produce a N-S ⊥ to their winding axis

* Now during the remaining -ve half of cycle N changes to S & vice-verca

* This entire setup will produce a rotating magnetic field

Slip

CLYDE

* The speed of rotor is not equal to synchronous speed

$$N_r \neq N_s$$

* Just say if $N_r = N_s$ then

$$\frac{d\phi}{dt} \propto (N_s - N_r)$$

* That means $\frac{d\phi}{dt}$ will be 0

no rate of change in flux

* Hence induced emf in rotor also becomes 0. leading to no torque

* Now how can rotor rotate at N_r or N_s when torque is 0

∴ N_r can never be equal to N_s

* N_r will always be less than N_s & how less that will depend on slip

$$\text{Slip} = \frac{N_s - N_r}{N_s} \times 100\%$$

* The load on motor decides the value of slip

Suppose $N_s = 1000$ rpm — CLYDE
Slip = 1%

$$\text{Slip} = \frac{N_s - N_r}{N_s}$$

$$0.01 = \frac{1000 - N_r}{1000}$$

$$N_r = 990 \text{ rpm}$$

Slip = 4%	→ $N_r = 960$ rpm	$f_r = 2Hz$
Slip = 50%	→ $N_r = 500$ rpm	$f_r = 25Hz$
Slip = 80%	→ $N_r = 200$ rpm	$f_r = 40Hz$
Slip = 100%	→ $N_r = 0$ rpm	$f_r = 5Hz$

Usually No Load Slip = 1%
Full Load Slip = 4%

Value of slip for stationary motor = 100%

Also slip cannot be 0

$$f_r = \text{Slip} \times f_s$$

f_r: Induced freq; f_s: Supply freq

If $f_s = 50Hz$

Losses in IM
→ Core loss
→ Copper loss
→ Friction loss

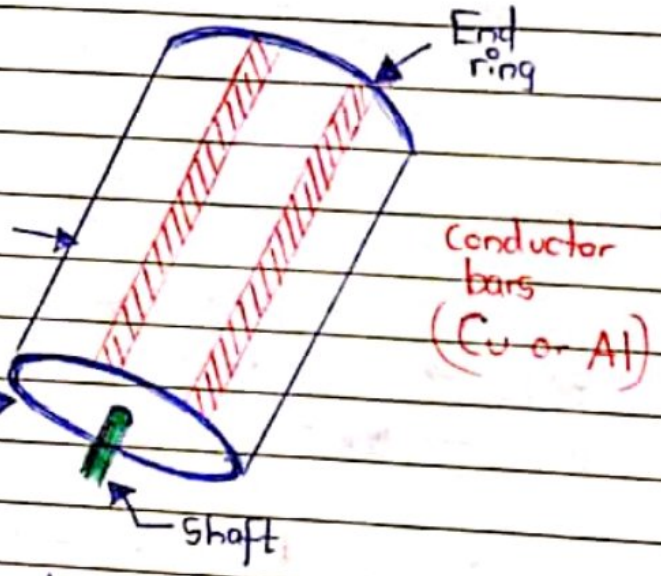
Types Of IM

- Based on construction
  - ↳ Squirrel cage IM
  - ↳ Wound round rotor
  - ↳ Double cage

} Stator Construction Same.

CLYDE

① Squirrel Cage IM

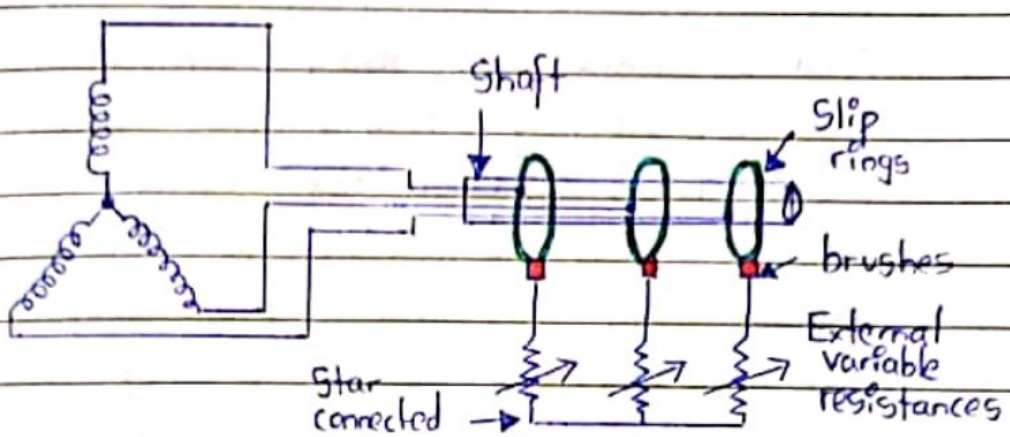


* Here conductor bars are shorted to end ring
* Conductor bas are skewed wrt shaft.
* Cogging & Crawling are 2 phenomenon occurs in squirrel cage IM

Page No. 107
Date

② Wound round rotor

CLYDE



* Rotor has 3ϕ winding connected in star connected to shaft via slip rings & brushes
* Brushes only provide a sliding contact when shaft rotates
* External variable resistances are connected in star to brushes
* By external variable resistance we can vary the rotor resistance
* External variable resistance are added to increase starting torque by varying rotor resistance.

∴ Crawling :-

- Takes place in only squirrel cage IM where starting torque is low
- In this phenomenon, motor runs at v 'low' speed (1/7th of synchronous speed) despite of giving full rated voltage.
- This happens due to space harmonics.

- Space harmonics are produced by non-sinusoidal fluxes
- If the fluxes produced bet^n stator & rotor are non-sinusoial, we say space harmonics are introduced
- This can happen due to
  - ↳ magnetic saturation
  - ↳ inequalities in airgap length
  - ↳ non uniform slots

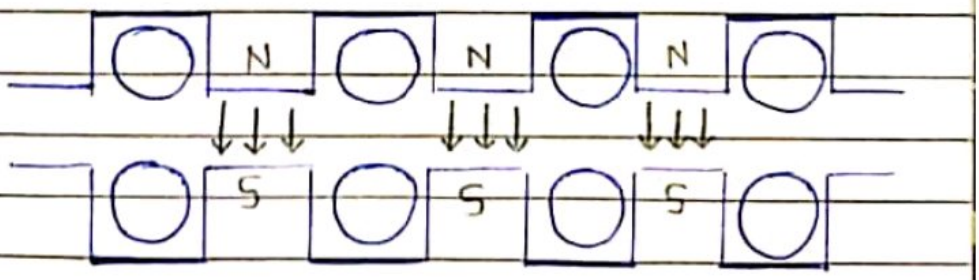
- Non-sinusoidal flux induces voltage & current in rotor leading to harmonics causing vibration & noise

Cogging :-

CLYDE

- It is a phenomenon where a squirrel cage IM fails to start even when full rated voltage is applied to stator winding
- It happens when the stators slots are integral multiples of rotor slots
- Cogging can be reduced by using skewed rotor.
- We can also recover the motor from cogging by reducing the load torque during starting.
- Cogging happens only in squirrel cage IM as it has low value of starting torque & no way to increase it.
- Whereas in wound round rotor, we can vary resistance such that starting torque.

* If no of slots in rotor is 4



* & no of slots in stator are also 4
* If supply is given to stator, a RMF

will be created inducing emf in rotor.

* The air gap bet^n the stator & rotor bet^n slots will create mag field
* These forces are called alignment torque
* This will try to block the rotor motion
* So alignment torque will be v high if rotor & stator are integral multiples
* Alignment torque & motor torque will be greater than starting torque not allowing motor to start.

CLYDE

Page No. 111
Date

ICCP - Impressed Current Cathodic Protection

* Ships hull undergoes corrosion as it is immersed in an electrolyte like seawater

* Due to this, one electrode will become cathode (ship) & other electrode will become anode

CLYDE

Causes of corrosion

↳ Dissimilar metals in ships hull
↳ Presence of dissolved O_2 in SW
↳ Metallic ion concentration
↳ Cavitation.

Presence of dissolved O_2

* When 2 plates overlap, the more stagnant water under plates is depleted of O_2 in such a way that the shielded area becomes anodic & subjects to corrosion.

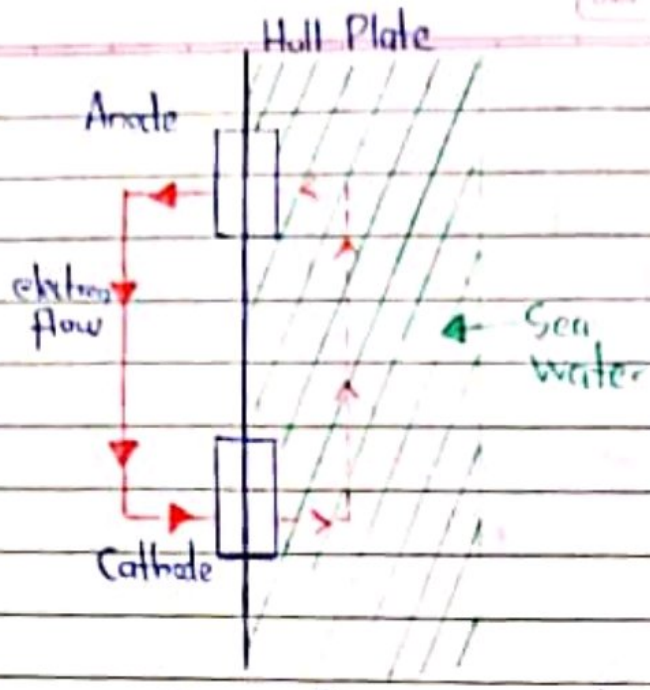
Anode : Oxidation - loss of é

$$\underset{\text{Iron}}{Fe} \rightarrow \underset{\text{Metal ions}}{Fe^{++}} + 2e^-$$

Cathode : Reduction - gain of é

$$2H_2O + 2e^- \rightarrow \underset{\text{Hydrogen gas}}{H_2} + \underset{\text{Hydroxyl ions}}{2OH^-}$$

Hydrolysis of water



CLYDE

* electrons flow from anode to cathode
* at anode, Fe metal ions are released
* at cathode, H_2 gas & OH^- ions are released
* These OH^- ions again go to anode & produce

$$2OH^- \rightarrow H_2O + \frac{1}{2} O_2 + 2e^-$$

* Due to more O_2 more Fe metal ions are produced
* Also $2Fe^{++} + 2OH^- \rightarrow Fe(OH)_2$

$$Fe(OH)_2 \xrightarrow{O_2} Fe_2(OH)_3$$
(rust)

* This will rust the anode of ship

Page No. 113
Date

* To protect this, we use another anode more anodic than the one already existing

* This anode is called sacrificial anode.

Metal Ions Conc

* Exposing 1 part metal hull to high velo flow of SW causes the metal ions of electrolyte to be washed away from this area.

CLYDE

* This becomes even more anodic

Cavitation

* When fluid is under extreme agitation, it causes periodic formation & collapse of bubbles on moving surfaces like propeller

* This causes crystallization & fatigue of metal surfaces & produces areas that are more anodic to less turbulence areas

* In ICCP system, we apply external DC source.

CLYDE

If AC source, sometimes current will flow into cathode, sometimes into anode

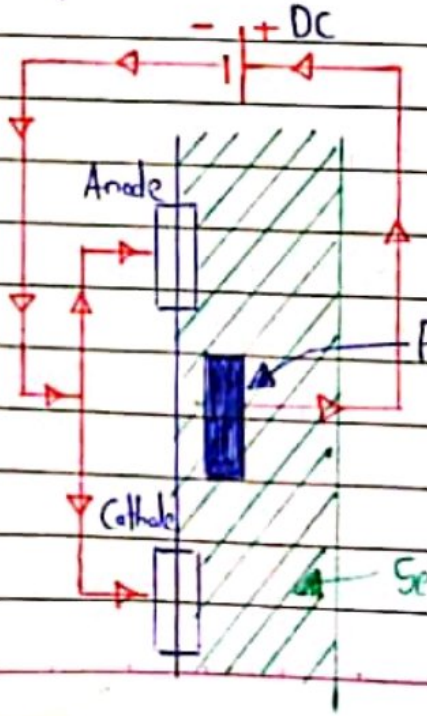
We want cathode & anode to be fixed

Ship — Sac Anode

* We step down ships AC power, & converting into DC

* 1 side of DC is connected to ships hull & other side of DC is connected to platanized anode

* This platinized anode is electrically insulated from hull



* Now after supplying DC, é was being lost by anode but also é from DC will be supplied

* DC supply makes cathode & anode at same potential so no é will be lost

* Pt anode is a noble metal slowing down corrosion rate.

CLYDE

System Operation

① Reference electrode → Zinc or Ag/AgCl

② We measure the reference electrode via voltmeter wrt hull

③ This will show some potential which we compare with set value

④ The difference value is fed to amplifier

⑤ This amplifier controls DC output coming out of transformer - rectifier assembly

⑥ This is the supplied to platanized anodes

* We should supply 220mV to hull for satisfactory protection.

CLYDE

* The value of protection current must be critically controlled to just prevent corrosion.

* Beyond that value, the increase in rate of release of hydroxyl ions will cause sponginess & flaking of anti-fouling paint.

* Reference electrodes can determine correct value of protection current.

* The amt of current req by system depends on area beneath waterline, temp of sw & speed of vessel

Q Why ICCP system turned off at ports?

Stray current arising from ICCP sys circulates in structures made of metal (@ ports) which may initiate corrosion or accelerate process

At ports, ICCP will try to protect jetty & thereby increase current in system leading to overload

Checks on ICCP system

① Record the output current & voltages of reference electrode

② Check & clean propeller shafts slip rings & brushes → This is because shaft is earthed.

③ Inspect rudder stock earth strap

MGPS - Marine Growth Preventive System

* Sea water contains both macro & micro organisms like worms, molluscs, barnacles, algae, hard shells etc

* These stick to surface of ship & flourish over there causing

- Impairing of heat transfer sys
- Overheating of water-cooled machinery
- Increased rate of corrosion
- Reduced eff causing loss of vessel speed

* MGPS sys located in sea chest or strainer on both sides

Here control panel provides supply to 2 anodes

1 is Cu Anode
Other is Al or Ferrous alloy Anode } DC Current

CLYDE

Page No. 119
Date

* DC current is passed through Cu anodes which produce ions that are carried with sw in whole pipe sys

* These Cu ions prevent marine organisms from settling down & multiplying on surface.

* The second anode prevents corrosion of metal surface. The iron anodes help in preventing layers of oxide film of metals from breaking down by corrosive agents (Sulphur) of sw.

* This sys also gives protection to v/vs, condensers, engine cooling sys

* Control panel measures & monitors the output of each anodes

* Al anode when current supplied produces Al hydroxide. This reduces corrosion on ferrous components in sw sys It forms a Cu-Al film which acts as anti-corrosive layer

∴ Max current for MGPS sys is 2 Amps ~ 10 Amps

At normal sea condition
Cu = 0.9 Amps
Al = 1.1 Amps

CLYDE

Shaft Earthing

CLYDE

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

* Now as propeller rotates, static charges are developed which creates potential difference bet^n shaft & hull

* If PD is developed & shaft is not earthed, spark erosion will be caused.

* This can result in pitting of bearing

① To avoid electrolytic corrosing of shaft, slip ring is clamped to shaft & earthed to hull via brushes

② This shaft earthing consists of graphite brushes where 1 end is connected to hull & other end to voltmeter

③ When ship earthing is OK, it will show below 50mV

④ Clean the slip ring & brushes on regular basis

* We also connect the rudder stock via bonding cable to hull to equalize PD betn rudder & hull

CLYDE

Routine Checks

① Record the o/p current & all voltages on daily basis → ICCP
② Check ref electrode voltage on daily basis
③ Check & clean the slip rings & brushes of propeller shaft every week
④ Inspect the rudder stock earth strap every month

CLYDE

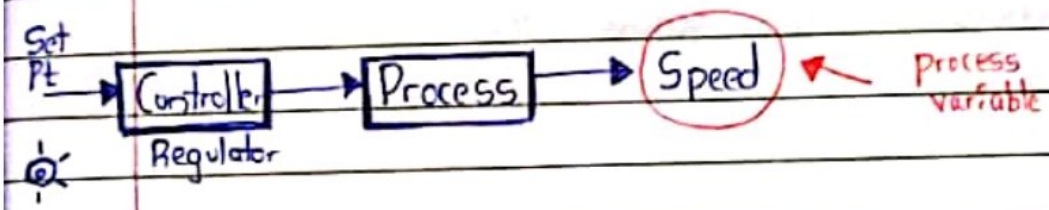
Input → Process → Predefined output

Ex- fan as process

Process → Speed, Torque, Direction } Process variable

(Because they are process o/p and they vary)

lets take 1 process variable & see how to control it



* So here regulator controls to current & voltage to vary the speed

* Set pt can be defined as desired value of process variable

Ex- if we set speed 1, we want out process variable to become 1

* This is open control loop.

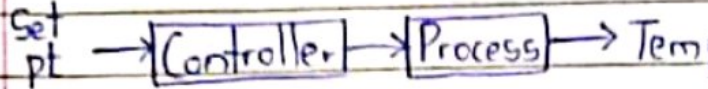
* Here we do not aim for process variable to become equal to set pt.

* Change in SP will produce desirable change in PV

Closed control loop.

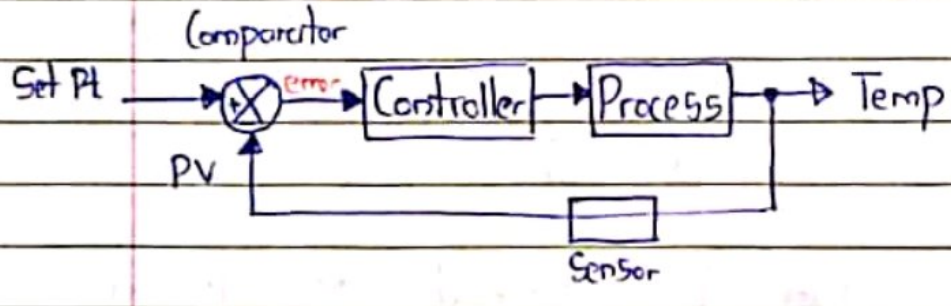
Lets take ex of Air Condition.

CLYDE



* Here process variable is temp.
* lets see how to regulate this process variable at desired setpt

We can so that when we have a sensor which senses temp & sends this value to comparator.



* So comparator continously compares set pt to feed back of process variable.

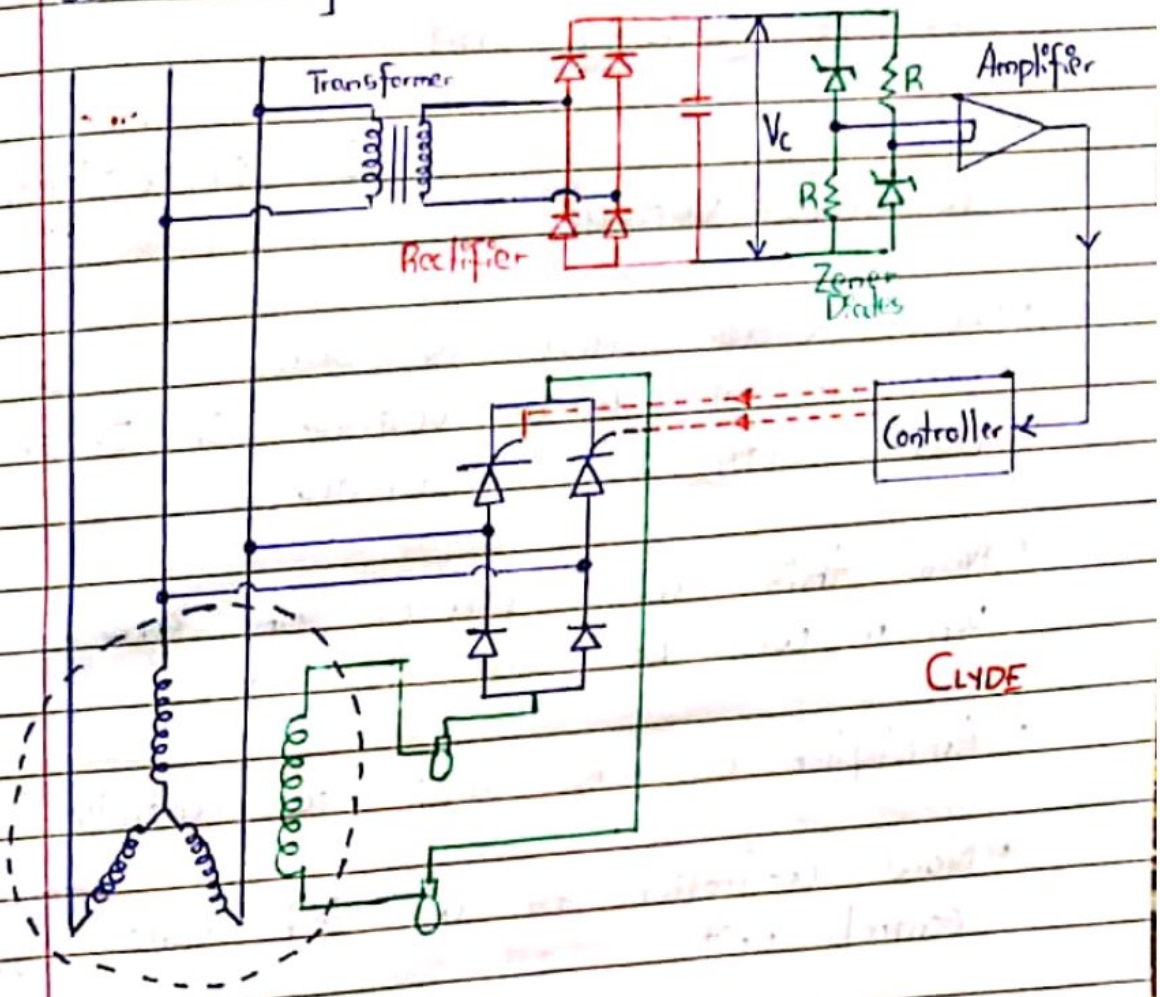
* The error bet^n both are sent to controller.

* Sometimes bet^n controller & process, there is a actuator

AVR

Page No. 125
Date

So basically AVR is a closed control loop.



CLYDE

* In AVR, our set pt is rated voltage & process variable is line voltage
* Now in order to control line voltage, we need to sense this voltage
* Hence we need a voltage sensing circuit
* It is easier to sense DC, ∴ we step down the AC and the convert it to DC

* Transformer & rectifier is a voltage sensing unit
* This will produce a DC proportional to line voltage
* Zener diode value is same as DC produced at rated voltage & zener diode acts as comparator
* Now this will produce an error which will be sent to amplifier
* Amplifier o/p is sent to controller
* Now controller is a SCR gate trigger control unit
* Controller o/p will go to actuator
* The actuator has a SCR & diode which acts as control rectifier
* The controller sends gate signals as input to SCR

Finally a DC excitation is given to winding producing a line voltage

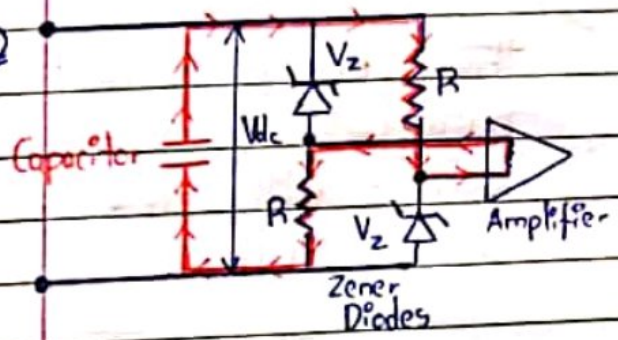
CLYDE

Page No. 127
Date

* So if line voltage drops, we have to increase excitation such that it goes back to rated voltage.

* To increase excitation, we have to decrease firing angle of SCR

Case ①

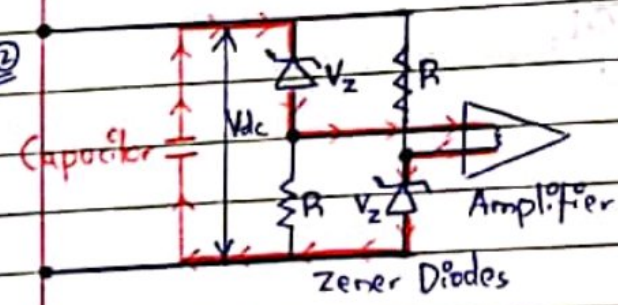


Here V_z acts as setpt.

CLYDE

* Now if $V_{line} < V_{rated}$ · then $V_{dc} < V_z$
∴ current won't flow through zener diode
This will produce a negative error, $e<0$

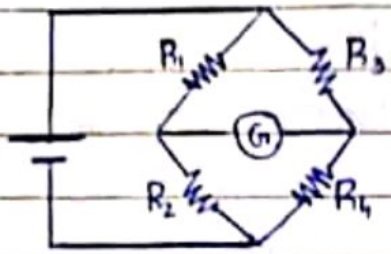
Case ②



* Now if $V_{line} > V_{rated}$ then $V_{dc} > V_z$
∴ current will now flow through zener diode
This will produce a positive error $e>0$

* If $V_{line} = V_{rated}$, error will be 0 as zener diodes are about to conduct but dsn't conduct

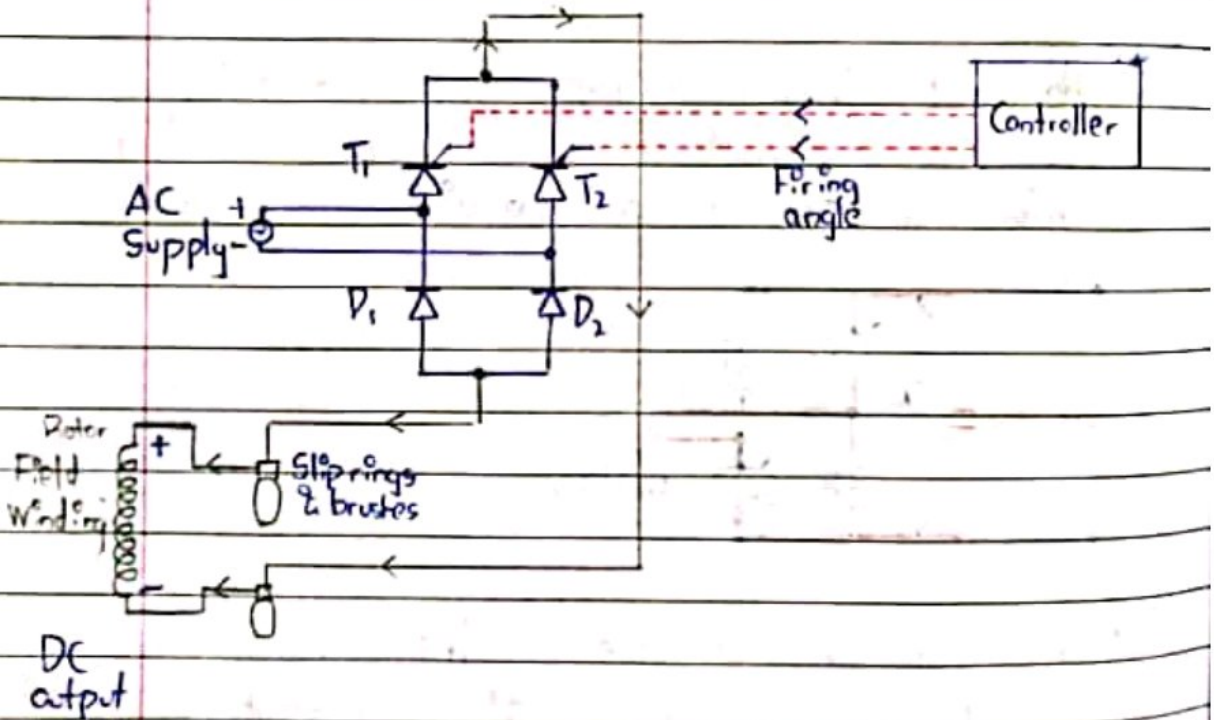
Wheatstone Bridge Concept



If $\frac{R_1}{R_3} = \frac{R_2}{R_4}$

the bridge is balance & current through galvanometer = 0

If $\frac{R_1}{R_3} \neq \frac{R_2}{R_4}$ the bridge is not balanced & some current will flow through galvanometer.



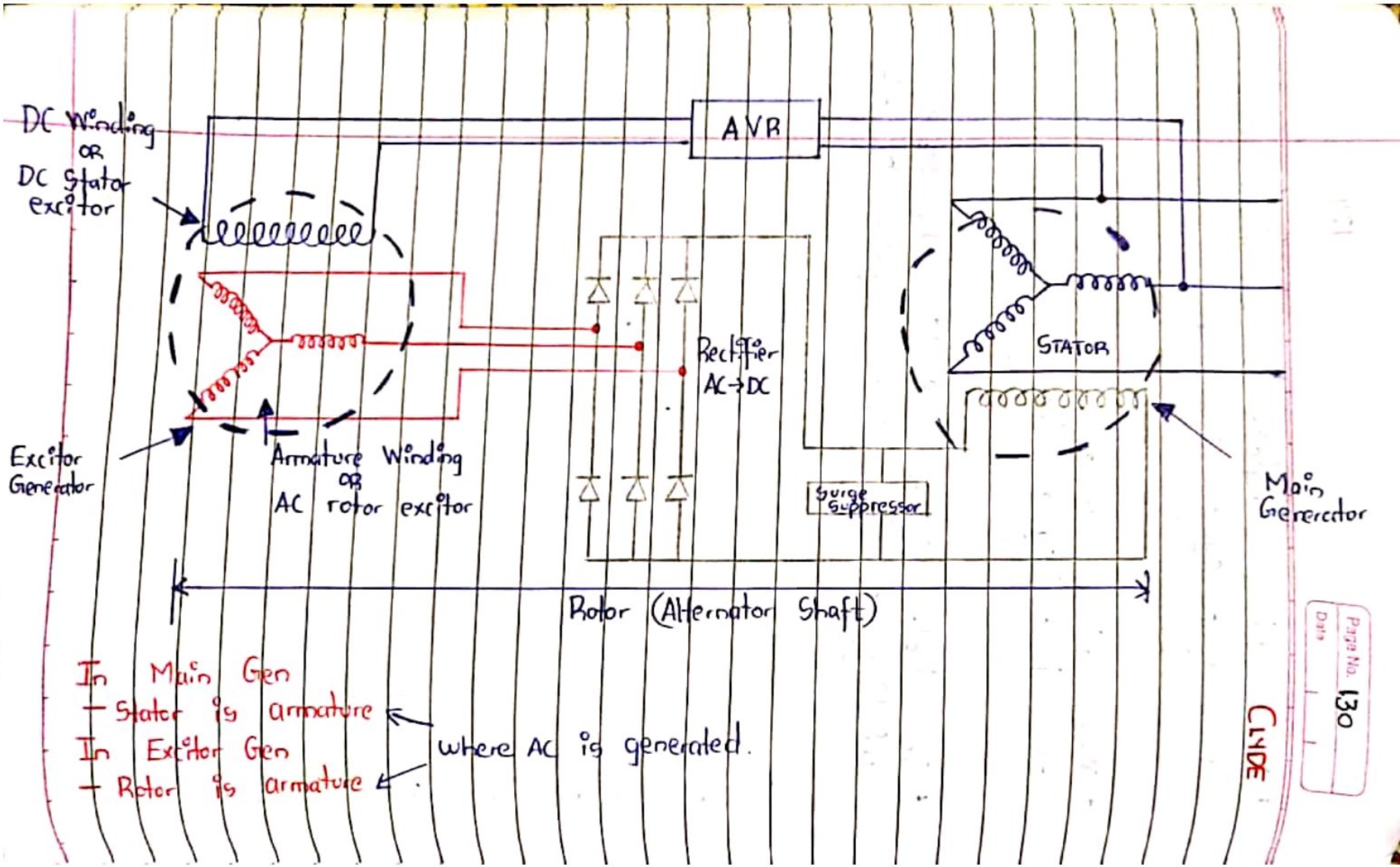
* If we increase firing angle, voltage will redce at DC output
* If we increase firing angle, voltage will increase at DC output

* When firing angle α is given in +ve half cycle then
T_1 & D_2 will conduct

* When firing angle α is given in -ve half cycle then
T_2 & D_1 will conduct

* In both cases direction to field winding remains same giving DC o/p.

CLYDE



Brushless Alternator

Page No. 131
Date

① In brushless alternator, since we do not have slip rings & brushes we need to produce DC on rotor itself

② Now here AVR job is ~~the~~ to sense load & produce as DC excitation.

③ Residual magnetism is at DC stator excitor winding

④ Now when rotor rotates, it will produce a AC in conductor.

⑤ Either you rotate conductor or you rotate mag field, in any case there should be relative motion to produce AC - acc to faradays law

⑥ Same thing happens in main generator

⑦ Rectifier converts AC → DC
They are called power diodes having high power rating.

⑧ They are rotating along with rotor & hence we call rotating diodes

CLYDE

Operation : CLYDE

* There is residual magnetism to DC stator excitor
* So now when rotor rotates, AC will be induced in armature winding
* This AC is converted to DC by rectifiers
* This DC will produce the voltage acc to rated voltage. (AC)

Case ① Suppose $V_{line} < V_{rated}$

* AVR will increase more DC output voltage.
* Hence AC put induced in armature winding will increase
* Rectifier converts into DC which will also be increased
* This will increase the line voltage in 3 phase winding
* ∴ line voltage will go back to rated voltage.

Case (2) Suppose $V_{line} > V_{rated}$ CLYDE

* AVR will decrease the DC output voltage.
* Hence AC induced in armature winding will decrease
* Rectifier converts into DC which will also be decreased
* This will decrease the line voltage in 3 phase winding
* ∴ line voltage will go back to rated voltage.

Purpose of surge suppressor (voltage dependent resistor)

* If there is a sudden load change, there will be a sudden current
* This can cause a v high surge voltage to be generated
* This voltage will pass through diode & damage the diodes
* Surge suppressor resistance $\propto \frac{1}{V}$
* So if voltage increases, Surge suppressor resistance drops & current will definately follow a low resistive path

* It reduces it resistance, so that the current can get an alternative path

Residual Magnetism

CLIDE

* Residual magnetism is there in DC stator exciter due to property of retentivity
* When a ferromagnetic material acquires magnetic properties when contact with permanent magnet or & electromagnet.
* These magnetic properties does not disapper when permanent magnet or electromagnet is removed for some period of time.
* If DC winding has lost its residual magnetism, we do field flashing
* Field Flashing is a process to restore to restore residual magnetism by passing a 12V DC supply to winding for 5sec
* If generator is ideal for long time, no DC flowing & hence residual magnetism is lost.
* Heat, Shock, vibrations are the other means

How to test if residual magnetism is there or not?

* When we start an alternator, a residual voltage builds up at terminals.

* This residual voltage must be greater than 5V AC

CLYDE

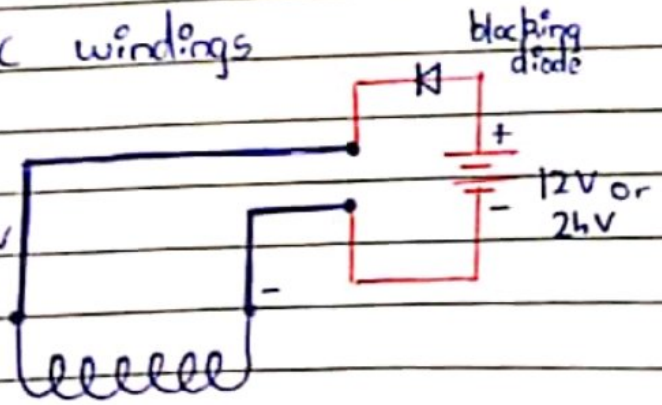
* If less than 5V AC, alternator won't be able to produce rated voltage

* This indicates loss of residual mag.

* Field flashing is done to restore residual mag.

① Disconnect DC windings from AVR

② Connect 12 or 24V battery



* Field flashing to be done for only 5 seconds.

Page No. 136
Date

Generater Specifications

CLYDE

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

- Now we want both generators to share equal load, so we want our generators to have a characteristic called Droop.

- When load on alternator increases, the voltage dips

- AVR senses the dip & brings back voltage to rated

CLYDE

Speed Droop = $\frac{N_{NL} - N_{FL}}{N_{FL}} \times 100\%$

or

Freq Droop

↓

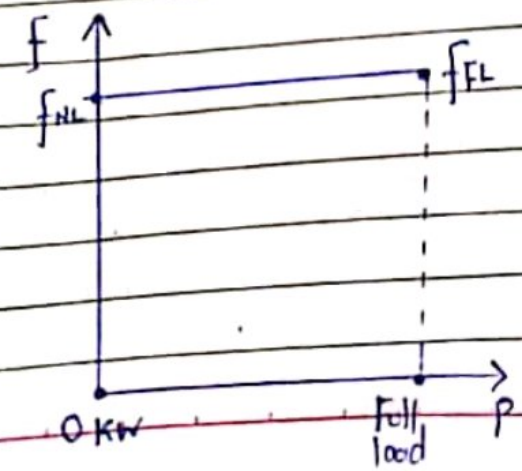
Responsible for active load sharing.

or

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

Suppose we have 2 alternators & both are set at 0 droop. then we cannot share load

0 Droop means - isochronous mode



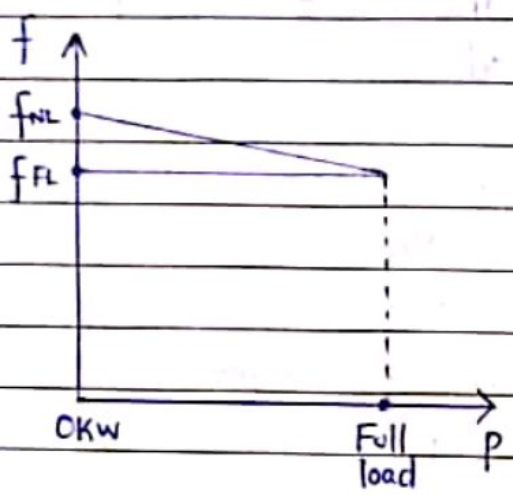
When alternator not paralleled freq does not change when load is increased

So $f_{NL} = f_{FL}$

* So freq set to 0 when alternator not paralleled. called isochronous mode.

Now,

* If you want to parallel 1 alternator with other, some droop is req.



* Consider an alternator with droop.
* So as load increases, the freq drops

These 2 cases explains isochronous droop & speed droop

CLYDE

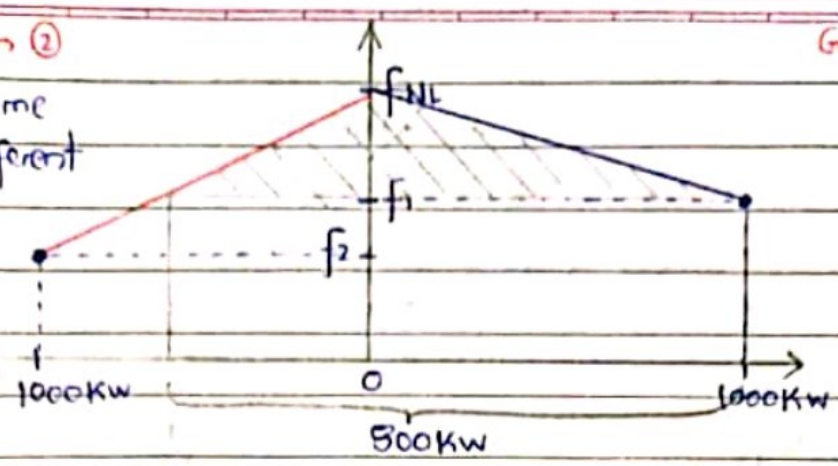
Case I

Page No. 139
Date

Gen ②

Gen ①

Ratings Same
Droop Different



Suppose f_{NL} same for both
Assume rated load of both are 1000KW
lets assume f_1 rated freq for gen①
& f_2 rated freq for gen②

Now if 800 KW load has come
how to find load share

Means Gen ① takes more load &
Gen ② takes less load

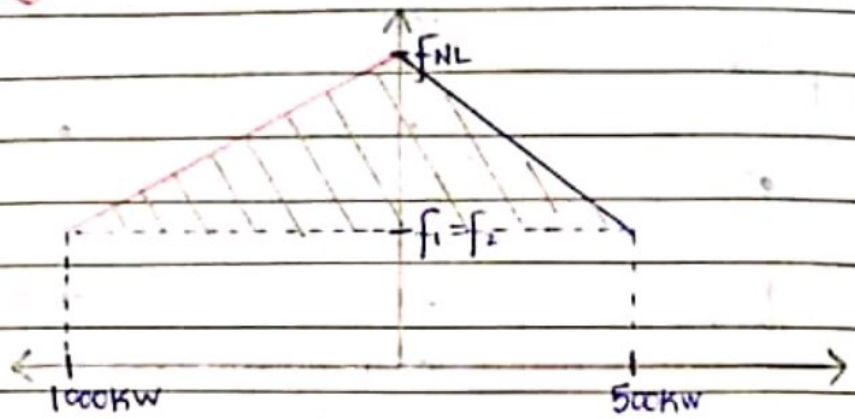
So the gen will lesser drop (gen①)
will take more load.

CLYDE

Case II Droop same
Rating different

Page No. 140
Date

Gen ② Gen ①



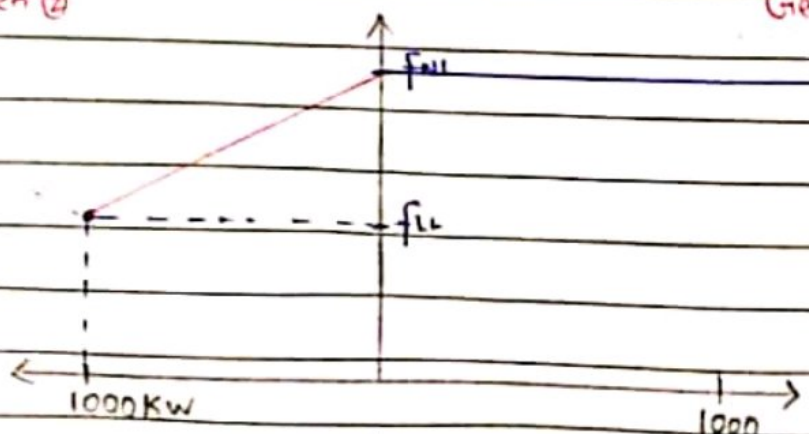
Here Gen ② will take more load & Gen ① will take less load.

Case III CLYDE
Ratings same
Droop same

Equal load sharing.

Case IV
1 alternator is isochronous
2 alternator is droop

Gen ② Gen ①



If 800KW load comes
Gen ① will take full load.

Paralleling

CLYDE

We can buy 1 big generator to take up all load. So, why more generators are req?

- We need more than 1 generator so that we can carry out scheduled maintenance on other
- If only 1 generator, & that stops working, We won't have any reliability of another power source.
- If we have only low loads, Power factor will become low. If PF low, eff will reduce & more fuel will be used. Useful power produced is less.

Need for more than 1 generator

* Increased reliability & redundancy
* Low cost for power generation
* Expandability & flexibility.
* Decreased low load operation

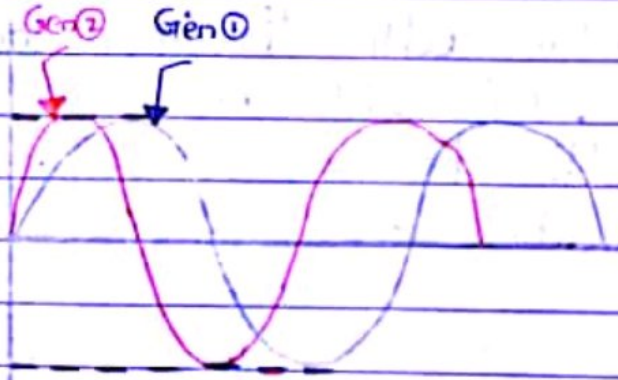
Before paralleling, what are the requirements ?

CLYDE

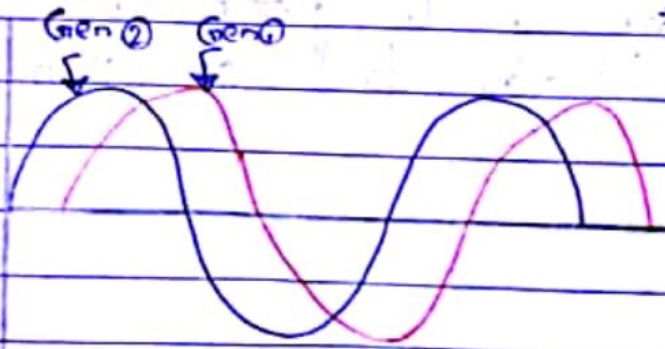
We need to match
- → Voltage
- → Frequency
- → Phase angle

R_1 voltage to be matched with R_2
Y_1 voltage to be matched with Y_2
B_1 voltage to be matched with B_2

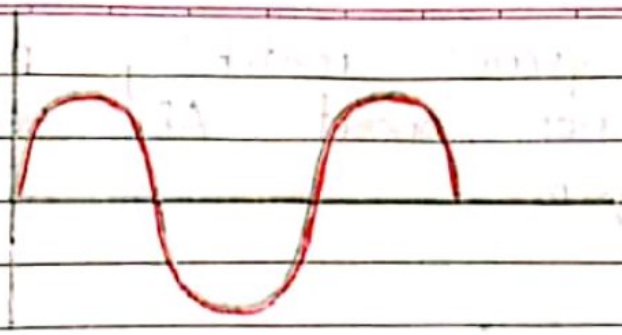
This means voltage match



* Here voltage matches as peak voltage of both generators are same



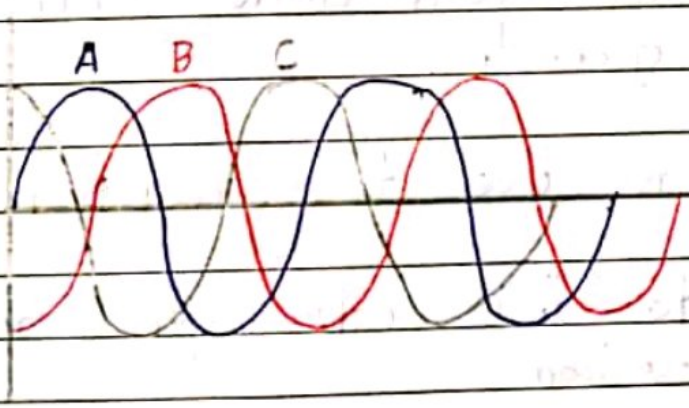
* Here freq also matches



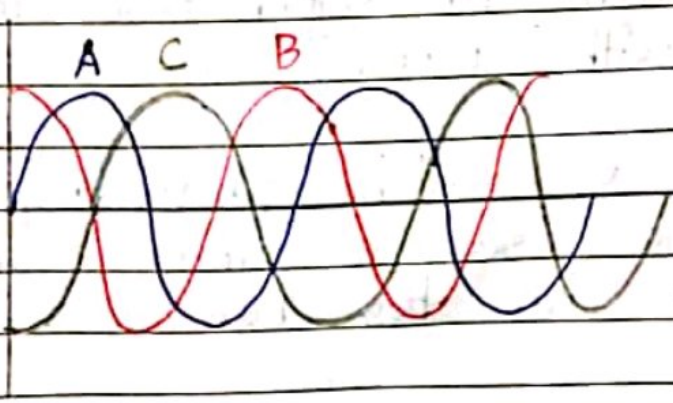
* Here no phase angle bet" 2 gen.

Apart from phase, freq & voltage, Phase Sequence also should match

Phase sequence is sequence or order in which phase voltage in a 3ϕ system reach their peak value



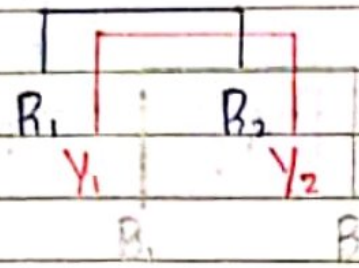
A-B-C Sequence



A-C-B Sequence

* Phase sequence matching means we cannot connect ABC seq to ACB sequence

CLYDE



If R_1 connected R_2
Y_1 Connected Y_2
B_1 Connected B_2

This is phase seq.

* If voltages don't match, 1 generator will draw current from other generator.

* This is due to circulating current.

* Due to this other gen can trip on overload

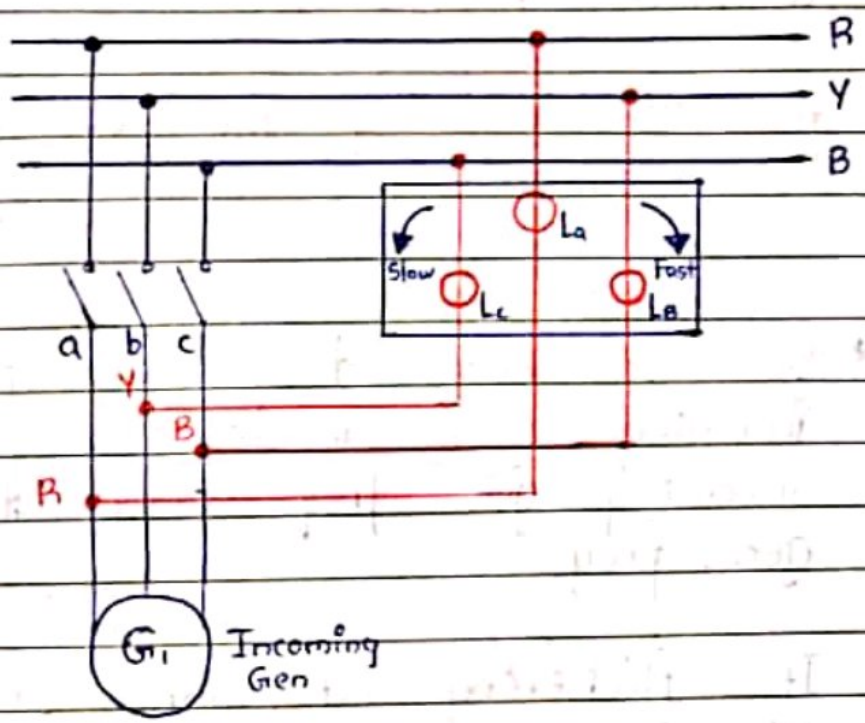
→ To avoid all this, we need to synchronize incoming gen with running gen or busbar.

* Means we match phase, freq, voltage & phase seq & then only connect to bus bar

This is called synchronization.

3 lamp method

CLYDE



* This method is 2 bright & 1 dark lamp

B is connected to C
C is connected to B
Means there is 120 phase shift

So A lamp will be dark.
& B & C lamp will glow

Now the lamps will flicker when synchronizing

We have to see the direction of rotation of flicker.

* If flickering of lights in clockwise direction means

freq of incoming gen > busbar freq
or
running gen freq

* So we have to low speed of incoming gen inorder to bring incoming gen freq close to running gen freq.

If flickering of lights in anticlockwise direction means

freq of incoming gen < busbar freq
or
running gen freq.

* So we have to raise speed of incoming gen inorder to bring incoming gen freq close to running gen freq.

Now,
Clockwise fast rotation means
Diff in freq is more

Clockwise slow rotation means
Diff in freq is less

CLYDE

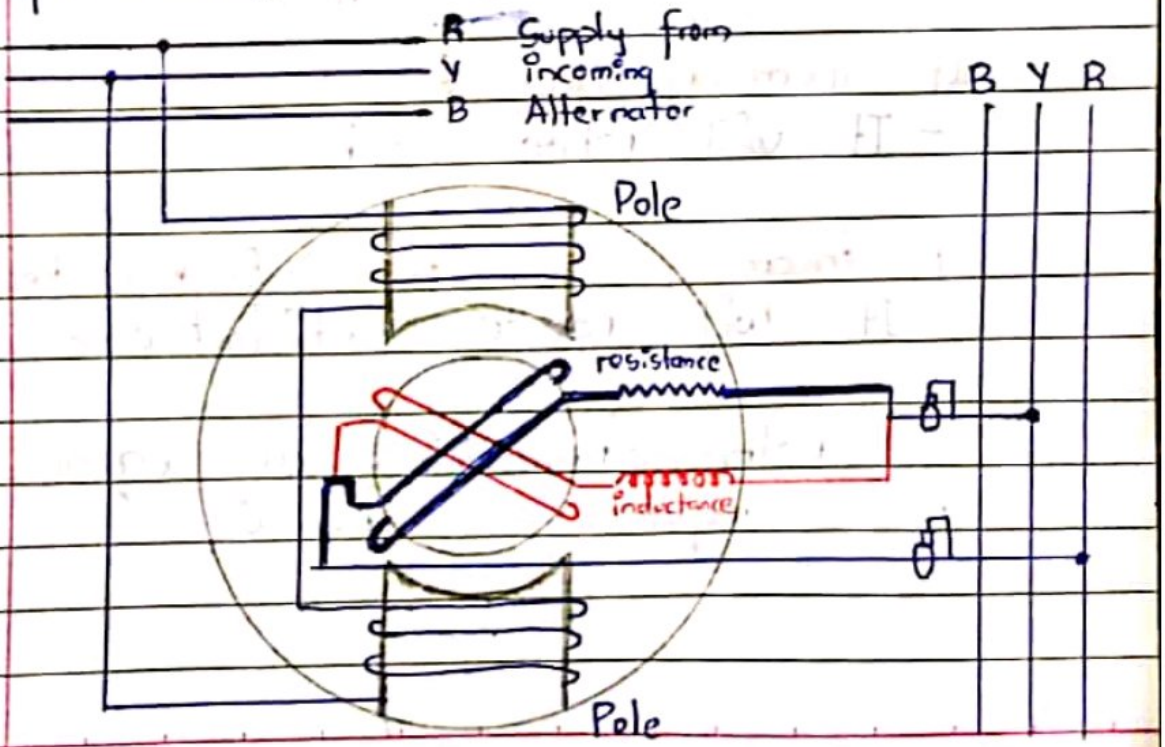
When freq is equal
A → glows dim
B & C → glows bright

* Other method we have is 3 dark lamp method.

SYNCHRO SCOPE

* It is a device used to measere freq difference and phase angle of 2 generators

* It is safe only when freq diff & phase angle =0



There are 2 coils on rotor
1 → resistive circuit
1 → inductive circuit.

In a resistor
current is in phase with voltage

In an inductor
current is lagging voltage by 90°

Here we produce a 90° phase shift so we can produce a torque to rotate rotor.

The direction of torque will depend on freq difference

If incoming gen freq < Busbar freq
- It will rotate clockwise

If incoming gen freq > Busbar freq
- It will rotate anticlockwise

If both frequencies are equal, then torque will be 0

Alternator Safeties

CLYDE

① Differential relay

- It is connected two CT connected to either sides of stator winding.
- This provides protection against internal faults within stator winding.

② Earth leakage relay

- It is connected to a core balanced CT

③ Under voltage / over voltage relay
④ Under freq / over freq relay

- These both are connected with a PT connection

⑤ Reverse power relay

- This requires both CT & PT connections

⑥ Over current relay

- This is operated when we have a v high fault current.

⑦ Negative phase sequence relay.

All these relays are connected to a master relay which will finally open the circuit breaker

Over Current Relay

- Over current can cause heating of windings & if allowed to continue it will damage insulation & can lead to short circuit.

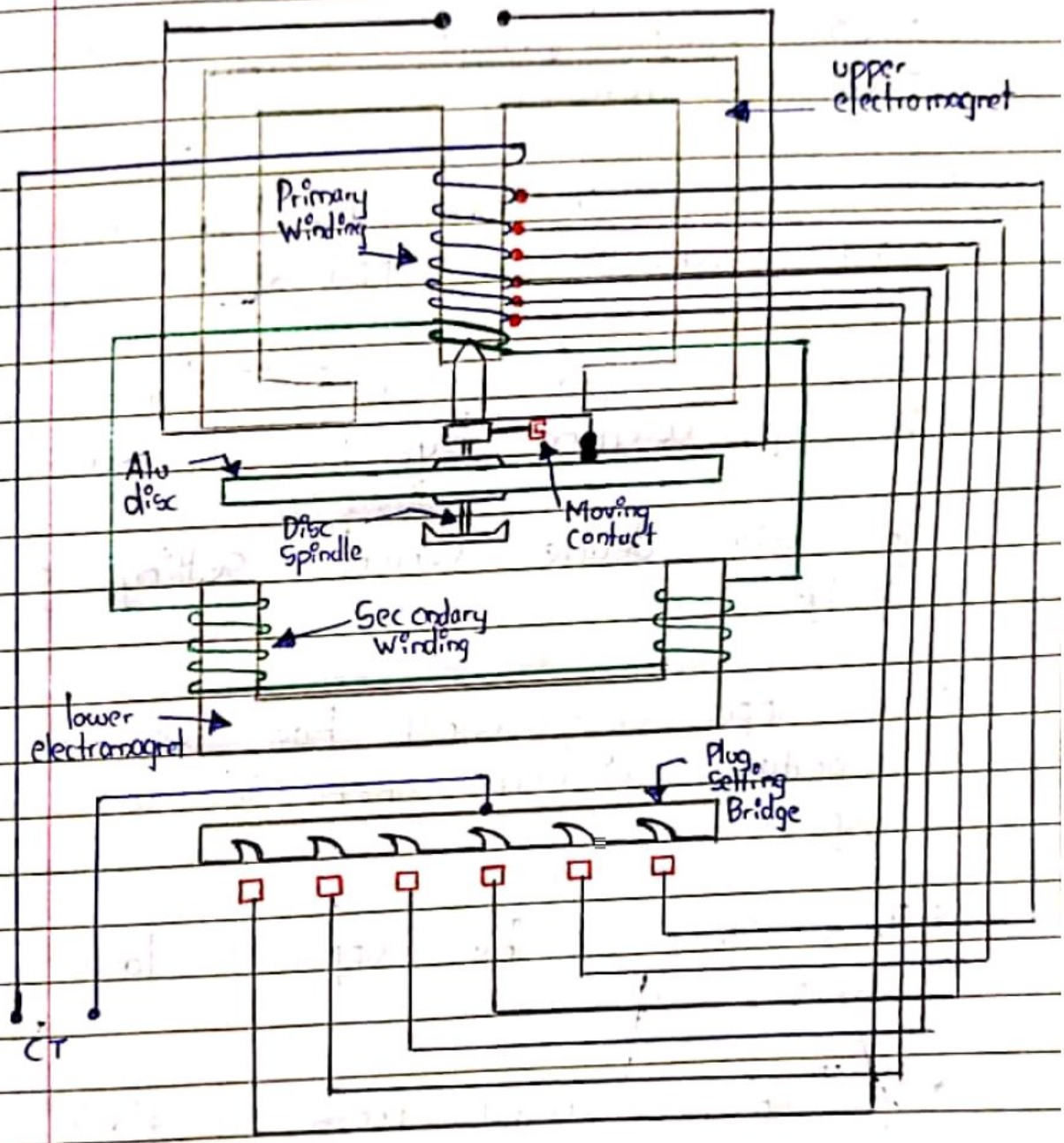
- Overcurrent can be caused by high starting currents of large motors or fault on distribution side of switchboard

* If fault current (I) > 0.7 to 2 times of rated current
Trip time 1 to 10s

* If fault current (I) > 0.2 to 10 times of rated current
Trip time 0.1 to 1s

Page No. 151
Date

Trip Circuit



CLYDE

* It consists of 2 electromagnet
  - upper electromagnet
  - lower electromagnet

* The upper electromagnet has primary winding which has tappings

* So we can choose no. of turns in primary winding by plug setting bridge

* This will deride current setting of bridge

* The upper electromagnet has also a secondary winding which is a closed loop

* This connects the upper & lower electromagnet

* So when current from CT flows through primary winding: based on no. of turns based on plug setting bridge, an emf will be induced in primary winding.

* Now due to mutual inductance, emf will also be induced in secondary winding.

* Now the current in primary & secondary winding will produce a flux but there will be a phase shift

* Due this phase shift, since we have 2 fluxes, we can generate a EMF.

* This induce eddy currents in Alu disc due to faradays law

* Eddy currents will produce a torque & will rotate disc

* Now disc has a fixed & movable contact

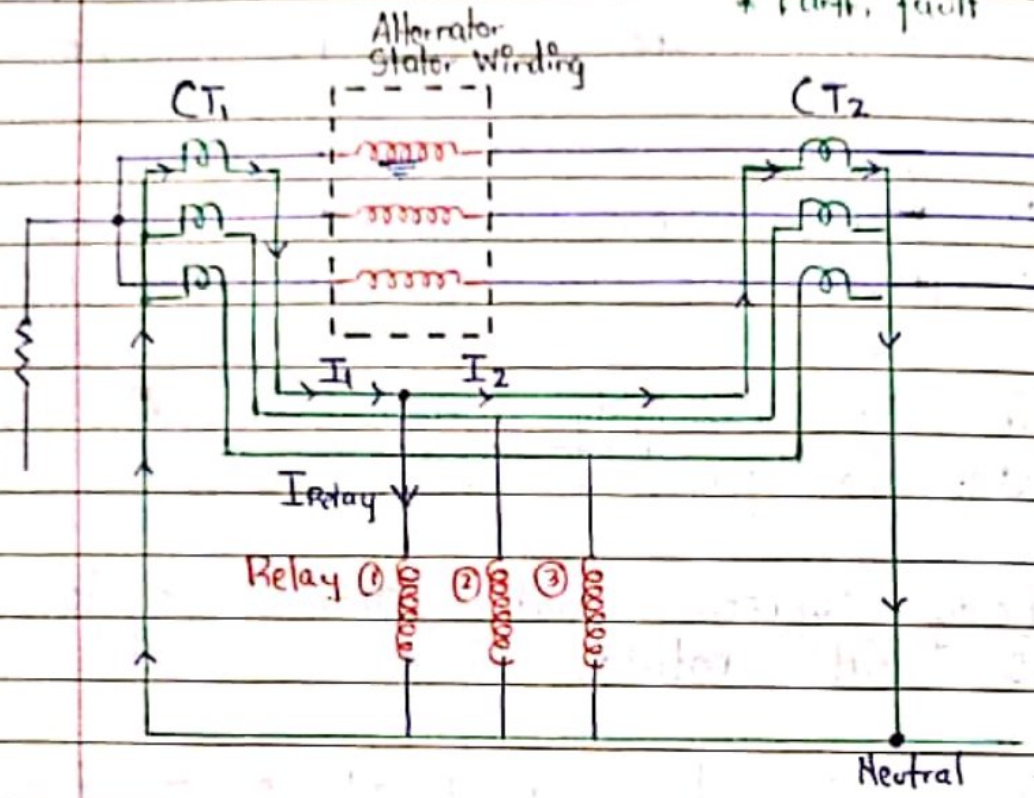
* As disc rotates, the movable contact also rotates

* The moment movable contact touches fixed contact, trip setting will activate

* We are setting the overcurrent trip by plug setting bridge

DIFFERENTIAL RELAY - Internal Faults

* Short Circuit fault
* Earth fault



* If the insulation of alternator stator windings fails, there can be an earth fault or line fault.

* Also if insulation betⁿ 2 windings fails, then short circuit fault can happen betⁿ 2 windings.

* Thats why we do IR test betⁿ 1 winding & body and also betⁿ 2 windings to check insulation.

CT → steps down current to flow through relays

PT → steps down voltage to flow through relays

Case ① - Earth Fault

* Suppose no fault in 1st winding, so current passing through CT_1 will be same as current passing through CT_2

* So when no fault I_1 will be equal to I_2 & current flowing through relay will be 0. This will not energize trip circuit

* Now if fault on 1st winding happens, current from both CT's will flow through this pt of fault.

* This will cause $I_1 + I_2$ to flow through relay which will energize trip circuit

CLYDE

Case ② - Short Circuit Fault

* Now if fault betn 2nd & 3rd winding happens, current flowing through CT_1 & CT_2 of both windings will be different

* This will produce a relay current which will energize trip current.

* If current flowing is 0.1 times rated current, trip will happen.

REVERSE POWER RELAY

* When there is no load on alternator it consumes some fuel to overcome frictional & mech losses to produce some KW power

* If we cut off fuel supply, & alternator still connected to busbar, it will start drawing active power to overcome frictional & mech losses

* Now alternator will act as a motor & start drawing current from busbar to rotate

* i.e 10 to 15% of rated power if alternator starts drawing then motoring will happen. We take 5sec delay to trip generator

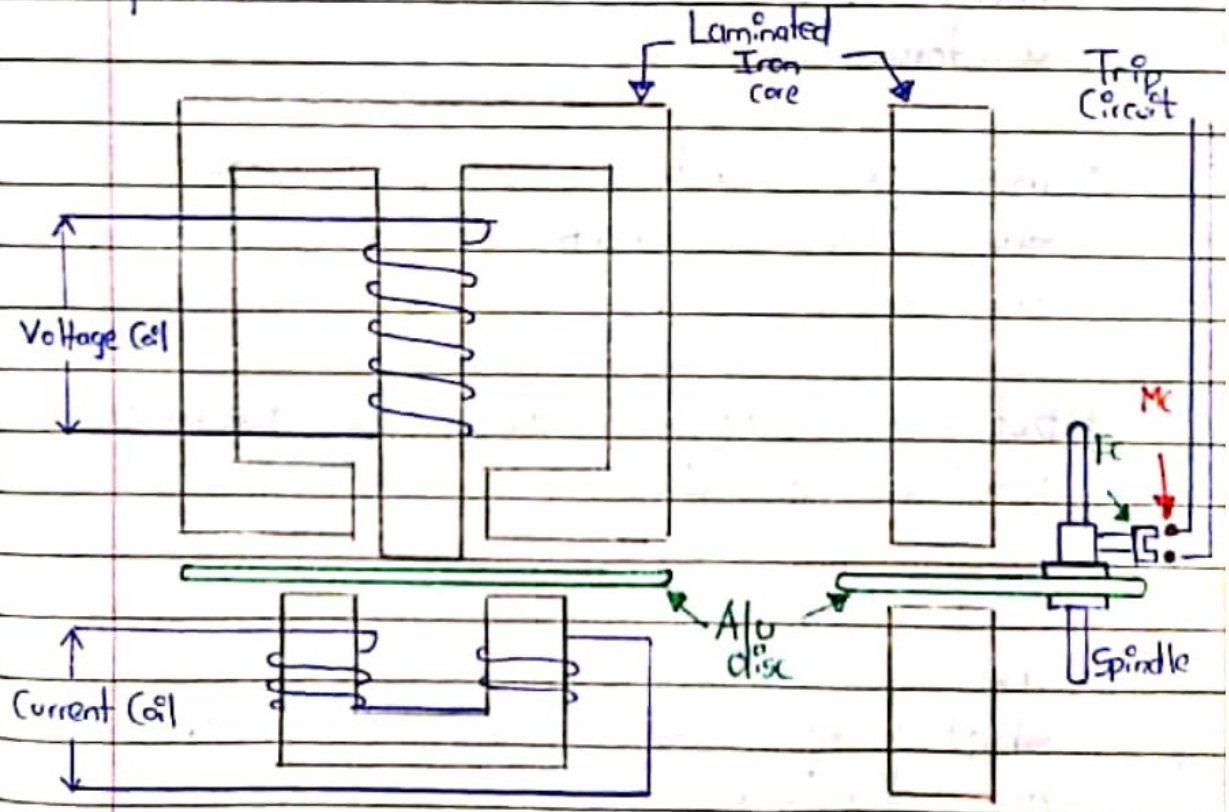
* Even in paralleling, if there is mismatch of freq, reverse power will flow. This should not happen hence we have a 5sec delay

* Reverse power relay is connected to CT & PT & these values it receives, it measures it to actuate trip. to ACB

CLYDE

CT & PT are instrument transformers so that high current of line & voltage doesn't flow through instruments & damage

* Reverse Power Relay is a directional relay which senses direction of active power.



* It has 2 electromagnets.

* A voltage coil is connected to upper electromagnet having higher inductance

* A current coil is connected to lower electromagnet having lower inductance.

* Due to higher inductange, current will lag voltage by 90°

* Under normal condition, 2 fluxes from both electromagnet will produce a torque

* This will induce eddy currents in Alu disc & make it a current carrying conductor.

* But a stopper tries to prevent rotation of disc

* Now in case of reverse power, the current will undergo phase shift of 180°. Due this this Alu dis also tries to rotate in opposite direction away from stopper.

* This will go & make contact with fixed contacts & activate trip circuit

CLYDE

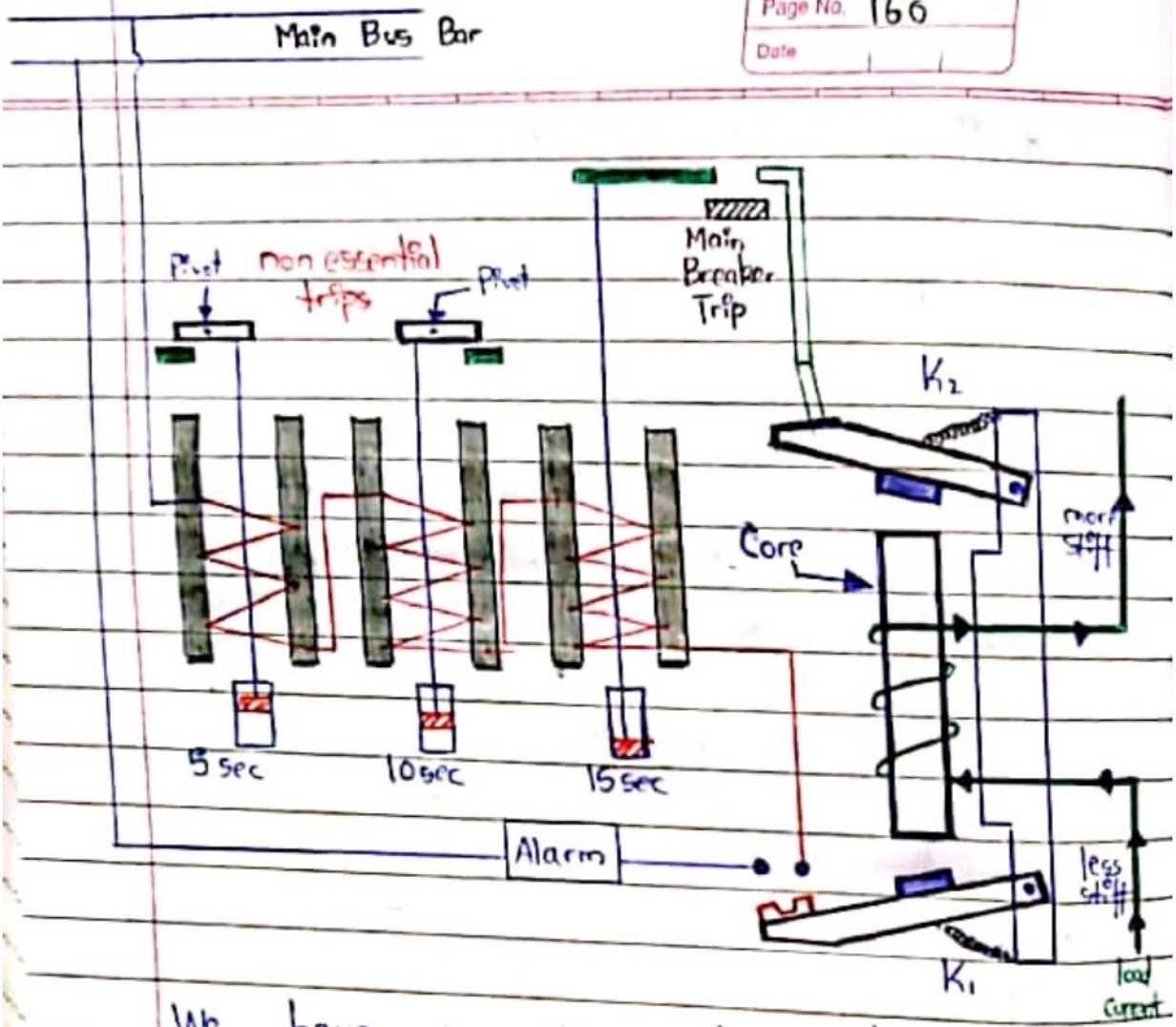
PREFEBENTIAL TRIP

* In case of overload of alternator, the alternator will trip

* This will result in loss of power to essential services too

* We won't allow that, so we try to preferentially trip the non-essential services so that essential services can still get power.

* From MSB, we generate this preferential trip



We have a core, where the load of that particular alternator is flowing

We have 2 levers on top & bottom of core held in position by spring.

Once current flows through core, it will make 1 side of core N & other side south.

These poles N & S will try to attract lever towards poles

But spring force won't allow lever to get attracted to poles

In normal condition, spring force is more & levers are held in place

Once current crosses overcurrent value spring force will become less

~~Upper~~ Lower lever will move first as upper lever has higher spring tension than lower lever

Once lever goes up, it activates alarm & also activates solenoid coils

Once solenoid coils are energized, plunger will tend to move up.

Plunger positions in all 3 are different

1st will take least time to go up
2nd will take little more time to go up
3rd will take max time to go up

So 1st will trip, some non-essential services, 2nd will trip some more also after that also overload does...

not decrease, then main breaker will trip.

In case of v high overcurrent due to a short circuit fault, the top lever will activate immediately as main breaker will trip.

This is called instantaneous trip.

1ST trip → AC & ventilation
2ND trip → Refrigerated cargo plant or
3RD trip → cargo pumps
Deck equipments

Lower value of overload then alarm + preferential trip

Higher value of overload then instantaneous trip.

ER Blower

a) Busbar & functions — CLYDE

* Busbar is a copper bar or plate which is used in ships main & eme switch-boards to conduct electricity from generators or from 1 electrical terminal to another

- Busbar cu plates or bars are connected via nuts, bolts
- Due to vibrations, the nuts, bolts could become loose & could lead to sparks

Busbar maintenance

① Can be done when ship is in blackout condition i.e when generators are not running & no power is supplied to main & eme switchboards
② The best time to do busbar maintenance is when ship in drydock

- Use rubber gloves & PPE
- Put lock out tag out at panel
- Ensure gen & eme gen & isolated

* Carry out visual checks of copper bars, bolts & nuts
* Tap plates to check any loose connection

* Use torque wrench to tighten nuts & bolts
* Check tightness of wire connections which is connected to circuit breakers
* Clean busbar & switchboard area by vaccum cleaner

9) Motor overhaul

* In motor, v fine air gap is there bet^n rotor & stator. If there is a deviation of shaft, rotor will start touching stator leading to short circuit or burning of windings

Before overhaul, check IR of stator winding by multimeter.

1 probe to winding & other to earth & switch in resistance mode.

① Before overhaul marking on motor housing & wires is v imp. This will ensure correct boxing back procedure

Also check direction of rotation of motor

② Safely remove coupling bet^n motor & plp

CLYDE

③ Check bearing condition

④ If insulation of motor is less, clean winding by cleaner. Apply insulation coating & keep a powerful halogen lamp for it to dry.

⑤ Clean cooling fan

⑥ Clean bearing housing & body of motor

Difference bet° Earth Neutral Sys & Insulated Neutral Sys

Earth Neutral Sys	Insulated Neutral Sys
① Used for HV sys above 1000V	Used for low voltage sys upto 1000V
② Will trip with 1 earth fault	Will not trip with 1 earth fault.
③ Essential services are affected with 1 earth fault	Essential services are continued even after 1 earth fault.
④ Fault finding is easy as quick isolation possible	Fault finding is complex.
⑤ More maintenance	Less maintenance
⑥ More space req	Less space req.
Here neutral is connected to earth by a neutral earth resistor. It is a step down transformer	Here neutral is not connected to earth

Alternator Maintenance

CLYDE

① Before starting any maintenance all safety precautions to be taken & alternator must be shut & locked down. Also post notice & placards on relevant places & also alternator heater to be isolated

② Clean alternator ventilation passage & air filter.

③ Check IR of stator & rotor winding. Air gap betn stator & rotor must be checked & maintained betn 1.5 to 2mm

④ Slip rings to be checked & renewed if worn out

⑤ Carbon brushes to be clean & check for free movement

⑥ AVR to be checked & cleaned off oil & dust

⑦ Lo level of pedestral bearing to be maintained & renewed periodically

⑧ Vaccum cleaner can be used to remove dust accumulated in inner parts of alternator

④ All connections in terminal box to be tightened properly.

⑩ Forced ventilation around alternator to be maintained at all times.

⑪ Foundation bolts of alternator to be checked for tightness.

⑫ After maintenance, do not take on load, only observe noise, temp, vibration & voltage generated.

Motor Maintenance

① Routine cleaning of dust, dirt, grease, oil from outside & inside motor. Dust can be removed by blowing air (not more than 1.75bar)

② Contamination by oil & grease from motor bearing is often cause of insulation failure

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

③ Check IR of stator & rotor.

④ Bearings must be cleaned, lubricated & renewed.

⑤ Housing must be clean & dry

CLYDE

Rotor -

- Check for signs of damage & overheating in cage winding & laminated steel core.

⑥ Cooling fan to be in good condition and well cleant

Motor maintenance after being flooded

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

	AC	DC
①	It has bi-directional current & current alternates from 1 direction to another	It has unidirectional current.
②	Cannot be stored	Can be stored
③	Magnitude of current varies with time	Current has constant magnitude
④	PF lies bet^n 0 & 1	PF alway 1
⑤	Can be transported over long distances	Cannot be transported over long distances

HV & Safeties

* The voltage used onboard above 1000V is called high voltage

IR

CLYDE

* It is the resistance offered to conductor to prevent current from leaking away

IR can drop due to
- moisture
- dust & dirt
- overloading causing overheating
- overcome its useful life

* Unit of IR is Ω
* It is measured by megger.

* For low voltage equipment upto 440V
min acceptable IR = 1 MΩ

* For high voltage equipment
min acceptable IR = KV + 1 MΩ

* IR is measured in hot condition just after stopping.

Earth Fault

* This is a fault that occurs due to break in insulation where conductor touches metal or hull directly.
* Earth fault in earth neutral sys would be like a short circuit fault & current starts flowing through hull.
* If this current increases beyond the current rating of gen, the gen will get damaged.
* Hence NER will limit earth current below the current rating of gen
* In insulated neutral sys, single earth fault would not cause any current to flow in hull
* This is because the circuit is not complete for current to flow
* However if 2nd earth fault happens 2 earth faults can cause short circuit

* Earth fault is monitored by Earth fault relay to create alarm & trip functions.

* Earth fault relay is on 440V & 220V distribution panels

* We have to carry out the IR & find out earth fault.

Single Phasing

* This is a fault where 1 phase of the 3 phases gets disconnected from motor terminals or 1 of 3 contactors are open, or 1 wire of motor is cut

Effect of single phasing :

① Motor will continue to run because of torque produced by remaining 2 phases to meet load demand

② As 2 phases are doing extra work of 1 default phase, they will overheat & damage windings

③ Single phasing reduces speed of motor & rpm will fluctuate

④ Due to uneven torque vibrations will be produced.

⑤ If winding melt this will lead to short circuit or earth fault.

⑥ So bimetallic strips melt & OCR will activate.

⑨ Motor Specification

- Rated full load current
  * Max value of current the motor can take from supply without damaging insulation of winding

- Rated voltage
  * Supply of voltage for motor to operate successfully.
  * If rated voltage not supplied overheating can take place.

- Rated freq.
  * Motor speed is affected by frequency.
  * If rated freq not supplied overheating can take place.

- Power rating
  * This is shaft power output of motor connected to rated voltage & freq when drawing rated current

- Rated speed
  * This is full load speed of motor when connected to rated voltage & freq

- IP (ingress protection)
  * Degree of protection given to motor enclosure

- Insulation Class

Insulation Class	Max Temp	Material Of Insulation
A	105	
E	120	
B	130	
F	155	
H	180	

What is IP 67
6 - complete protection against contact with live or moving parts inside enclosure
- protection against ingress of dust

7- Protection against water immersion.

Q MSB Safeties

- locating where MSB to be installed should have good ventilation, illumination & affected by min vibration.
- No water or oil pipes to pass over MSB
- Operating floor in front & behind MSB should be covered with anti-skid insulated rubber mats with a min thickness of 15mm.
- Panel doors to be kept locked
- Door opening must be interlocked by power supply.
- MSB to be dead front type i.e all live conductors to pass behind MSB
- MSB to be properly earthed
- Every incoming & outgoing feed must be protected by a fuse or breaker.
- All meters, switches, fuses, push buttons, lamps should be in good working condition & identified with nameplate.
- Red tape/ tag indicating HV & danger sign to be fitted.
- Appropriate ready to use CO_2 extinguisher to be kept nearby.
- Earth fault indication to be fitted on MSB panel.
- 24V battery supply for emg light to be provided

Q ACB Safeties

- UV Coil (set at 15% of rated voltage)
- Overcurrent
- Longer time delay (105~200% of FLC)
  Trip time 20~120 sec
- Short time delay (200~600% of FLC)
  Trip time 0.1~1 sec
- Instantaneous (1000% of FLC)
  Instant trip

- Arc contact
- Arc runner
- Arc chute
- Simultaneously closing of all 3 contacts
- Arcing contact make first & break after MC
- Reverse power trip
- Preferential trip

Q Types of circuit breaker

MCB (miniature circuit breaker) 5~100 Amps
MCCB (moulded case circuit breaker) 50~1500 Amps
ACB (air circuit breaker) 400~2000 Amps
VCB (vaccum circuit breaker) → HV
SF6 sulphur hex-fluoride → HV

Crane Safeties

① ~~Electronic~~ Electromagnetic fail safe brakes which do not allow crane to drop load when power failure.
- ↳ Centrifugal brakes fitted inside rotating drum
- ↳ Brake pads are always in applied state & pushed by magnetic springs when not in operation or power failure
- ↳ During operation, power is supplied spring gets pulled inward due to electromagnetic effect

② Emg stop
③ Motor fitted with limit switches in transverse & longitudinal direction.
④ Mech stoppers in both directions
⑤ Up & down of hook is attached with atomatic stop to prevent overload.
⑥ Motor has thermal protection trip

Battery Room Safeties

① Ventilation deck to be below battery to push out all gases
② Ventilation fan to be non sparking type

③ Use insulated tools while tightening terminals of battery.
④ Use plastic jug to fill / top up electrolyte level to avoid short circuit
⑤ Ensure vent cap is open at all times.
⑥ Ensure no smoking or naked lights in room
⑦ Make sure no ESB panel located in room
⑧ Always maintain electrolyte above electrodes but below vent caps.

Adv Of HV

- For given power, HV means lower current resulting in
  * Small generators, motors, cables
  * Saving space & wt
  * Reduction in cost
  * More efficient utilization of power

Dis-Adv Of HV

- Higher insulation req for cables
- Higher risk for danger

Q Why meter in KW & alternator rating in KVA

- Load on meter is mechanical & mech power is measured in watts
- Hence rating shows max mech power produced by meter.

Load on alternator / transformer is electrical & electrical loads consume some active & reactive power.
- The resultant of these 2 powers measured in VA or KVA

Q How to order fuse onboard

- Voltage rating
  Current rating
  Type of fuse
  Fusing factor
  Size

} These specs need to be matched.

Type of fuse → AC/DC fuse
High Rupter Capacity fuse
Semiconductor type
Semienclosed type
Kitkat fuse
Glass cartridge fuse

Q. Why motor cannot be run on star only?

- A motor is designed to run on delta connection. If made to run on star, it will not generate rated torque

$$T_{star} = \frac{1}{3} T_{delta}$$

- So if operated at full load, there will be overheating of windings
- Winding will burn if motor not tripped by OCR
- There wont be any change in speed as speed is decided on freq & not voltage.

Q. How to order lifeboat battery

① CCA & MCA rating
② Ah rating
③ Voltage rating
④ Type of battery
⑤ Maintenance free or flooded type
⑥ Battery life
⑦ Size & dimensions

Q After overhauling motor not rotating
- Connections to motor are loose
- Motor has tripped on overload. So reset
- Emc stop of motor active
- Fuse gone
- Windings damaged
- Check motor & p/p alignment

Q Alternator not developing voltage
- loss of residual magnetism
- SCR not getting firing angle
- Wrong adjustment of voltage setting in AVR
- Air gap increased

Q Reason for air gap & importance

Air gap can be increased by damage to motor shaft due to worn out bearings.

Large air gap draws more magnetizing current So PF will be low

More air gap can lead to less emf in rotor

Insulation resistance is measured by megohmmeter/ called as meggers.

IM	SM
* Rotor does not rotate at synchronous speed	Rotor rotates at synchronous speed
* Single excitation	Double excitation
* AC source	Armature → AC source Field → DC source
* Self starting	Not self starting
* Operates at lagging PF	Operates at lagging & leading PF
* Efficiency less	Efficiency more
* Cheaper	Costly
* Simple const	Complicated const.

— x — x — x —

You can also refer:
* D.T Hall
* Samundra Quick Reference Notes

Spcl Thanks To Amit Sir