Contoh:

Tentukan komponen simetris untuk tegangan fasa $V_a = 7{,}3 \angle 12{,}5^\circ$, $V_b = 0{,}4 \angle -100^\circ$ dan $V_c = 1{,}4 \angle 154^\circ$ V.

jawab:

$$V_{a0} = \frac{1}{3}(V_a + V_b + V_c)$$

$$= \frac{1}{3}(7{,}3\angle 12{,}5^\circ + 0{,}4\angle -100^\circ + 4{,}4\angle 154^\circ = 1{,}47\angle 45{,}1^\circ V$$

$$V_{a1} = \frac{1}{3}(V_a + a V_b + a^2 V_c) .$$

$$\frac{1}{3}[(7{,}3\angle 12{,}5^\circ + (1\angle 120^\circ)(0{,}4\angle -100^\circ) + (1\angle 240^\circ)(4{,}4\angle 15$$

$$= 3{,}97\angle 20{,}5^\circ V .$$

$$V_{a2} = \frac{1}{3}(V_a + a^2 V_b + a V_c) .$$

$$= \frac{1}{3}[7{,}3\angle 12{,}5^\circ + (1\angle 240^\circ)(0{,}4\angle -100^\circ) + (1\angle 120^\circ)(4{,}4\angle 154$$

$$= 2{,}52\angle -19{,}7^\circ V .$$

$$V_{b0} = V_{a0} = 147\angle 45{,}1^\circ V .$$

$$V_{b1} = a^2 V_{a1} = (1\angle 240^\circ)(3{,}97\angle 20{,}5^\circ) = 3{,}97\angle 260{,}5^\circ V .$$

$$V_{b2} = a V_{a2} = (1\angle 120^\circ)(2{,}52\angle -19{,}7^\circ) = 2{,}52\angle 100{,}3^\circ V .$$

$$V_{c0} = V_{a0} = 1{,}47\angle 45{,}1^\circ V .$$

$$V_{c1} = a V_{a1} = (1\angle 120^\circ)(3{,}97\angle 20{,}5^\circ) = 3{,}97\angle 140{,}5^\circ V .$$

$$V_{c2} = a^2 V_{a2} = (1\angle 240^\circ)(2{,}52\angle -19{,}7^\circ) = 2{,}52\angle 220{,}3^\circ V$$

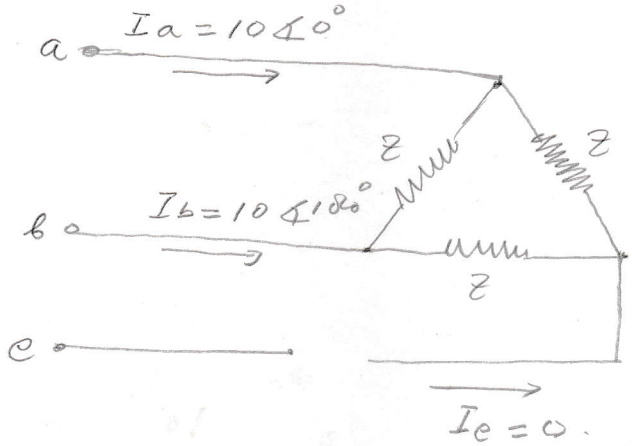
PR.

Tentukan komponen simetris untuk arus fasa.

$I_a = 125\angle 20^\circ$; $I_b = 175\angle -100^\circ$ dan $I_c = 95\angle 155^\circ$ A.

Soal : PR :

Suatu penghantar saluran tiga fase terbuka.
Arus yg mengalir ke beban yg dihubungkan Δ, melalui saluran a mengalir arus 10 A.
Melalui saluran B mengalir arus $10 \angle 180^\circ$ A.
Dengan arus dalam saluran a sbagai pedoman dan dg memisalkan bahwa saluran C terbuka : hit gb.

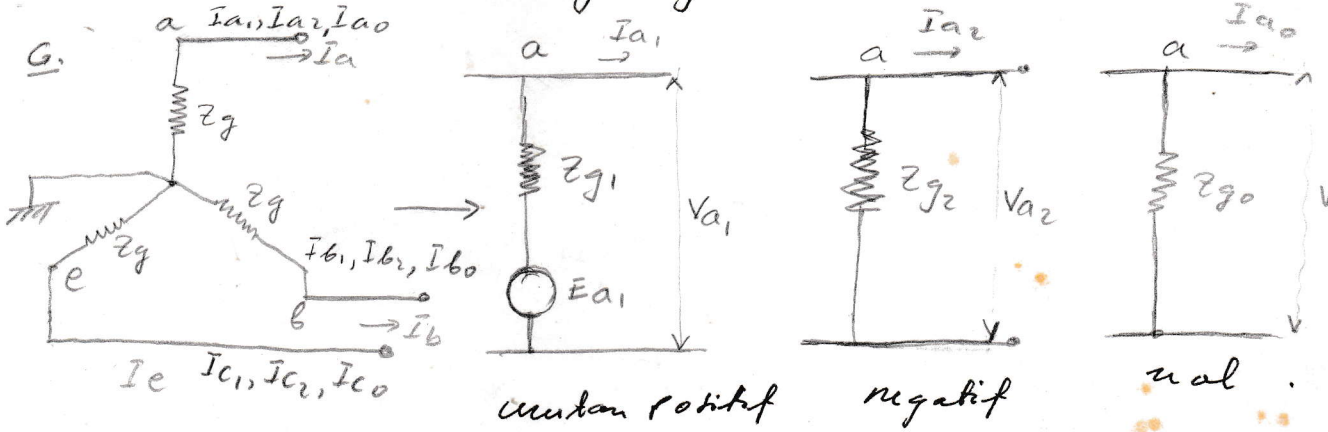


Hitunglah komponen2 simetrisnya arus saluran.

Komponen simetris digunakan untuk menganalisa sistem yg tidak seimbang misalnya pada saat terjadi hubung singkat 2 fase dan 1 fase.
Suatu komponen untuk arus menyebabkan tegangan jatuh sesuai dengan untuk arus nya dan tidak mempengaruhi untuk arus lainnya, berarti ada untuk yg seimbang yaitu untuk positip, negatif dan nol akan terdiri suatu jaringan dg untuk yang sesuai.
Artinya adanya ketidak seimbangan arus atau tegangan menimbulkan impedans untuk yaitu. untuk positif negatif dan nol.

untuk jaringan suatu Generator:

Generator ditanahkan langsung:



untuk positif negatif nol.

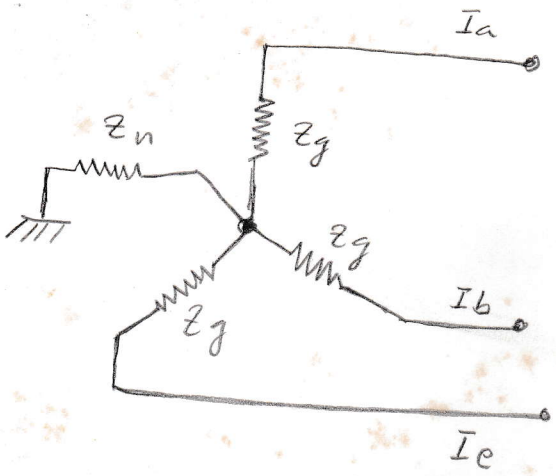
Persamaan tegangan:

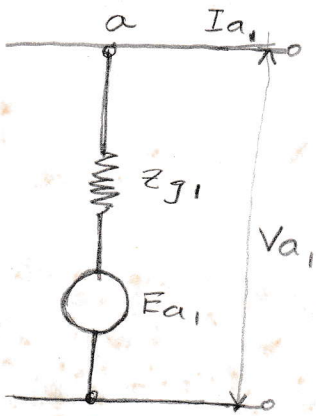
$V_{a1} = E_{a1} - I_{a1} \cdot Z_{g1}$ → $I_{a1} \cdot Z_{g1}$ merupakan tegangan jatuh.

$V_{a2} = - I_{a2} \cdot Z_{g2}$

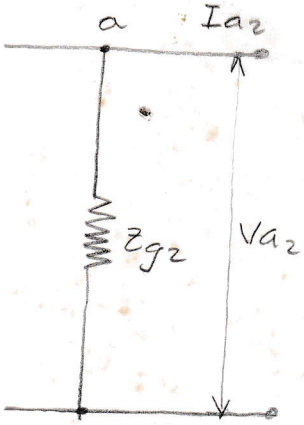
$V_{a0} = - I_{a0} \cdot Z_{g0}$

Generator ditanahkan melalui impedansi (Z_n)

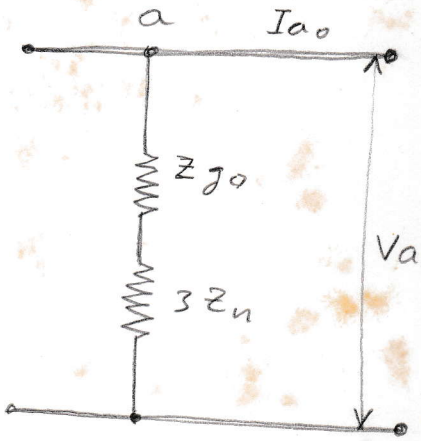




Positif



Negatif



Nol.

Persamaan tegangan:

$V_{a_1} = E_{a_1} - I_{a_1} Z_{g_1}$

$V_{a_2} = - I_{a_2} Z_{g_2}$

$V_{a_0} = - I_{a_0} Z_0 \rightarrow Z_0 = Z_{g_0} + 3 Z_n$.

Gangguan pada Generator tak berbeban:

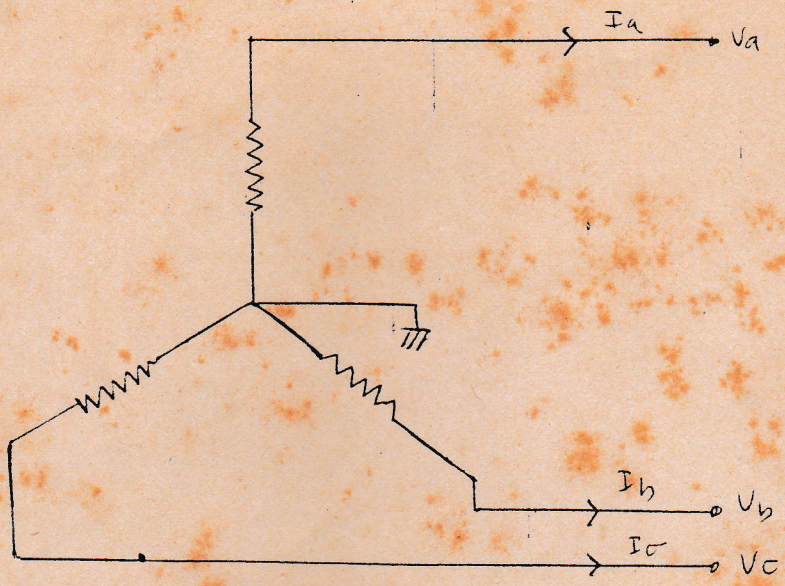
Generator beroperasi tidak berbeban terjadi gangguan:

- hubung singkat satu fasa ke tanah (1ϕ-G)
- hubung singkat dua fasa ketanah (1ϕ-1ϕ-G)
- hubung singkat tiga saluran ketanah (3ϕ-G).
- hubung singkat antar fasa-fasa (ϕ-ϕ).
- hubung singkat tiga fasa (3ϕ-F).

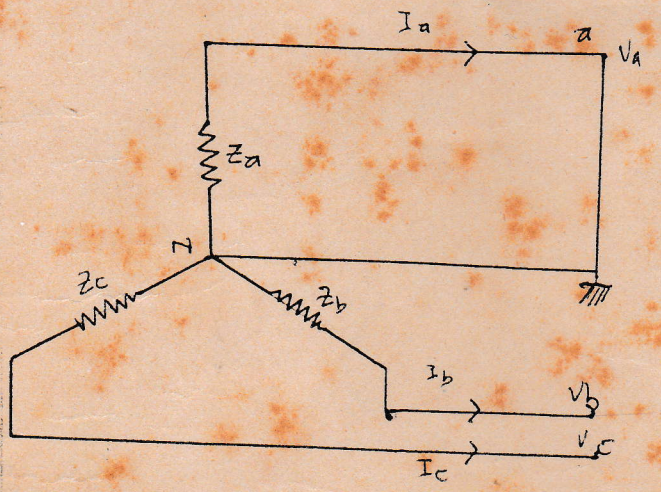
Generator netralnya ditanahkan secarang langsung.
Generator netralnya ditanahkan melalui impedansi.

Maka persamaan-persamaan arus dan tegangan dapat dihitung sebagai berikut:

I NETRAL GENERATOR DITANAHKAN SOLID



I·1. HUBUNG. SINGKAT SATU FASA KE TANAH (SINGLE LINE TO GROUND FAULT)



Persamaan - persamaan pada titik gangguan :

$$V_a = 0 \qquad (1)$$

$$I_b = 0 \qquad (2)$$

$$I_c = 0 \qquad (3)$$

dari (2) dan (3)

$$I_{a0} = \tfrac{1}{3}(I_a + I_b + I_c) = \tfrac{1}{3} I_a$$

$$I_{a1} = \tfrac{1}{3}(I_a + aI_b + a^2 I_c) = \tfrac{1}{3} I_a$$

$$I_{a2} = \tfrac{1}{3}(I_a + a^2 I_b + aI_c) = \tfrac{1}{3} I_a$$

Sehingga

$$I_{a0} = I_{a1} = I_{a2} = \tfrac{1}{3} I_a \longrightarrow I_a = 3 I_{a1}$$

Gangguan pada fasa b

$V_b = 0$, $I_a = 0$, $I_c = 0$

I_b, aI_c, $a^2 I_a$

$I_{b0} = \tfrac{1}{3}(I_b + I_c + I_a)$

$I_{b1} = \tfrac{1}{3}(I_b + aI_c + a^2 I_a)$

$I_{b2} = \tfrac{1}{3}(I_b + a^2 I_c + aI_a)$

$I_{b0} = \tfrac{1}{3} I_b$, $I_{b1} = \tfrac{1}{3} I_b$, $I_{b2} = \tfrac{1}{3} I_b$

$I_{b0} = I_{b1} = I_{b2} = \tfrac{1}{3} I_b$

$V_b = V_{b1} + V_{b2} + V_{b0} = 0 \rightarrow V_{b1} = -(V_{b0} + V_{b2}) \rightarrow V_{b1} = -(-I_{b0} z_0 - I_{b2} z_2)$

$V_{b1} = I_{b0} z_0 + I_{b2} z_2 \rightarrow V_{b1} = I_{b1}(z_0 + z_2) \rightarrow V_{b1} = E_b - I_{b1} z_1$

$E_b - I_{b1} z_1 = I_{b1}(z_0 + z_2) \rightarrow E_b = I_{b1}(z_0 + z_1 + z_2) \rightarrow I_{b1} = \frac{E_b}{z_0 + z_1 + z_2}$

$I_b = 3 I_{b1} = \frac{3 E_b}{z_0 + z_1 + z_2}$

dari (1)

$V_a = V_{a1} + V_{a2} + V_{a0} = 0 \rightarrow V_{a1} + V_{a2} + V_{a0} = 0$

$V_{a1} = -(V_{a0} + V_{a2})$ $\quad V_{a1} = -(V_{a2} + V_{a0})$

$V_{a1} = -(-I_{a0} z_0 - I_{a2} z_2)$

$= I_{a0} z_0 + I_{a2} z_2$

$V_{a1} = I_{a1}(z_0 + z_2)$

Dari persamaan Umum

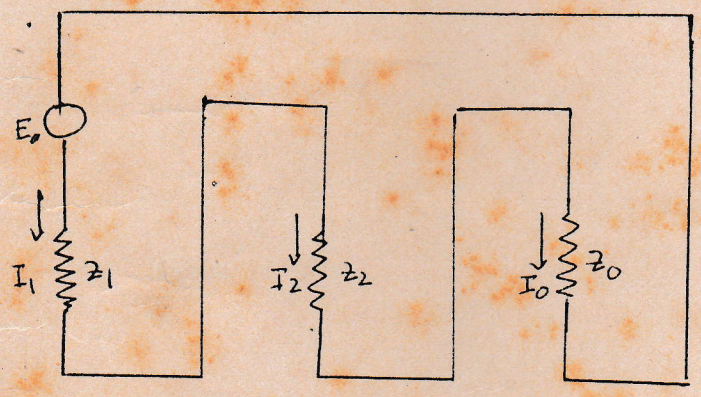
$V_{a1} = E_a - I_{a1} z_1$

$I_{a1}(z_0 + z_2) = E_a - I_{a1} z_1$

$I_{a1}(z_0 + z_1 + z_2) = E_a$

$$I_{a1} = \frac{E_a}{z_0 + z_1 + z_2} = I_{a0} = I_{a2}$$

Rangkaian ekuivalennya :



1 ϕ

dan

$V_{a0} = -I_{a0} z_0 = -I_{a1} z_0 \rightarrow I_{a1} = I_{a2} = I_{a0}$

$$V_{a0} = -\frac{z_0}{z_0 + z_1 + z_2} E_a$$

$$V_{a1} = E_a - I_{a1} z_1 = E_a - \frac{z_1}{z_0 + z_1 + z_2} E_a \times \left[\frac{z_0 + z_1 + z_2}{z_0 + z_1 + z_2}\right] E_a$$

$$= \frac{(z_0 + z_1 + z_2 - z_1) E_a}{z_0 + z_1 + z_2}$$

$$V_{a1} = \frac{z_0 + z_2}{z_0 + z_1 + z_2} E_a$$

$$V_{a2} = -I_{a2} z_2 = -I_{a1} z_2 = -\frac{z_2}{z_0 + z_1 + z_2} E_a$$

$\frac{E_a}{z_0 + z_1 + z_2} = I_{a1}$

arus gangguan I_f

$$I_f = I_a = I_{ao} + I_{a1} + I_{a2} = \frac{3E_a}{Z_0 + Z_1 + Z_2} \Longrightarrow I_f = 3I_{a1}$$

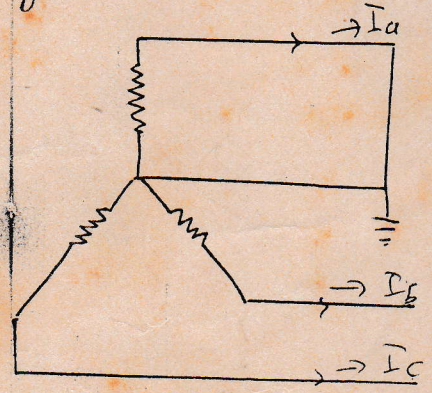
$$I_a = I_f = \frac{3E_a}{Z_0 + Z_1 + Z_2}$$

Z_0 Z_1 Z_2

Contoh : I.1

Sebuah generator dengan rating ~~500 MVA~~ 100 MVA, 23 KV mempunyai, $X'' = X_2 = 15\%$ dan $X_0 = 5\%$. Netralnya ditanahkan dengan kuat. Apabila terjadi suatu gangguan tunggal line ke tanah pada terminal - terminalnya. Hitung arus sub peralihan pada fasa yang mengalami gangguan.

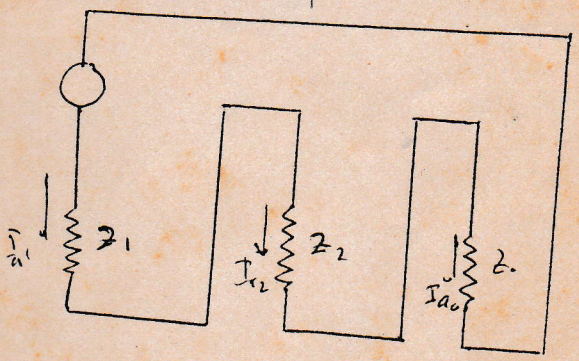
jawab :



$E_a = 1$ pu

$Z_1 = J0,15$ pu $\quad Z_0 = J0,05$ pu

$Z_2 = J0,15$ pu



Untuk gangguan tunggal saluran ke tanah, berlaku

$$I_{a1} = I_{a2} = I_{ao}$$

$$I_{a1} = \frac{E_a}{Z_0 + Z_1 + Z_2} = \frac{1}{J0,15 + J0,15 + J0,05} = -J2,857 \text{ pu}$$

$$\frac{\frac{1}{J0,35} \cdot \frac{J0,35}{J0,35}}{} = -J2,857 \text{ pu}$$

$$I_a = I_{ao} + I_{a1} + I_{a2} = 3I_{a1} = 3 \cdot -J2,857 \text{ pu}$$

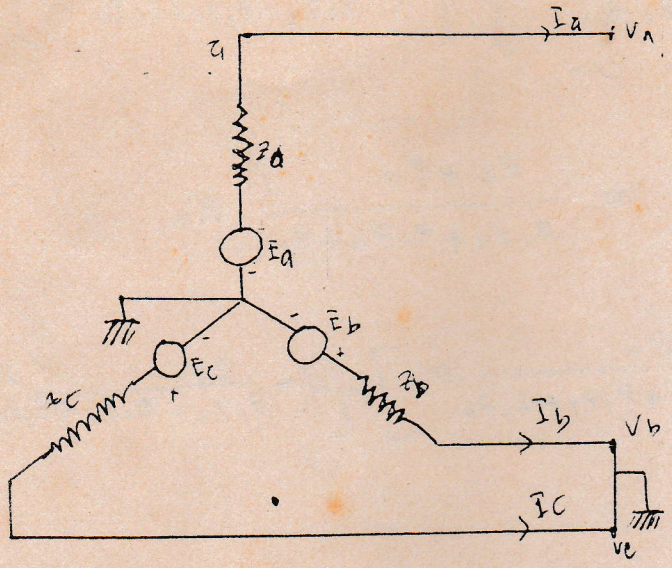
$$= -J8,571 \text{ pu}$$

$$I_{dasar} = \frac{100\,000 \text{ KVA}}{\sqrt{3}\ 23 \text{ KV}} = 2510,22 \text{ A}$$

∴ arus gangguan :

$$I_a = 8,571 \times 2510,22 = 21515,096 \text{ A}$$

I. 2. GANGGUAN DUA SALURAN KE TANAH. Phasa B & C (DOUBLE LINE TO GROUND FAULT)



Persamaan - persamaan pada titik gangguan :

$$I_a = 0 \quad (1)$$

$$V_b = 0 \quad (2)$$

$$V_c = 0 \quad (3)$$

dari (2) dan (3) diperoleh :

$$V_{a0} = \frac{1}{3}(V_a + V_b + V_c) = \frac{V_a}{3}$$

$$V_{a1} = \frac{1}{3}(V_a + aV_b + a^2V_c) = \frac{1}{3}(V_a + 0 + 0) = \frac{V_a}{3}$$

$$V_{a2} = \frac{1}{3}(V_a + a^2V_b + aV_c) = \frac{1}{3}(V_a + 0 + 0) = \frac{V_a}{3}$$

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

dari (1)

$$I_a = I_{a1} + I_{a2} + I_{a0} = 0$$

$$I_{a1} = -(I_{a2} + I_{a0})$$

dari persamaan umum : (persamaan sebelumnya)

$$V_{a0} = -I_{a0} Z_0 \rightarrow I_{a0} = -\frac{V_{a0}}{Z_0} = -\frac{V_{a1}}{Z_0}$$

$$V_{a2} = -I_{a2} Z_2 \rightarrow I_{a2} = -\frac{V_{a2}}{Z_2} = -\frac{V_{a1}}{Z_2}$$

$$I_{a1} = -(I_{a2} + I_{a0}) = -\left(-\frac{V_{a1}}{Z_2} - \frac{V_{a1}}{Z_0}\right)$$

disamakan pangkatnya

$$I_{a1} = -\left(-\frac{1}{Z_2} - \frac{1}{Z_0}\right) V_{a1} \rightarrow \left(\frac{1}{Z_2} + \frac{1}{Z_0}\right) V_{a1}$$

$$I_{a1} = \frac{Z_2 + Z_0}{Z_2 Z_0} V_{a1}$$

$$V_{a1} = \frac{Z_2 Z_0}{Z_2 + Z_0} I_{a1}$$

karena

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

$$V_{a1} = \frac{Z_2 \cdot Z_0}{Z_2 + Z_0} \cdot I_{a1}$$

sehingga

$$\frac{Z_2 Z_0}{Z_2 + Z_0} I_{a1} = E_a - I_{a1} Z_1$$

$$I_{a1}\left(\frac{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0}{Z_2 + Z_0}\right) = E_a$$

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

$$= \frac{E_a (Z_2 + Z_0)}{(Z_0 Z_2 + Z_1 (Z_0 + Z_2))} \times \frac{\frac{1}{Z_2 + Z_0}}{\frac{1}{Z_2 + Z_0}}$$

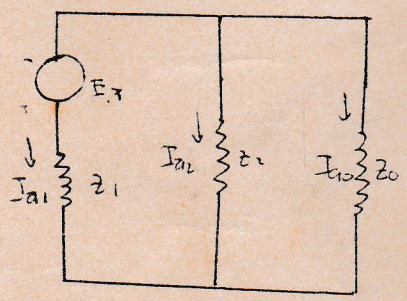
$$\rightarrow \frac{[Z_0 Z_2 + Z_1 (Z_0 + Z_2)]}{Z_2 + Z_0}$$

$$I_{a1} = \frac{E_a}{Z_1 + \frac{Z_0 Z_2}{Z_2 + Z_0}}$$

$$\left(\frac{Z_0 Z_2}{Z_2 + Z_0}\right) + \frac{Z_1 (Z_0 + Z_0)}{Z_2 + Z_0}$$

$$\frac{Z_0 Z_2}{Z_2 + Z_0} + Z_1$$

Rangkaian ekivalennya :



$$I_{a2} = -\frac{Z_0}{Z_2 + Z_0} I_{a1} \rightarrow \left[-\frac{Z_0}{Z_2 + Z_0}\right]\left[\frac{E_a}{Z_1 + \frac{Z_0 Z_2}{Z_2 + Z_0}}\right]$$

$$I_{a2} = -\frac{Z_0}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0} E_a$$

$$I_{a0} = -\frac{Z_2}{Z_2 + Z_0} I_{a1} \rightarrow \left[-\frac{Z_2}{Z_2 + Z_0}\right]\left[\frac{E_a}{Z_1 + \frac{Z_0 Z_2}{Z_2 + Z_0}}\right]$$

$$I_{a0} = -\frac{Z_2}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0} E_a$$

Arus gangguan

$$I_f = I_b + I_c$$

$$= (a^2 I_{a1} + a I_{a2} + I_{a0}) + (a I_{a1} + a^2 I_{a2} + I_{a0})$$

2 ϕ Tr

$$= I_{a1}(a^2 + a) + I_{a2}(a + a^2) + 2 I_{a0}$$

(a^2 : a^{-1}, a : a^{-1})

$$I_f = -I_{a1} - I_{a2} + 2 I_{a0}$$

$$= \frac{-Z_2 - Z_0 + Z_0 - 2Z_2}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0} E_a = \boxed{-3 \frac{Z_2}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0} E_a}$$

Tegangan - tegangan urutan :

$$I_{a1} = \frac{Z_2 + Z_0}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0} \cdot E_a$$

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

$$= E_a - \frac{(Z_2 + Z_0) Z_1}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0} E_a \rightarrow \left[\frac{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0}\right] \cdot E_a$$

$$= \frac{E_a (Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0 - Z_2 Z_1 - Z_0 Z_1)}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0}$$

$$= \frac{Z_2 Z_0}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0} E_a$$

$$V_{a2} = -I_{a2} Z_2 = \frac{Z_0 Z_2}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0} E_a$$

$$V_{a0} = -I_{a0} Z_0 = \frac{Z_0 Z_2}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0} E_a$$

$\therefore V_{a1} = V_{a2} = V_{a0}$

tegangan - tegangan saluran :

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

$$= \frac{3 Z_0 Z_2}{Z_1 Z_2 + Z_1 Z_0 + Z_2 Z_0} E_a$$

$V_b = 0$

$V_c = 0$

Contoh : I 2

Suatu sistem dengan tegangan supply 110 KV. line to line dengan impedansi saluran $Z_1 = j33{,}62$, $Z_2 = j38{,}37$ $Z_0 = j39{,}95$ Tentukan arus - arus phasa untuk jenis gangguan dua saluran ke tanah, juga tegangan - tegangan saluran.

Jawab :

$$E_a = \frac{110}{\sqrt{3}} = j63{,}510 \text{ kV}$$