UNIT - II

UNSYMMETRICAL FAULTS

Introduction :- The unsymmetrical faults will have faulty parameters at random. They can be analysed by using the symmetrical components. The standard types of unsymmetrical faults considered for analysis include the following —

Line-to-ground (L-G) fault

Line-to-Line (L-L) fault

Double Line-to-Ground (L-L-G) Fault

Three-phase-to-Ground (LLL-G) Fault

Further the neutrals of various equipment may be grounded or isolated, the faults can occur at any general point 'F' of the given system, the faults can be through a fault impedance, etc. Of the various types of faults as above, the 3-ϕ fault involving the ground is the most severe one.

In the analysis of unsymmetrical faults, the following assumptions will be made—

1) The generated emf system is of positive seq. only

2) No current flows in the network other than due to fault i.e. load current are neglected (no load)

Consider now the symmetrical relation equations derived from the three sequence networks corresponding to a given unsymmetrical system as a fn. of seq. impedances and the positive seq. voltage source in the form as under —

$$\left.\begin{aligned} V_{a0} &= -I_{a0}Z_0 \\ V_{a1} &= E_a - I_{a1}Z_1 \\ V_{a2} &= -I_{a2}Z_2 \end{aligned}\right\} \longrightarrow (1)$$

In matrix form —

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \begin{bmatrix} 0 \\ E_a \\ 0 \end{bmatrix} - \begin{bmatrix} Z_0 & 0 & 0 \\ 0 & Z_1 & 0 \\ 0 & 0 & Z_2 \end{bmatrix} \begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} \longrightarrow (2)$$

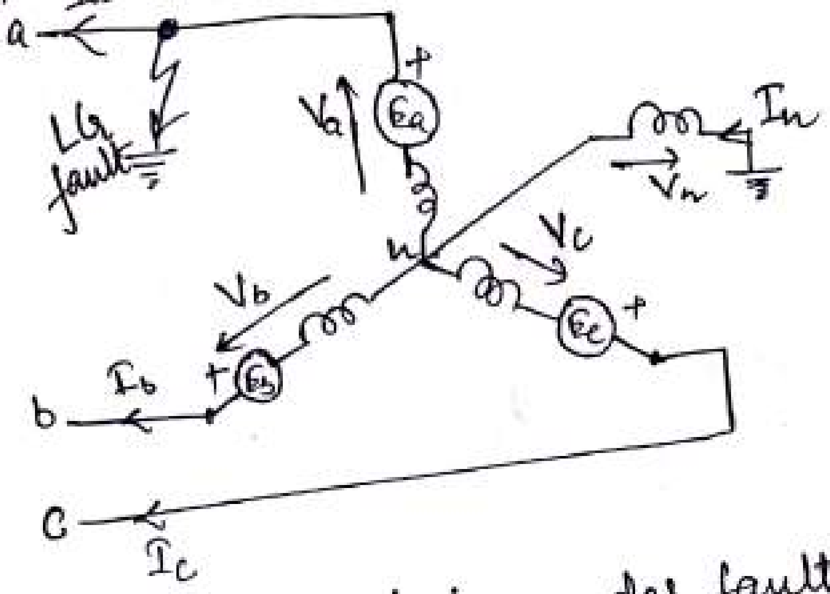
During unsymmetrical fault analysis of any given type of fault, two sets of equations as follows are considered for solving them simultaneously to get the required fault parameters —

1) Equations for the conditions under fault
2) Equ. for the ~~cond~~ sequence components as per equ. (2)

Single Line to Ground Fault (L-G) on a Conventional (Unloaded) Generator :

Let E_a, E_b and E_c be the internally generated voltages and Z_n be the neutral impedance.

The fault is assumed to be on the phase 'a' as shown in fig.



Now consider the conditions under fault —

$I_a = I_a,\ I_b = 0,\ I_c = 0\ \&\ V_a = 0 \longrightarrow (3)$

Now consider the symmetrical components of the current I_a with $I_b = I_c = 0$ given by

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix}\begin{bmatrix} I_a \\ 0 \\ 0 \end{bmatrix} \longrightarrow (4)$$

from equ. (4)

$$I_{a1} = I_{a2} = I_{a0} = I_a/3 \longrightarrow (5)$$

From equ. (2) & (5), we get

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \begin{bmatrix} 0 \\ E_a \\ 0 \end{bmatrix} - \begin{bmatrix} Z_0 & 0 & 0 \\ 0 & Z_1 & 0 \\ 0 & 0 & Z_2 \end{bmatrix}\begin{bmatrix} I_{a1} \\ I_{a1} \\ I_{a1} \end{bmatrix} \longrightarrow (6)$$

Pre-multiplying equ. (6) by [1 1 1], we get

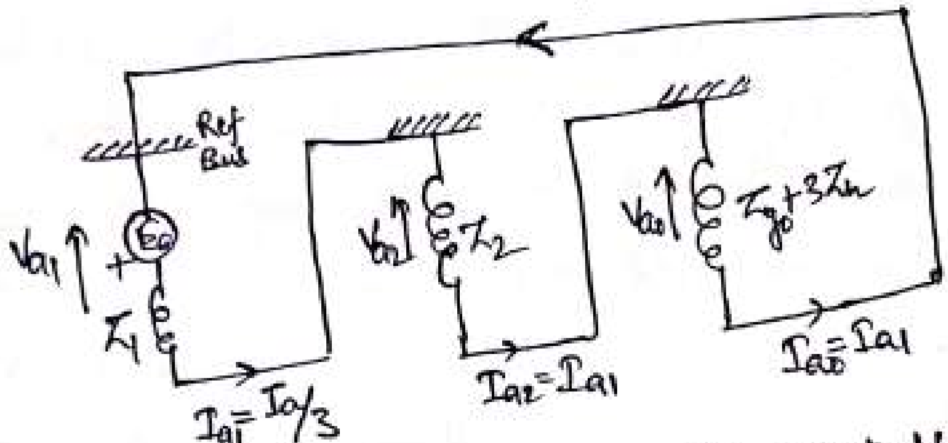
$$V_{a1} + V_{a2} + V_{a0} = -I_{a1}Z_0 + E_a - I_{a1}Z_1 - I_{a2}Z_2$$

i.e.
$$V_a = E_a - I_{a1}(Z_1+Z_2+Z_0) = 0 \quad (\text{from equ. } 3)$$

In other words

$$\boxed{I_{a1} = \frac{E_a}{Z_1+Z_2+Z_0}} \rightarrow (7)$$

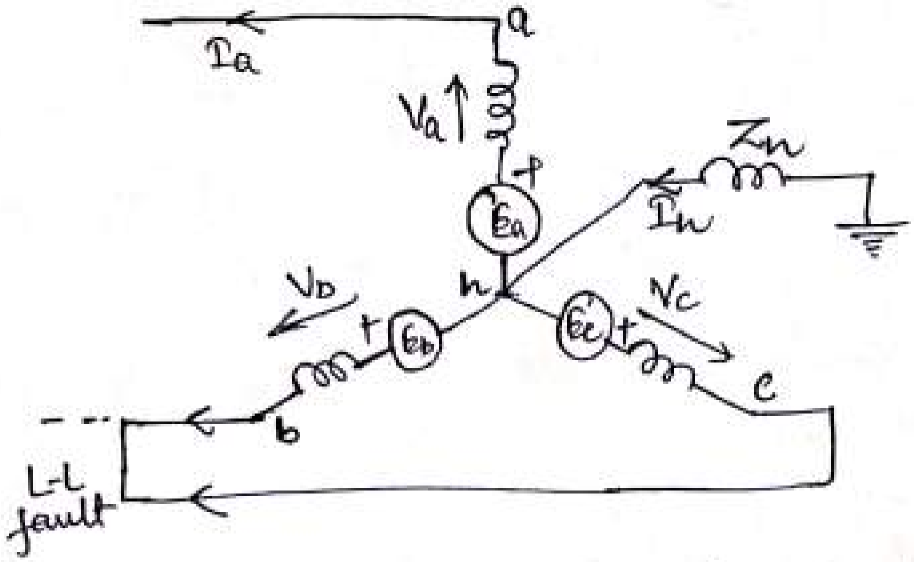
Sequence n/w for L-G fault on Phase 'a' of a unloaded Generator :



Equ. (7) derived as above implies that the three seq. networks are connected in series to simulate a LG fault. Further the following relations satisfied under the fault conditions —

1) $I_{a1} = I_{a2} = I_{a0} = I_a/3 = E_a/(Z_1+Z_2+Z_0)$
2) Fault Current $I_f = I_a = 3I_{a1} = 3E_a/(Z_1+Z_2+Z_0)$
3) $V_{a1} = E_a - I_{a1}Z_1 = E_a(Z_2+Z_0)/(Z_1+Z_2+Z_0)$
4) $V_{a2} = -E_a Z_2/(Z_1+Z_2+Z_0)$
5) $V_{a0} = -E_a Z_0/(Z_1+Z_2+Z_0)$
6) Fault Phase Voltage $V_a = 0$
7) Other Phase voltages
$V_b = \alpha^2 V_{a1} + \alpha V_{a2} + V_{a0}$
$V_c = \alpha V_{a1} + \alpha^2 V_{a2} + V_{a0}$
8) If $Z_n = 0$ then $Z_0 = Z_{g0}$
If $Z_n = \infty$ then $Z_0 = \infty$

Line to Line Fault on a Unloaded Generator :



Consider a line-to-line (L-L) fault between phase 'b' and 'c' as shown in fig., at the terminals of a conventional (unloaded) generator, whose neutral is grounded through a reactance. Consider now the conditions under fault as under —

Condition under fault —

$$I_a = 0,\ I_b = -I_c \text{ and } V_b = V_c \longrightarrow (8)$$

Now consider the symmetrical components of the voltage V_a with $V_b = V_c$, given by —

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_b \end{bmatrix} \longrightarrow (9)$$

After solving eqn (9)

$$V_{a1} = V_{a2} \longrightarrow (10)$$

Now symmetrical components of current

$\therefore$

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \alpha & \alpha^2 \\ 1 & \alpha^2 & \alpha \end{bmatrix}\begin{bmatrix} 0 \\ I_b \\ -I_b \end{bmatrix} \longrightarrow (11)$$

from equ. (11)

$$I_{a0} = 0 \;\&\; I_{a2} = -I_{a1} \longrightarrow (12)$$

Using equ. (10) & (12) in equ. (2) & since $V_{a0} = 0$ (I_{a0} being 0), we get —

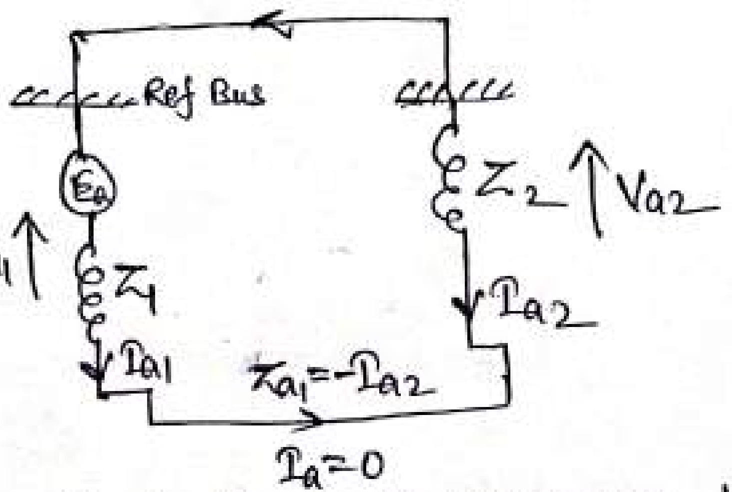
$$\begin{bmatrix} 0 \\ V_{a1} \\ V_{a1} \end{bmatrix} = \begin{bmatrix} 0 \\ E_a \\ 0 \end{bmatrix} - \begin{bmatrix} Z_0 & 0 & 0 \\ 0 & Z_1 & 0 \\ 0 & 0 & Z_2 \end{bmatrix}\begin{bmatrix} 0 \\ I_{a1} \\ -I_{a1} \end{bmatrix} \longrightarrow (13)$$

Pre-multiplying equ. (13) throughout by [0 1 -1] we get,

$$V_{a1} - V_{a1} = E_a - I_{a1}Z_1 - I_{a1}Z_2 = 0$$

or

$$\boxed{I_{a1} = \frac{E_a}{(Z_1 + Z_2)}} \longrightarrow (14)$$



Equ. (14) shows that the three sequence N/W's are connected such that the zero sequence N/W is absent and only the positive and negative seq. N/W's are connected in series-opposition to simulate the L-L fault as shown in above fig.

Further the following relations satisfied under the L-L fault condⁿ —

1) $I_{a1} = -I_{a2} = E_a/(Z_1+Z_2)$ & $I_{a0} = 0$

2) Fault Current $I_f = I_b = -I_c = \left[\sqrt{3}\ E_a/(Z_1+Z_2)\right]$

3) $V_{a1} = E_a - I_{a1}Z_1 = E_a Z_2/(Z_1+Z_2)$

4) $V_{a2} = V_a = E_a Z_2/(Z_1+Z_2)$

5) $V_{a0} = 0$

6) Fault phase voltage $V_b = V_c = \alpha V_{a1} + \alpha^2 V_{a2} + V_{a0}$

$$= (\alpha+\alpha^2)V_{a1}$$

$$= -V_{a1}$$

7) $V_a = V_{a1} + V_{a2} + V_{a0} = 2V_{a1}$