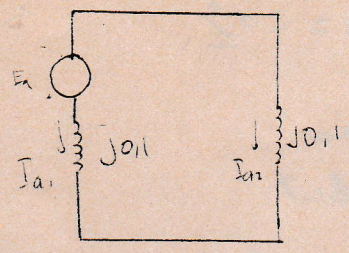


gangguan line to line

$I_a = 0$

$I_b = -I_c$

$V_b = V_c$

$I_{ao} = 0$

arus - arus urutan

$$I_{a1} = \frac{E_a}{Z_1 + Z_2} = \frac{1}{j0,1 + j0,1} = -j5 \text{ pu}$$

$$I_{a2} = -I_{a1} = j5 \text{ pu}$$

arus saluran :

$$I_a = I_{ao} + I_{a1} + I_{a2} = 0 - j4 + j4 = 0$$

$$I_b = I_{ao} + a^2 I_{a1} + a I_{a2} = (a^2 - a) I_{a1}$$

$$= -j\sqrt{3} \frac{1}{j0,1 + j0,1} = 5\sqrt{3} \text{ pu}$$

$$= 8,66 \text{ pu}$$

$$I_c = I_{ao} + a I_{a1} + a^2 I_{a2} = (a - a^2) I_{a1}$$

$$= -I_b = -8,66 \text{ pu}$$

$$I_{dasar} = \frac{30.000 \text{ kVA}}{\sqrt{3} \cdot 15 \text{ kV}} = 1154 \text{ A}$$

Arus saluran :

$I_a = 0$

$I_b = 8,66 \times 1154 = 9993,64 \text{ A}$

$I_c = -8,66 \times 1154 = -9993,64 \text{ A}$

Arus gangguan

$I_f = I_b = -I_f = 9993,64 \text{ A}$

Tegangan - tegangan saluran :

$$V_a = 2 \frac{Z_2}{Z_1 + Z_2} E_a = 2 \frac{j0,1}{j0,1 + j0,1} \cdot 1 = 1 \text{ pu}$$

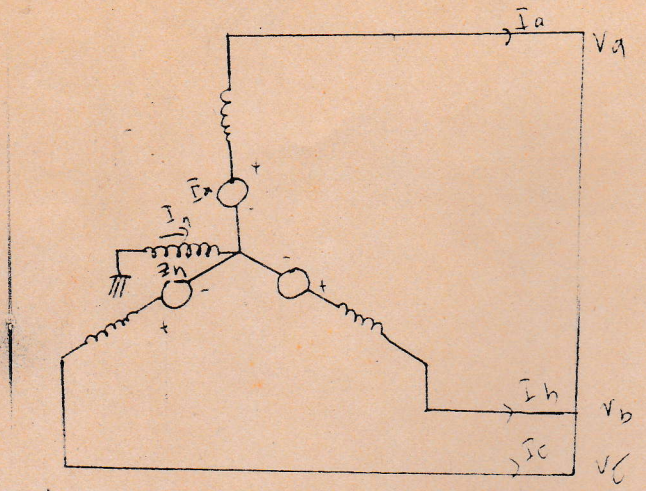
$$= 1 \text{ pu} \times 15 \text{ kV} = 15 \text{ kV}$$

$$V_b = -\frac{Z_2}{Z_1 + Z_2} E_a = -\frac{j0,1}{j0,1 + j0,1} \rightarrow -0,5 \text{ pu}$$

$$= -0,5 \text{ pu} \times 15 \text{ kV} = -7,5 \text{ kV}$$

$$V_c = V_b = -7,5 \text{ kV}$$

II.5 GANGGUAN TIGA PHASA (THREE PHASE FAULT)



Persamaan - persamaan pada titik gangguan :

$$V_a - V_b = 0 \quad (1)$$
$$V_a = V_b$$
$$V_a - V_c = 0 \quad (2)$$
$$V_a = V_c$$
$$I_a + I_b + I_c = 0 \quad (3)$$

dari (1) dan (2)

$$V_{a0} = \frac{1}{3}(V_a + V_b + V_c) = V_a \quad -1$$
$$V_{a1} = \frac{1}{3}(V_a + aV_b + a^2V_c) = \frac{1}{3}(1 + a + a^2)V_a = 0$$
$$V_{a2} = \frac{1}{3}(V_a + a^2V_b + aV_c) = \frac{1}{3}(1 + a + a^2)V_a = 0$$

dari (3) $\quad -1$

$$I_{a0} = \frac{1}{3}(I_a + I_b + I_c) = \frac{1}{3} \cdot 0 = 0$$

dari persamaan umum

$$V_{a1} = E_a - I_{a1} Z_1 = 0$$
$$E_a = I_{a1} Z_1$$
$$I_{a1} = \frac{E_a}{Z_1}$$
$$V_{a2} = -I_{a2} Z_2 = 0$$
$$I_{a2} = 0$$

$$V_{a0} = -I_{a0} Z_0 = -I_{a0}(Z_0' + 3Z_n)$$

$Z_0 = Z_0' + 3Z_n$: terhingga nilainya

$$V_{a0} = -I_{a0} Z_0 = 0$$

arus - arus saluran :

$$I_a = I_{a0} + I_{a1} + I_{a2} = 0 + \frac{E_a}{Z_1} + 0 = \frac{E_a}{Z_1}$$
$$I_b = I_{a0} + a^2 I_{a1} + aI_{a2} = 0 + a^2 \frac{E_a}{Z_1} + 0 = a^2 \frac{E_a}{Z_1}$$
$$I_c = I_{a0} + aI_{a1} + a^2 I_{a1} = 0 + a \frac{E_a}{Z_1} + 0 = a \frac{E_a}{Z_1}$$

arus gangguan :

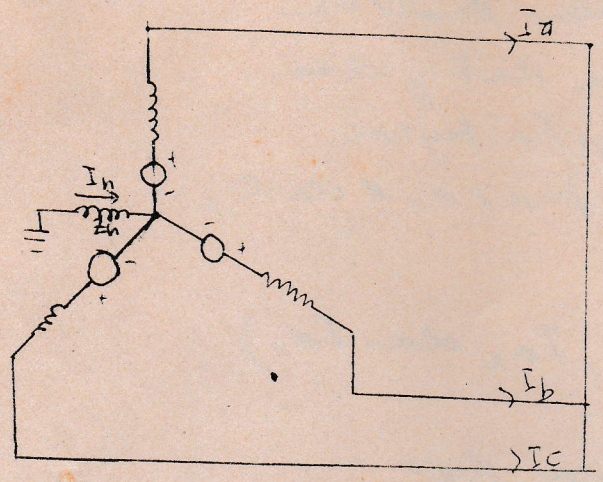
$$I_f = I_{a1} = \frac{E_a}{Z_1}$$

tegangan saluran :

$$V_a = V_{a0} + V_{a1} + V_{a2} = 0$$
$$V_b = V_{a0} + a^2 V_{a1} + aV_{a2} = 0$$
$$V_c = V_{a0} + aV_{a1} + a^2 V_{a2} = 0$$

Contoh : II-5 :

Hitunglah arus - arus saluran dan tegangan - tegangan saluran untuk jenis gangguan 3 ϕ dari generator pada contoh II 1.



$E_a = 1$ pu

$Z_1 = j0{,}1$ pu

$Z_2 = j0{,}1$ pu

$Z_0^1 = j0{,}05$ pu

$Z_n = 0{,}4\,\Omega$

$$I_{dasar} = \frac{30.000\ KVA}{\sqrt{3} \cdot 15\ KV} = 1154\ A$$

arus - arus urutan

$$I_{a1} = \frac{E_a}{Z_1} = \frac{1}{j0{,}1} = -j10\ pu$$

$$I_{a2} = I_{a0} = 0$$

arus saluran

$$I_a = I_{a0} + I_{a1} + I_{a2} = -j10\ pu$$

I_a sebenarnya $= 10 \cdot 1154 = 11540\ A$

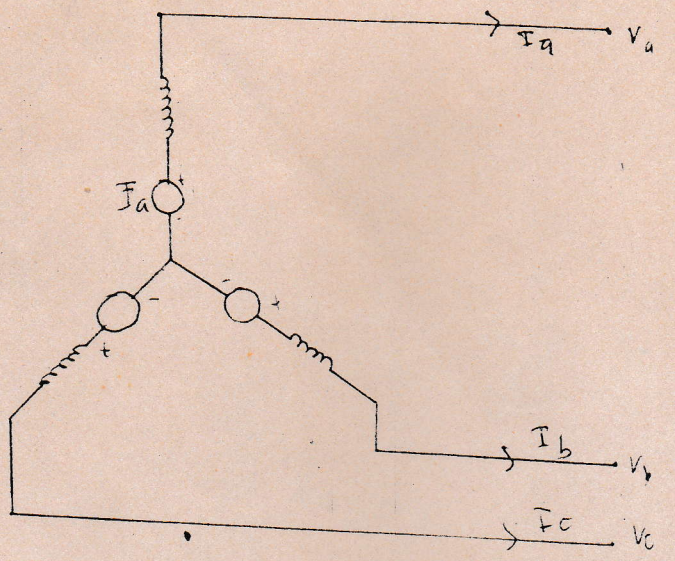
$$I_b = a^2 I_{a1} = (-0{,}5 - j0{,}866) \cdot -j10 = (5j - 8{,}66)\ pu$$
$$= 10 \angle 150^\circ\ pu$$

I_b sebenarnya $= 10 \angle 150^\circ \times 1154\ A = 11540 \angle 150^\circ\ A$

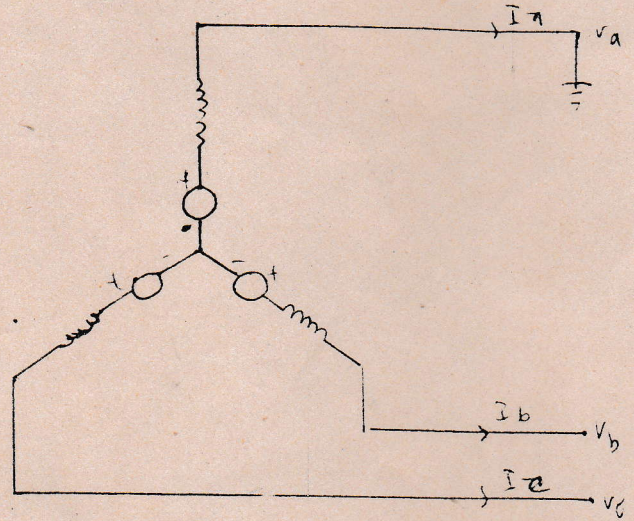
$$I_c = a I_{a1} = (-0{,}5 + j0{,}866) \cdot -j10 = (j5 + 8{,}66)\ pu$$
$$= 10 \angle 30^\circ\ pu$$

I_c sebenarnya $= 10 \angle 30^\circ \times 1154\ A = 11540 \angle 30^\circ\ A$

III. NETRAL GENERATOR TIDAK DITANAHKAN



III. 1. GANGGUAN SATU FASA KE TANAH (SINGLE LINE TO GROUND FAULT)



Persamaan - persamaan pada titik gangguan :

$V_a = 0$ (1)

$I_b = 0$ (2)

$I_c = 0$ (3)

$I_n = 0$ (4)

dari (2) dan (3) ; (4)

$$I_{a0} = \frac{1}{3}(I_a + I_b + I_c) = \frac{1}{3} I_a = 0$$

$$I_{a1} = \frac{1}{3}(I_a + aI_b + a^2 I_c) = \frac{1}{3} I_a = 0$$

$$I_{a2} = \frac{1}{3}(I_a + a^2 I_b + aI_c) = \frac{1}{3} I_a = 0$$

sehingga

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

dari (1)

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

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

$$= -(-I_{a0} Z_0 - I_{a2} Z_2)$$

$$= -I_{a0} Z_0 + I_{a2} Z_2$$

$$V_{a1} = I_{a1} (Z_0 + Z_2)$$

dari persamaan umum

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

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

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

$$I_{a1} = \frac{E_a}{Z_0 + Z_1 + Z_2} = I_{a0} = I_{a2}$$

karena tidak ditanahkan netral generatornya

$$Z_0 = Z_0' + 3Z_n = Z_0' + n = n$$

Sehingga

$$I_{a1} = \frac{E_a}{Z_1 + Z_2 + n} = 0 = I_{a0} = I_{a2}$$

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

$$V_{a2} = -Z_2 I_2 = 0$$

$$V_{a0} = -Z_0 I_0 = -\frac{Z_0 E_a}{Z_1 + Z_2 + Z_0} = -\frac{n E_a}{Z_1 + Z_2 + n} = -\frac{n E_a}{n} = -E_a$$

Tegangan - tegangan saluran :

$$V_a = V_{a0} + V_{a1} + V_{a2} = -E_a + E_a + 0 = 0$$

$$V_b = V_{a0} + a^2 V_{a1} + a V_{a2} = -E_a + a^2 \cdot E_a + a \cdot 0$$

$$= E_a (a^2 - 1) = \sqrt{3}\, E_a \angle -150^\circ$$

$$V_c = V_{a0} + a V_{a1} + a^2 V_{a1} = -E_a + a E_a + a^2 \cdot 0$$

$$= E_a (a - 1) = \sqrt{3}\, E_a \angle 150^\circ$$

Tegangan terminal :

$$V_n = -I_n Z_n = -3 I_{a0} Z_n = -\frac{3 Z_n E_a}{Z_0 + Z_1 + Z_2}$$

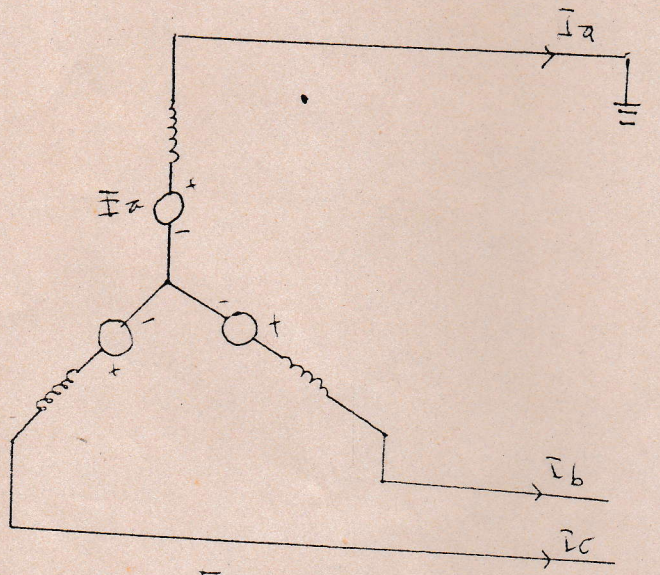
$$= -\frac{n E_a}{Z_0 + Z_1 + Z_2} = -\frac{n E_a}{n} = -E_a$$

contoh : III.1

Sebuah generator mempunyai rating 30 MVA, 15 kV mempunyai $X'' = X_2 = 10\%$ dan $X_0 = 5\%$. Netral generator tidak dihubungkan ke tanah.

Kecilnya generator dihubungkan ke sistem, tegangannya diatur menjadi 12 kV. Bila tiba2 suatu gangguan satu phasa ke tanah, hitung tegangan saluran dan tegangan netral!

jawab.



$$E_a = \frac{12\ kV}{15\ kV} = 0{,}8\ pu$$

$$Z_1 = j0{,}1$$

$$Z_2 = j0{,}1$$

$$Z_0 = j0{,}05$$

$$Z_0 = Z_0' + 3Z_n = j0{,}05 + n = n$$

$$kV_{dasar} = 15\ kV$$

$$I_{a1} = \frac{E_a}{Z_1 + Z_2 + Z_0} = \frac{0{,}8}{j0{,}1 + j0{,}1 + n} = 0 = I_{a0} = I_{a2}$$

tegangan - tegangan untuk

$$V_{a1} = E_a - I_{a1} Z_1 = 0{,}8 - 0 \cdot j0{,}1 = 0{,}8\ pu$$

$$V_{a2} = -I_{a2} Z_2 = -0 \cdot j0{,}1 = 0$$

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

$$= -\frac{n \cdot 0{,}8}{n} = -0{,}8\ pu$$

tegangan - tegangan saluran.

$$V_a = V_{a0} + V_{a1} + V_{a2} = -0{,}8 + 0{,}8 + 0 = 0$$

$$V_b = V_{a0} + a^2 V_{a1} + a V_{a2} = -0{,}8 + a^2\, 0{,}8 + 0$$

$$= 0{,}8\,(a^2 - 1)$$

$$= \sqrt{3} \cdot 0{,}8 \angle -150^\circ = 1{,}386 \angle -150^\circ\ pu$$

$$= 1{,}386 \angle -150^\circ \times 15\ kV = 20{,}79 \angle -150^\circ\ kV$$

$$V_c = V_{a0} + a V_{a1} + a^2 V_{a2} = -0{,}8 + a\,0{,}8 + 0 = 0{,}8\,(a - 1)$$

$$= \sqrt{3}\ 0{,}8 \angle 150^\circ = 1{,}386 \angle 150^\circ\ pu$$

$$= 1{,}386 \angle 150^\circ \times 15\ kV = 20{,}79 \angle 150^\circ\ kV$$

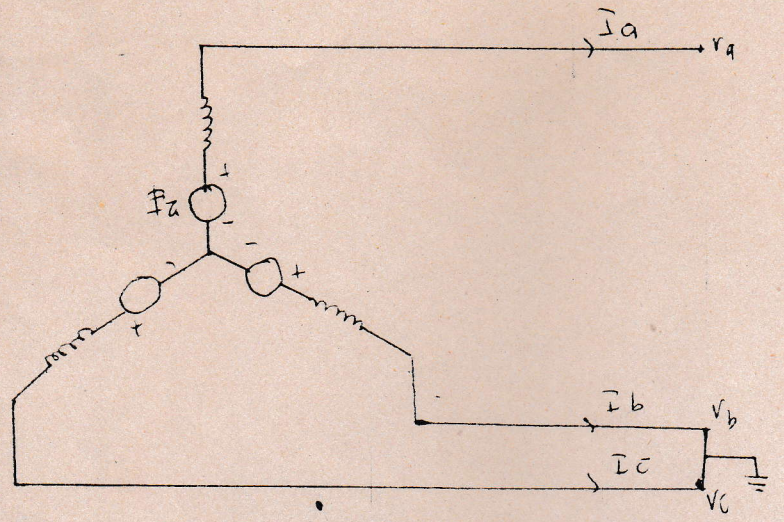
V summa :

$$V_n = -I_n Z_n = -\frac{3 Z_n E_a}{Z_0 + Z_1 + Z_2} = -\frac{n \dot{E}_a}{Z_1 + Z_1 + n} = -\frac{0{,}8\, n}{n}$$

$$= -0{,}8$$

$$= -0{,}8 \times 15\,KV = 12 \angle 180^\circ\, KV$$

III 2. GANGGUAN DUA SALURAN KE TANAH (DOUBLE LINE TO GROUND FAULT)



Persamaan - persamaan pada titik gangguan

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

$$I_b + I_c = 0 \quad (2)$$

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

dari (1) & (2)

$$I_{a0} = \frac{1}{3}(I_a + I_b + I_c) = 0$$

$$I_{a1} = \frac{1}{3}(I_a + aI_b + a^2 I_c) = \frac{1}{3}(0 + aI_b - a^2 I_b)$$

$$= \frac{1}{3}(I_b(a - a^2)) = \frac{1}{3}j\sqrt{3}\, I_b$$

$$I_{a2} = \frac{1}{3}(I_a + a^2 I_b + aI_c) = \frac{1}{3}(0 + a^2 I_b - aI_b)$$

$$= \frac{1}{3}(I_b(a^2 - a)) = -\frac{1}{3}j\sqrt{3}\, I_b$$

$$I_{a2} = -I_{a1}$$

dari (3)

$$V_{a0} = \frac{1}{3}(V_a + V_b + V_c) = \frac{1}{3}(V_a + 0 + 0) = \frac{V_a}{3}$$

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

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

$$\therefore V_{a0} = V_{a1} = V_{a2} = \frac{V_a}{3}$$

dari persamaan umum :

$$V_{a2} = -I_{a2} Z_2$$

$$V_{a0} = -I_{a0} Z_0$$

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

$$V_{a1} = -I_{a2} Z_2 = I_{a1} Z_2$$

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

$$I_{a1} = \frac{E}{Z_1 + Z_2} = -I_{a2}$$

arus gangguan : $I_f = I_b = -I_c = I_{a0} + a^2 I_{a1} + aI_{a2}$

$$V_{a1} = V_{a2} = V_{a0} = \frac{Z_2}{Z_1 + Z_2} E_a$$

tegangan - tegangan saluran :

$$V_a = V_{a0} + V_{a1} + V_{a2} = \frac{3 Z_2}{Z_1 + Z_2} E_a$$

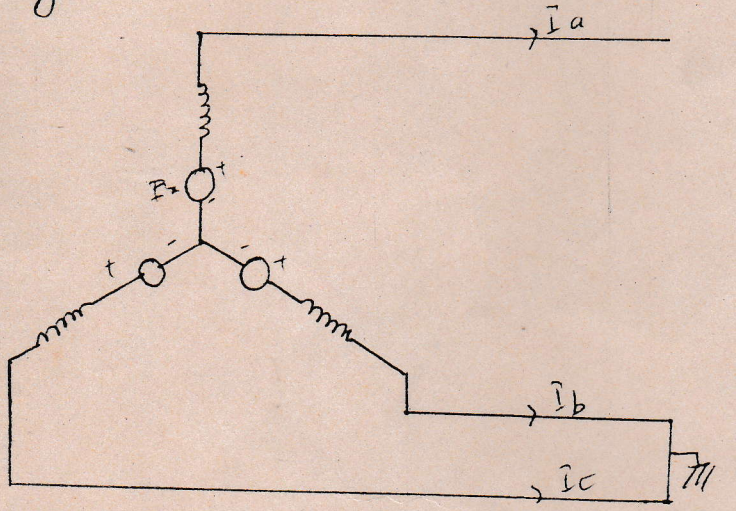
$$V_b = V_{a0} + a^2 V_{a1} + a V_{a2} = V_{a1}(a^2 + a + 1) = 0$$

$$V_c = V_{a0} + a V_{a1} + a^2 V_{a1} = V_{a1}(a^2 + a + 1) = 0$$

Contoh : III . 2

Untuk gangguan dua saluran ke tanah, hitunglah tegangan - tegangan dan arus - arus urut peralihan dari generator pada contoh III . 1 ; apabila generator tersebut sebelum terhubung ke sistem, tegangannya diatur menjadi 10 kV.

jawab :



$$E_a = \frac{10\ KV}{15\ KV} = 0{,}667\ pu$$

$$Z_1 = J0{,}1$$

$$Z_2 = J0{,}1$$

$$Z_0' = J0{,}05$$

KV dasar = 15 KV

$$\text{dasar} = \frac{30.000\ KVA}{\sqrt{3}\ 15\ KV} = 1154 A$$

gangguan dua saluran ke tanah

$$I_a = 0$$

$$I_b + I_c = 0$$

$$V_b = V_c = 0$$

maka

$$I_{a0} = 0$$

$$I_{a1} = \frac{E}{Z_1 + Z_2} = \frac{0{,}667}{J0{,}1 + J0{,}1} = -J\ 3{,}335\ pu$$

$$I_{a2} = -I_{a1} = J3{,}335\ pu$$

arus - arus saluran :

$$I_a = I_{a0} + I_{a1} + I_{a2} = 0 - J3{,}335 + J3{,}335 = 0$$

$$I_b = I_{a0} + a^2 I_{a1} + a I_{a1} = 0 + J3{,}335(-a^2 + a) = -\sqrt{3}\ 3{,}335 = -5{,}776\ pu$$

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

$= 0 + I_{a1}(-a + a^2) = 0 + j3,335(-\sqrt{3}j)$

$= 5,776$ pu

tegangan salman :

$$V_a = 3 \frac{Z_2}{Z_1 + Z_2} = 3 \cdot \frac{j0,1}{j0,1 + j0,1} = 1,5 \text{ pu}$$

$V_b = V_C = 0$

arus saluran sebenarnya :

$I_a = 0$

$I_b = -5,776 \times 1154 = 6665,5 \angle 180^\circ A$

$I_C = 5,776 \times 1154 = 6665,5 \angle 0^\circ A$

tegangan phasa A

$V_a = 1,5 \times 15 \text{ KV} = 22,5 \text{ KV}$.