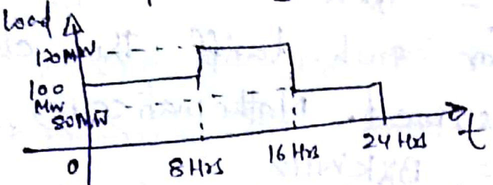
Department of Electrical Engineering

5th semester (E)

Subject - Power System-II

Q.1 (a) **Load curve:** It is plot of load vs time.



The load curve may be daily, weekly, monthly etc.

Load factor - It is defined as the ratio of average load to maximum load.

$$\text{Load factor} = \frac{100\times8 + 120\times8 + 80\times8}{120\times24} = \frac{300}{360} = 0.83$$

$$= 83\%$$

Demand factor - It is the ratio of maximum demand to the connected load.

Connected load = 2000W

Maximum load = 1500W

$$\text{Demand factor} = \frac{1500}{2000} = 0.75 \ (75\%)$$

Diversity factor - It is the ratio of sum of consumers maximum demand to maximum load on the plant.

Plant capacity factor - It is the ratio of the average annual load to the plant capacity.

Plant use factor - It is the ratio of the maximum demand to the rated plant capacity.

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b) Differt type of tariffs :

(i) Flat demand rate – For such tariff the charge depends only on the maximum demand irrespective of energy consumed. Mathematically, $C = A \times KW$

(ii) Straight meter rate – for such tariff the charge depends only on the energy consumed. Mathematically,

$$C = B \times KWHr$$

(iii) Two-part tariff – for such tariff the charge depends on both – the maximum demand and the energy consumed. Mathematically, $C = A \times KW + B \times KWHr$

(iv) Block rate tariff – for such tariff, the charge depends on both – the maximum demand and the energy consumed, but energy consumed is divided into different slabs for which the charge/unit are different. Mathematically, it is expressed as

$$C = A \times KW + B_1 \times KWH_1 + B_2 \times KWH_2 + \cdots\cdots$$

(v) Power factor tariff – Such tariff is charged against the consumers (usually industrial) who are responsible for worsening the power factor. If a consumer worsens power factor by 0.01 then proper cost is charged against him and so on. Besides this he must pay for the maximum demand and the energy consumed.

(2) Factors affecting the site of a hydel power plant:

a) Availability of water
b) Water storage
c) Head of water
d) Accessibility of site
e) Environmental effects.

Classification according to available head:-

a) low head plants - When head of water is less than 30m, then such plant is called low head hydel power plant. A dam across the river creates the necessary head. The power plant is located near dam. No surge tank is required. Francis or Kaplan turbines are used.

b) Medium head plants - When the head of water is between 30m and 300m, then such plant is called medium head plants. A dam across the river or hilly areas create the necessary head. An open channel carries water from main reservoir to the forebay from where penstock carry water to turbine. Surge tank may or may not be employed according to available head. Francis or Kaplan turbines are used.

c) High head plants - for such plants the available head is greater than 300m. Such plants are located in hilly areas. Dam is constructed to provide storage of water. Penstock carries the stored water to turbine. Surge tank (s) is mandatory. Pelton turbine is used for such plants.

Classification according to available load :

a) Base load plant – Such plants feed the base load of the system. They supply almost constant load throughout and so operate on high load factor. Such plants are of large capacity. Run-off river plants without pondage and reservoir plants are base load plants. Tariff for such plant is lower.

b) Peak load plant – Such plants feed the peak load of the system. They supply load for short duration of time in a period. Such plants are of small capacity. Run-off river plants with pondage are peak load plants. They operate at low load factor.

c) Pumped storage plant – Such plants are special type of peak load plants and are employed when the available water is very much limited. Such plants are reversible. During peak load period, they operate as peak-load plants and use the stored water for power generation. During off-peak period the plant operates in reverse mode i.e. pumps back the water of tail race into head race. The required energy is taken from some base load plant.

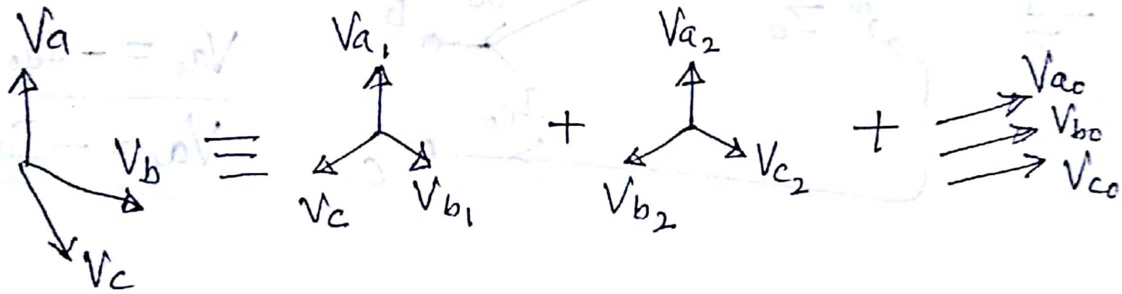
(3) The theory of symmetrical components — It states that a system consisting of three unbalanced phasors can be resolved into Positive sequence Component (PSC), Negative sequence component (NSC) and Zero Sequence component (NSC) whse,

PSC $\triangleq$ the balanced 3-ϕ component which sequence is same as that of the original 3-ϕ unbalanced system.

NSC $\triangleq$ the balanced 3-ϕ component which sequence is reverse of that of the original 3-ϕ unbalanced system.

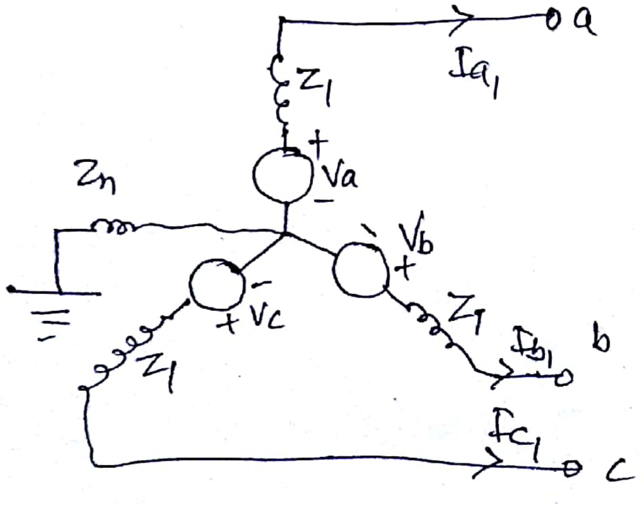
ZSC $\triangleq$ the set of three equal and in-phase vectors

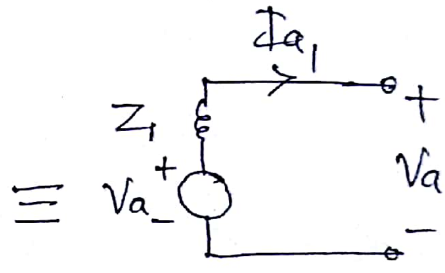
3-ϕ UBS $\equiv$ PSC + NSC + ZSC



Sequence networks of unloaded 3-ϕ alternator:

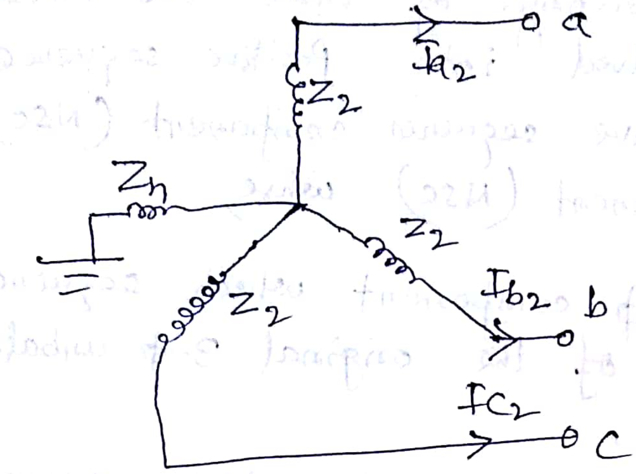
a) Positive Sequence network:





$$V_{a_1} = V_a - I_{a_1} Z_1$$

b) Negative sequence network:



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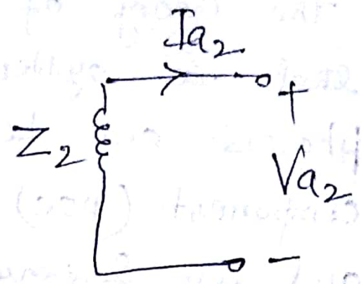
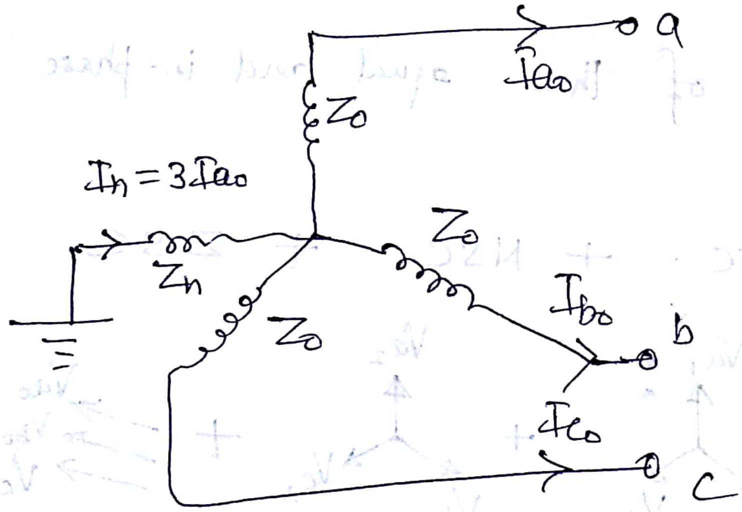


$$V_{a_2} = -I_{a_2} Z_2$$

c) Zero sequence network



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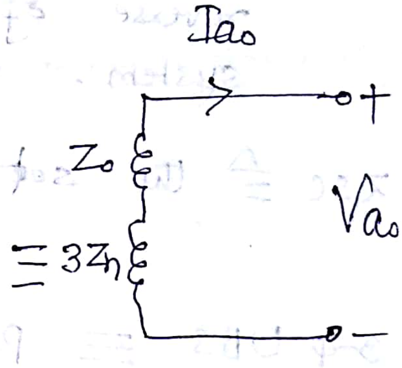
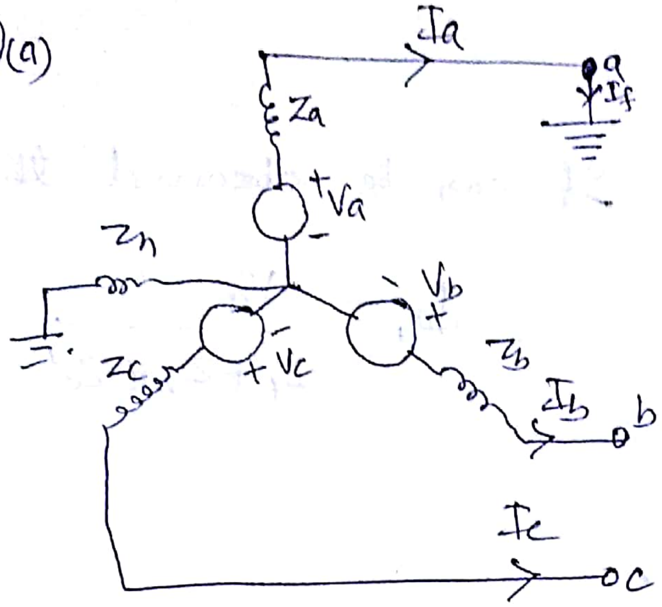


$$V_{a_0} = -I_{a_0}(Z_0 + 3Z_n)$$

$$V_{a_0} = -I_{a_0} Z_0'$$

4 (a)



Such fault (L-G) is represented by equations:

$$V_a = 0, \quad I_b = 0, \quad I_c = 0$$

Applying the theory of symmetrical components to current-phasors:

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix}\begin{bmatrix} I_a \\ 0 \\ 0 \end{bmatrix}$$

$$= \begin{bmatrix} I_a/3 \\ I_a/3 \\ I_a/3 \end{bmatrix}$$

$$\Rightarrow \quad I_{a0} = I_{a1} = I_{a2} \quad \ldots\ldots (1)$$

Also,

$$V_a = 0$$

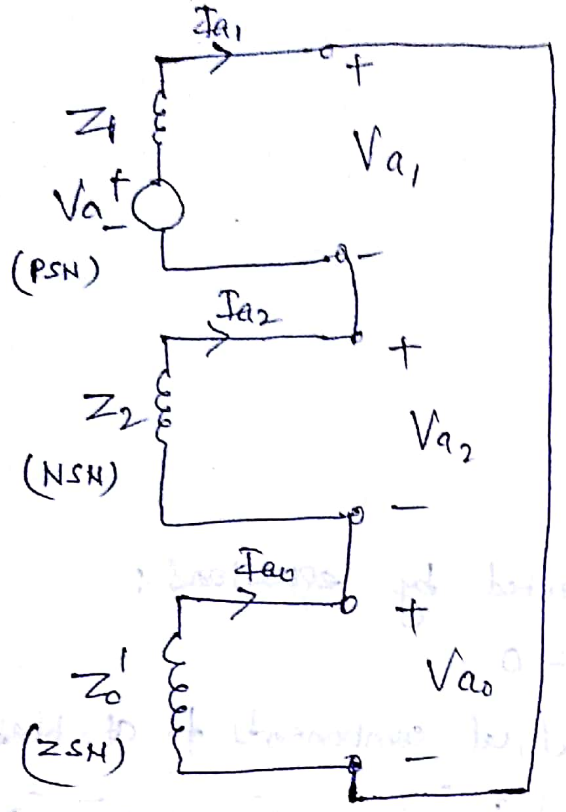
$$V_{a1} + V_{a2} + V_{a0} = 0$$

$$V_a - I_{a1}Z_1 - I_{a2}Z_2 - I_{a0}Z_0' = 0$$

$$V_a - I_{a1}Z_1 - I_{a1}Z_2 - I_{a1}Z_0' = 0$$

$$I_{a1} = \frac{V_a}{Z_1 + Z_2 + Z_0'} \quad \ldots\ldots (2)$$

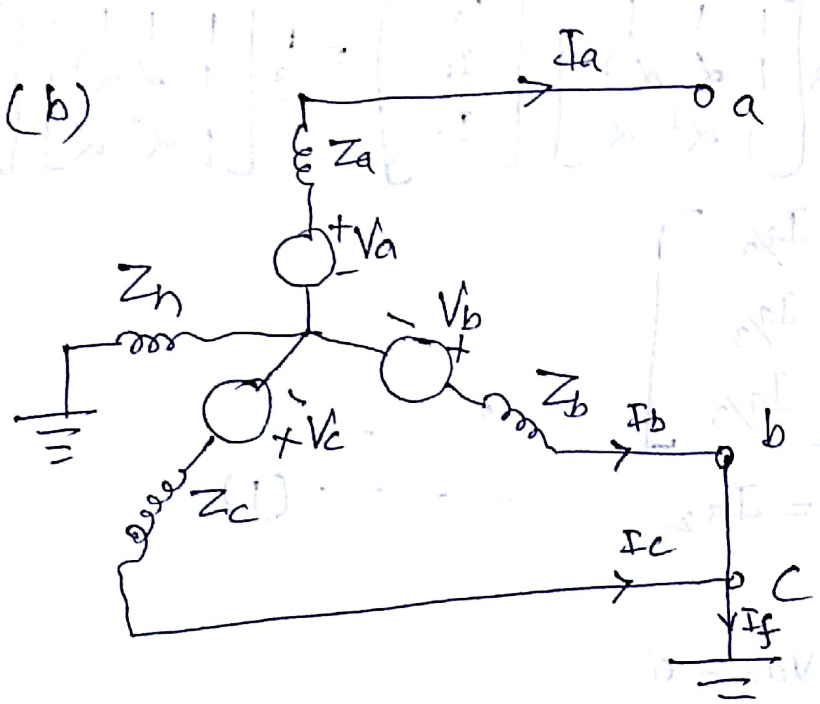
From (1) and (2) we conclude that for L-G fault PSN, NSN and ZSN must be connected in series as:



It can be observed that

$$I_{a_1} = \frac{V_a}{Z_1 + Z_2 + Z_0'}$$

(b)



The LL-G fault is characterized by electrical equations

$$V_b = V_c = 0 \quad \text{and} \quad I_a = 0$$

Applying the theory of symmetrical component to voltage-phasors:-

$$\begin{bmatrix} V_{a_0} \\ V_{a_1} \\ V_{a_2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \begin{bmatrix} V_a \\ 0 \\ 0 \end{bmatrix}$$

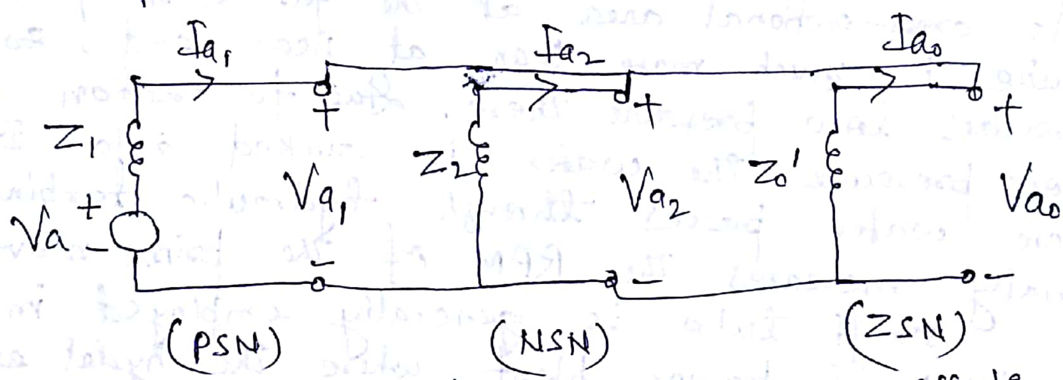
$$= \begin{bmatrix} V_a/3 \\ V_a/3 \\ V_a/3 \end{bmatrix}$$

$$\Rightarrow V_{a_0} = V_{a_1} = V_{a_2} \quad \cdots\cdots (1)$$

Also, $I_a = 0$

$$I_{a_1} + I_{a_2} + I_{a_0} = 0 \quad \cdots\cdots (2)$$

From (1) and (2) it is concluded that for LL-G fault PSN, NSN and ZSN must be connected in parallel, as:



5 (a) Condenser — It is an apparatus that effects condensation of the steam exhausted from turbine. It helps in maintaining low pressure at the exhaust thereby allowing the increased expansion of steam in the turbine to a very low pressure. This helps in increasing the RPM of the prime mover. Ultimately it improves the plant efficiency. The exhaust steam is condensed and is pumped back to the boiler by boiler feed pump. Maintenance of high vacuum in condenser is essential for efficient operation. Any leakage of air into condenser destroys the vacuum.

Modern TPP use surface condenser. It consists of an air-tight cylindrical shell having a chamber at each end. Water tubes extend between the chambers. Cooling water flows through the tubes. The steam is admitted from the top and gets condensed due to contact with the tube surfaces. The condensed steam leaves from bottom. For efficient operation the rise of temperature in cooling water should be around 10°C.

b) Draft tube – It is a divergent tube made of concrete and is fitted at exhaust terminal of the reaction turbine.

Tail race.

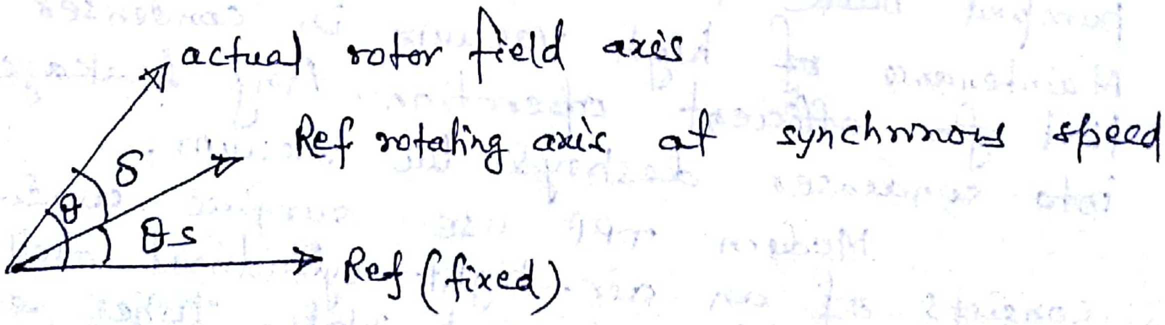
As cross-sectional area at the far end of draft tube is much more than at near end, so it provides low pressure there. Due to creation of low pressure the water is sucked into it and more water passes through hydraulic turbine. This finally increases the RPM of the prime mover.

Draft tube is generally employed in low-head hydel power plant, where the hydel energy ~~level~~ is of poor level.

c) Swing Equation – If some load is added to a synchronous machine the rotor will decelerate and if some load is removed the rotor will accelerate.

i.e. $J\frac{d^2\theta}{dt^2} = T_m - T_e$ (Alternator)

$= T_e - T_m$ (Motor)



Now, $\theta = \theta_s + \delta = \omega_s t + \delta$

$$\frac{d\theta}{dt} = \omega_s + \frac{d\delta}{dt}$$

$$\frac{d^2\theta}{dt^2} = \frac{d^2\delta}{dt^2}$$

So, $J\frac{d^2\delta}{dt^2} = T_m - T_e$ (Alternator)

$= T_e - T_m$ (Motor)

or, $J\omega\frac{d^2\delta}{dt^2} = \omega(T_m - T_e) = P_m - P_e$ (Alternator)

$= \omega(T_e - T_m) = P_e - P_m$ (Motor)

As per the concept of H-constant,

$$H = \frac{\text{stored KE in MJ}}{\text{Rating in MVA}} = \frac{SKE}{G}$$

or, $GH = SKE = \frac{1}{2}mv^2 = \frac{1}{2}m(\omega r)^2$

$= \frac{1}{2}(mr^2)\omega^2 = \frac{1}{2}J.\omega^2$

$= \frac{1}{2}(J.\omega)\omega = \frac{1}{2}M.\omega$

or, $M = \frac{2GH}{\omega} = \frac{2GH}{2\pi f} = \frac{GH}{\pi f}$

So, the swing equation in terms of inertia constant is

$$\frac{GH}{\pi f} = P_m - P_e \text{ (Alternator)}$$

$$= P_e - P_m \text{ (Motor)}$$