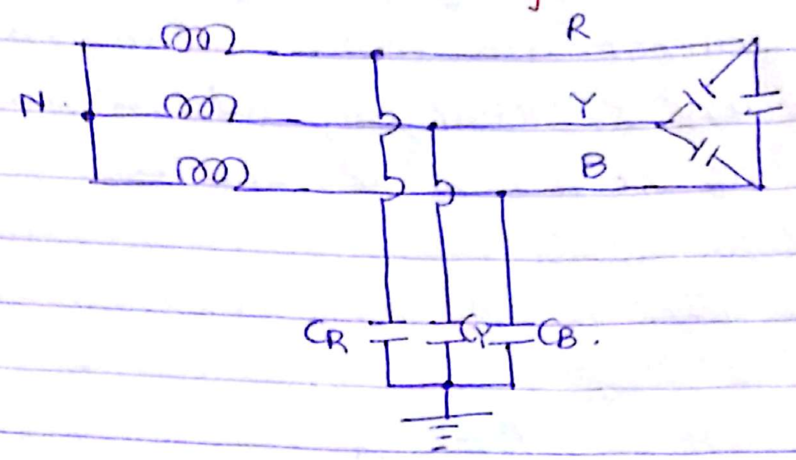
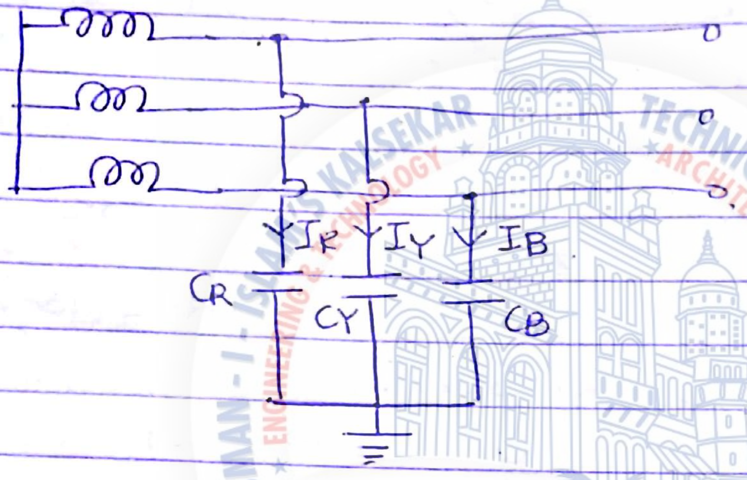
* Module 6.

• Ungrounded neutral system:





(a) Normal condition

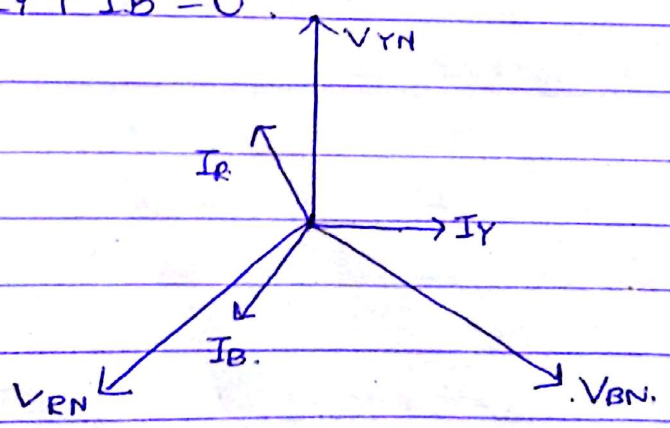
→ line is perfectly transposed, so $C_R = C_Y = C_B$.

→ phase voltages V_{RN}, V_{BN}, V_{YN} has same value,

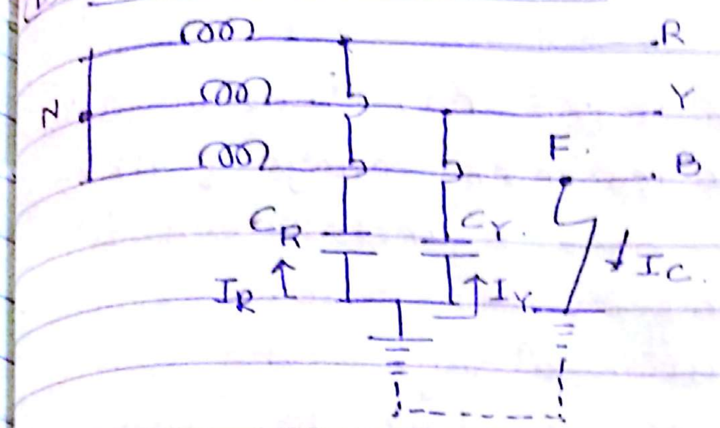
∴ $I_R = I_Y = I_B = \frac{V_{ph}}{X_c}$ → line to neutral voltage.

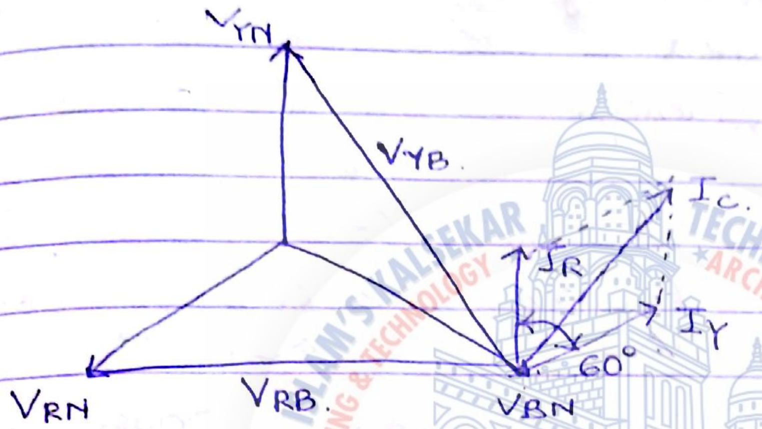
→ I_R, I_Y, I_B lead V_{RN}, V_{BN}, V_{CN} by $90°$.

→ $I_R + I_Y + I_B = 0$.



(ii) Abnormal Condition : (L-G fault).





→ Consider single line to ground fault at pt F in 'B'

→ Voltages driving I_R & I_Y are V_{BR} & V_{BY}.

→ Since I_R & I_Y are capacitive, I_R leads V_{BR} & I_Y leads V_{BY} by 90°.

→ $I_C = I_R + I_Y$

→ $I_R = \frac{V_{BR}}{X_C} = \frac{\sqrt{3}\, V_{ph}}{X_C}$.

→ $I_Y = \frac{V_{BY}}{X_C} = \frac{\sqrt{3}\, V_{ph}}{X_C}$.

∴ $I_R = I_Y = \frac{\sqrt{3}\, V_{ph}}{X_C}$.

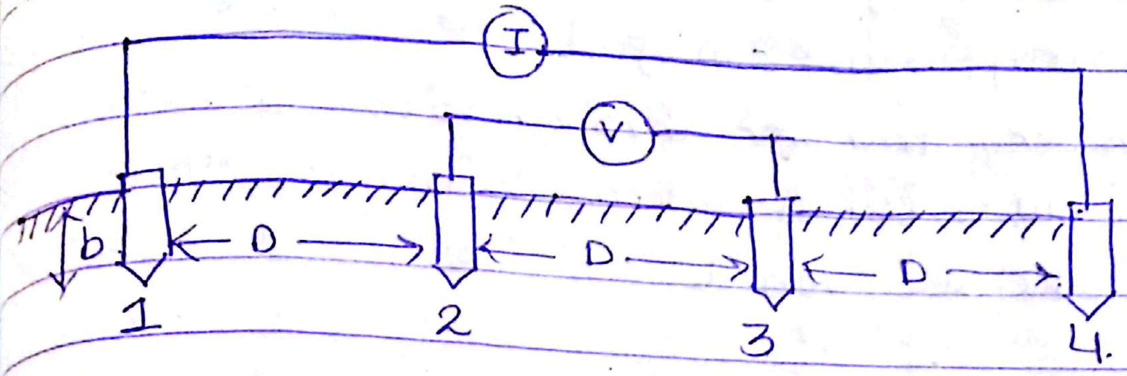
$= \sqrt{3} \times$ per phase capacitive current under normal condition.

→ $I_C = I_R + I_Y$

$= 2 I_R \cos(60/2) = 2 I_R \cos 30 = 2 I_R \times \frac{\sqrt{3}}{2} = \sqrt{3}\, I_R$.

(magnitude of I_R & I_Y are equal & angle between them is 60°.

* Measurement of Soil Resistivity.



- It is measured by 4 electrodes suggested by F Wenner.
- 4 rods are driven inside earth at equal distances.
- 'I' known current is passed between electrode 1 & 4 & voltage is measured across rod 2 & 3.
- We know that $R = \frac{V}{I}$, ρ is deduced from following,

$$\rho = \frac{4\pi D \, V/I}{1 + \frac{2D}{\sqrt{D^2+4b^2}} - \frac{2D}{\sqrt{4D^2+4b^2}}}$$

$\rho \rightarrow$ Soil Resistivity

$D \rightarrow$ horizontal distance between 2 successive electrodes

$b \rightarrow$ dept of burial.

if;

$b << D$ then

$\rho = 2\pi D \, V/I$.

- A number of readings with different values of spacing & in different directions should be taken. Average value of 'ρ' should then be used in design.

* Tower footing Resistance & Counterpoises.

(1) Effectiveness of ground wire depends on 'TFR'

(2) TFR is the resistance offered by the tower footing to the dissipation of 'I'

(3) 'V' depends on the 'R' 'V = IR'

(4) ∴ ↓ value of 'TFR' causes the voltage between wire earth & ground to be ↓. ∴ ↓ line insulation stress

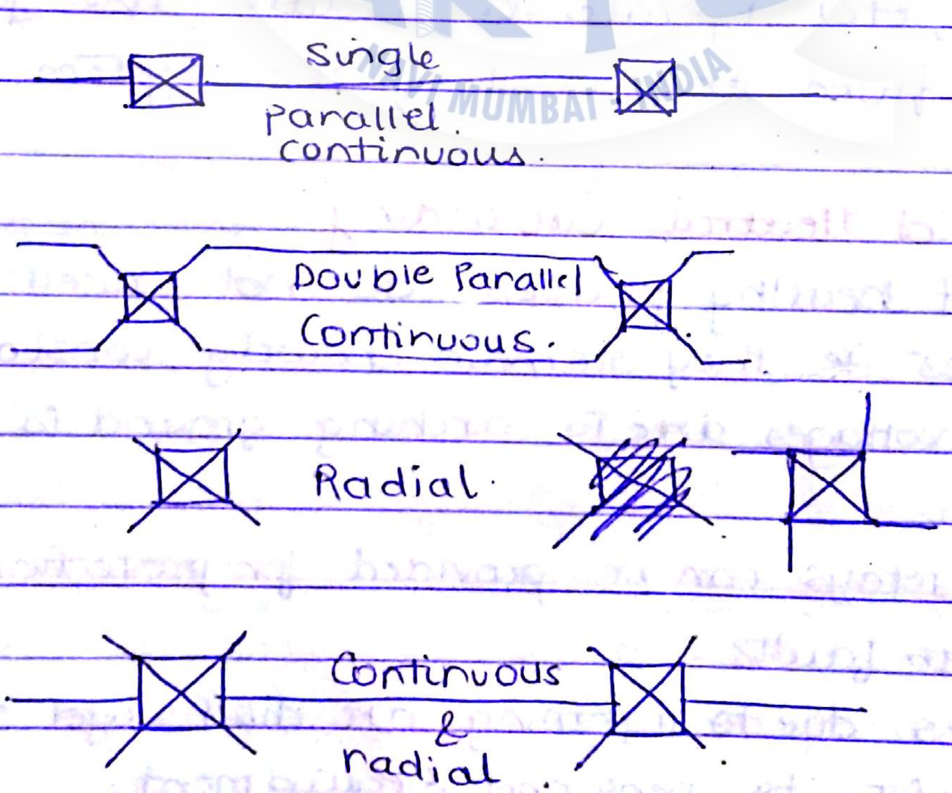
(5) TFR = 20 Ω (EHV line)
= 10 Ω (HV lines).

(6) It is normal practice to provide one or two drivin rods at tower footing to achieve low 'R'

(7) In soils of high resistivity (sandy soil, rocks) use of drivin rods do not adequate ↓ Resistance

(8) In such cases counterpoise is used, tied to tower base run '||' or at some angle to line.

(9) Aim is to ↓ R by increasing area of contact of earth with grounding system.



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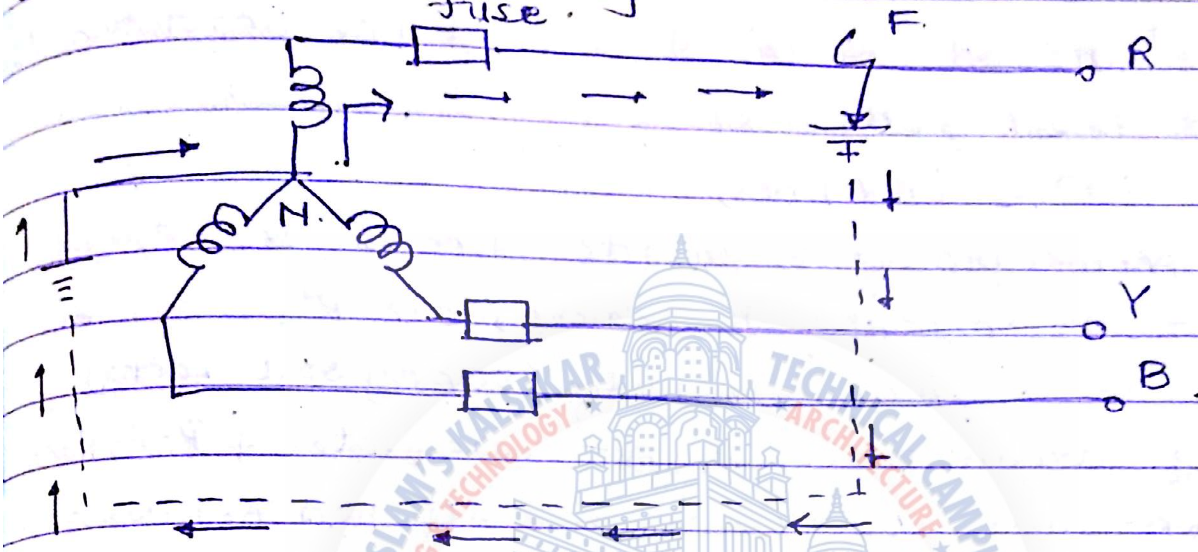
(10) * Neutral Grounding.

The process of connecting neutral point of a 3ϕ system to earth either directly or through some circuit element (Resistance, Reactance) is neutral grounding.



- During earth fault, the 'I' path is completed through the earthed neutral. & the protective device (fuse, etc). operate to isolate the faulty conductor from the rest of the system

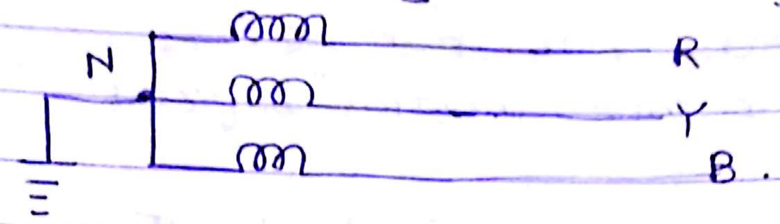
* Advantages of Neutral Grounding:

(1) Voltages of healthy phases do not exceed their Vph values. ie they remain nearly constant.
(2) The high voltages due to arching ground is eliminated.
(3). Protective relays can be provided for protection against earth faults.
(4) Overvoltages due to lightning are discharged to earth
(5) Greater safety to personnel & equipment.
(6) Improved service reliability
(7) Operating & maintainence expenditures are reduced

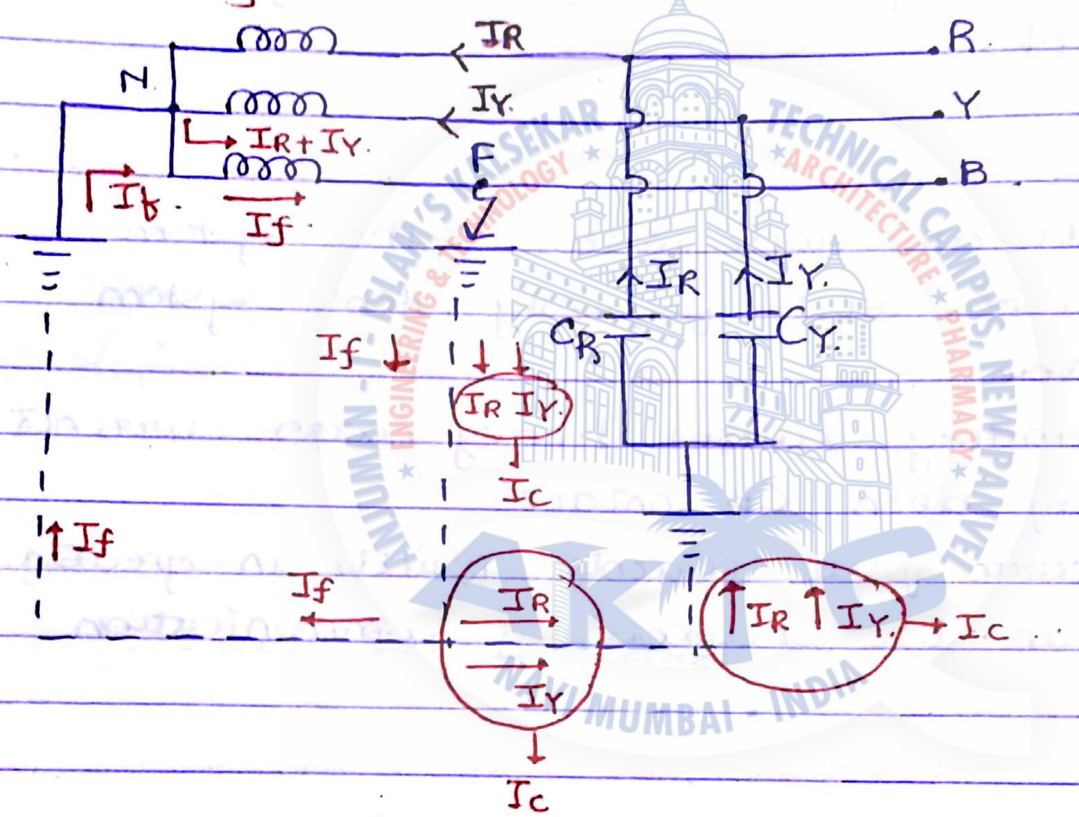
* Methods of neutral Grounding:

(i) Solid or effective grounding

When the neutral pt of a 3ϕ system (3ϕ generator, 3ϕ transformer) is directly connected to earth through a wire of negligible 'R' is called as solid grounding or effective grounding.



Advantages:



(1) Neutral is effectively earthed at ground potential.

(2) Consider (L-G) fault in 'B'. The capacitive currents flowing in healthy phases are IR & IY. Total capacitive current is Ic. Plus there is IF supplied by the power source.

Path of If : Point F – Ground – Neutral pt – winding – fault

Path of Ic : fault pt F – Ground – Respective Capacitance – line R & Y – neutral – [illegible] phase B

Prof. Tahoora Qureshi

$V \propto E$

$\therefore R \propto V$ $R = \frac{V}{I}$

Path of Ic is capacitive & If is inductive. Two currents are in phase opposition & cancell each other. ∴ No arching ground & no overvoltages.

3) Earth fault causes the faulted phase voltage to go zero E. But with this arrangement, the other two healthy phases will have the same voltage level because neutral is fixed at zero potential.

(4) Earth faults frequently occur. Earth fault relay can be provided with this type of arrangement.

Disadvantages:

(1) Most faults are earth faults so the system has to bear shocks frequently. Hence system goes unstable.

(2) Solid grounding causes heavy earth currents which may burn CB contact.

(3) Increased earth fault currents results in greater interference in the neighbouring communication lines

Applications:

(1) used where 'Z' of ckt is high to keep 'I' ↓.

(2) voltages upto 33KV. – Power Capacity 5000KVA.

(2) Resistance Grounding

→ When neutral point of 3ϕ system (eg 3ϕ Generator, 3ϕ Xmer) is connected to earth through resistor, it is called resistance grounding.

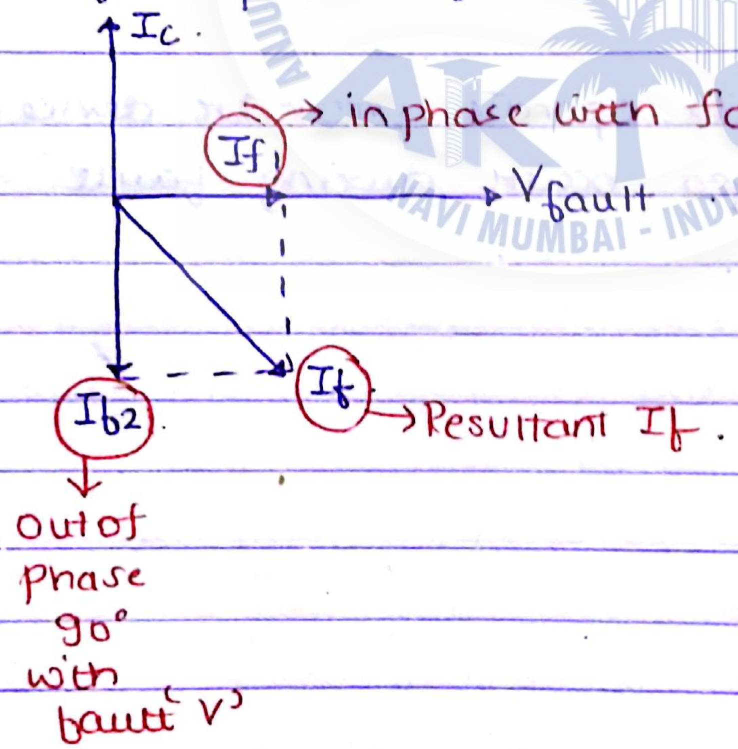
→ Value of 'R' should not be too low or too high.

- too low → acts like solid grounding with ↑ ground currents.
- too high → action like ungrounded system,

→ R is so selected that it limits the earth fault currents to 2 times the normal full load current.

Advantages:

(1) Suppose (E-(b)) fault occurs on B. We know If is inductive & it lags faulted voltage by 90° angle. depending upon value of 'R' & 'X' of system upto fault point. If can be resolved as.



So if $I_{b2} = I_c$ by adjusting 'R' system can be made to behave like solidly grounded system

(2) Earth fault current is ↓ due to 'R' ∴ ↓ interferance with communication ckt.

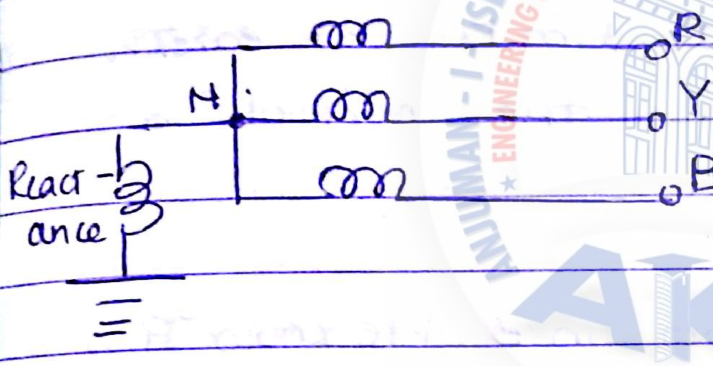
(3) Improves stability of the system.

Disadvantages:

(1) costlier.

(2) Large energy is generated in 'R' which has to be dissipated

* Reactance Grounding:



→ Same as that of Resistance Grounding. ↓ Earth fault current & by adjusting 'X' the current can be limited.

Disadvantages:

(1) Fault 'I' required to operate protective device is ↑ than 'R' grounding

(2) High transient voltages occur during fault condition.