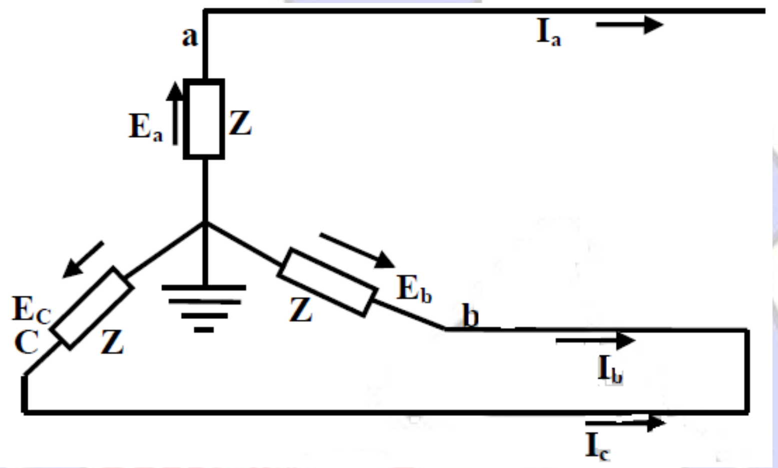
1- Line-To-Line Fault (L-L Fault):

The line to line fault takes place on phases 'b' and 'c'
The boundary conditions are

$V_b = Z_f I_b + V_c$ ……………………………….1
$I_b = -I_c$ or $I_b + I_c = 0$ ………………………..2
Vb=Vc, $I_a = 0$ ……………………………..3



The sequence network equations are:

$V_a^0 = 0 - Z^0 I_a^0$

$V_a^1 = E_a - Z^1 I_a^1$

$V_a^2 = 0 - Z^2 I_a^2$

The solution of these six equations will give six unknowns V_{a0}, V_{a1}, V_{a2}, and I_{ao}, $I_{a1}$and I_{a2}

$$\begin{bmatrix} I_a^0 \\ I_a^1 \\ I_a^2 \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} 0 \\ I_b \\ -I_b \end{bmatrix}$$

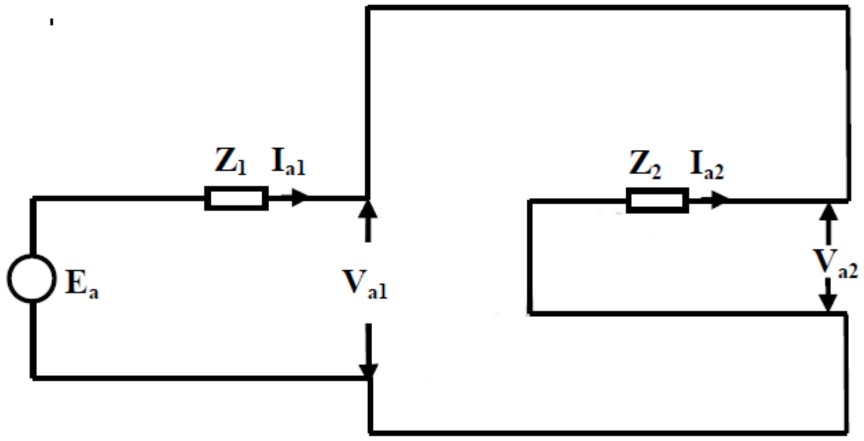
Expanding the matrix equation we have:

$I_a^0 = (1/3)\ [0 + I_b - I_b]$
$I_a^0 = 0$ ……………………………….4

$I_a^1 = (1/3)\ [0 + a I_b - a2\ I_b]$
$= (1/3)\ [a - a^2]\ I_b$ …………………………5
$I_a^2 = (1/3)\ [0 + a^2 I_b - a I_b]$
$= (1/3)\ [a^2 - a]\ I_b$ …………………………6
From 5&6 we have

$I_a^1 = -I_a^2$ ……………………………7

Which means for a line to line fault the zero sequence component of current is absent and positive sequence component of current is equal in magnitude but opposite in phase to negative sequence component of current, i.e., Transform equation 1 in terms of symmetrical components we have



$V_b = a^2V_a^1 + aV_a^2 + V_a^0$ …..8

$V_C = aV_a^1 + a^2V_a^2 + V_a^0$ ……9

Substituting the equations (8) and (9) equations (3)

$a^2 V_a^1 + a V_a^2 + V_a^0 = aV_a^1 + a^2V_a^2 + V_a^0$

$\therefore V_a^1 = V_a^2$ ….10

i.e., positive sequence component of voltage equals the negative sequence component of voltage. This also means that the two sequence networks are connected in opposition. Now making use of the sequence network equation and the equation (11) $\therefore V_a^1 = V_a^2$.

$E_a - I_a^1 Z_1 = -I_a^2 Z^2 = I_a^1 Z_2$

$$I_a^1 = \frac{E_a}{Z_1 + Z_2}$$

$I_f = I_b = -I_c = a^2I_a^1 + aI_a^2 + I_a^0$ ($I_a^2 = -I_a^1$, $I_a^0 = 0$)

$=(a^2-a)I_a^1 = -J\sqrt{3}\, I_a^1$

$$= \frac{-J\sqrt{3}E_a^1}{Z1+Z2}$$

NOTE:

1. The connection of sequence currents are connected in parallel.
2. The phase difference between I_a^1 and I_a^2 for line – to – line fault should be 180° (Ia1 = Ia2).

Line to Line fault with Z_f

$$I_f = \frac{-J\sqrt{3}\, E_a^1}{Z_1 + (Z_2 + Z_f)}$$