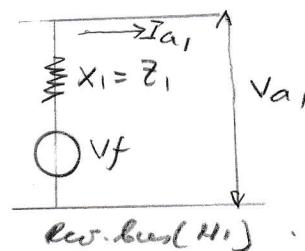
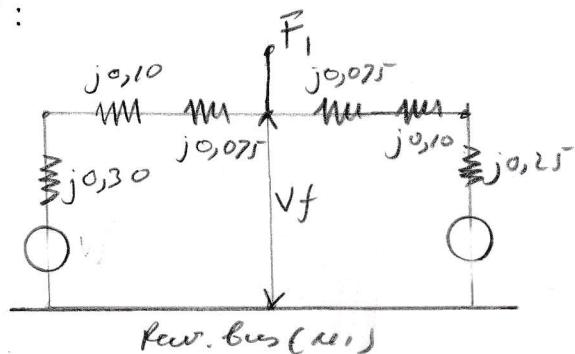


jawab:

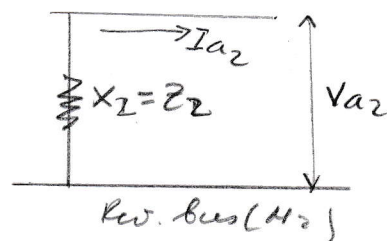
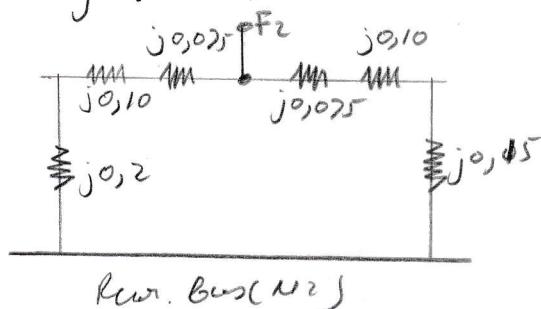


Reaktansi urutan positif $X_1 = Z_1$.

$$Z_1 = \frac{(j0,3 + j0,1 + j0,075)(j0,075 + j0,10 + j0,25)}{j0,475 + j0,425}$$

$$= \frac{j0,475 \cdot j0,425}{j0,90}$$

$$= j0,224 \text{ pu}$$

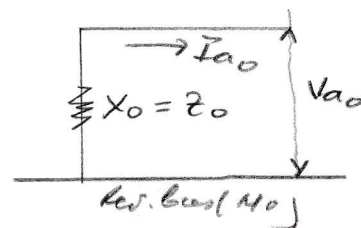
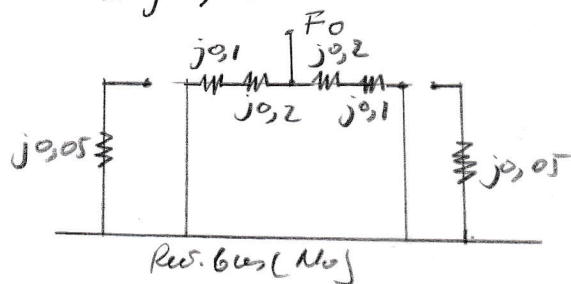


Reaktansi urutan negatif $X_2 = Z_2$

$$Z_2 = \frac{(j0,2 + j0,1 + j0,075)(j0,075 + j0,10 + j0,15)}{(j0,375 + j0,325)}$$

$$= \frac{j0,375 \cdot j0,325}{j0,70}$$

$$= j0,174 \text{ pu}$$



Reaktansi urutan nol $X_0 = Z_0$.

$$Z_0 = \frac{(j0,10 + j0,20)(j0,20 + j0,10)}{(j0,30 + j0,30)} = \frac{(j0,30)(j0,30)}{j0,60}$$

$$= j0,15 \text{ pu}$$

a). Arus gangguan satu fasa ketanah (I_f)

$$\begin{aligned}
 I_f &= \frac{3V_f}{z_1 + z_2 + z_0} \\
 &= \frac{3 \cdot 1}{(j0,224 + j0,174 + j0,15)} \\
 &= \frac{3,0}{j0,548} \\
 &= -j5,46 \text{ pu}
 \end{aligned}$$

b). Arus gangguan antar saluran (I_f)

$$\begin{aligned}
 I_f &= \frac{\sqrt{3} \cdot V_f}{z_1 + z_2} \\
 &= \frac{\sqrt{3} \cdot 1}{(j0,224 + j0,174)} \\
 &= \frac{1,73}{j0,398} \\
 &= -j4,35 \text{ pu}
 \end{aligned}$$

c). Arus gangguan lubang ringkai dua fasa ketanah (Fasa b dan c).

Arus komponen simetris:

$$\begin{aligned}
 I_{a1} &= \frac{V_f}{\left\{ z_1 + \frac{z_0 z_2}{z_0 + z_2} \right\}} \\
 &= \frac{1}{\left\{ j0,224 + \frac{j0,15 \cdot j0,174}{j0,324} \right\}} \\
 &= \frac{1}{j0,224 + j0,086} \\
 &= -j3,22 \text{ pu}
 \end{aligned}$$

$$\begin{aligned}
 I_{a_0} &= \frac{-\bar{I}_{a_1} z_2}{(z_0 + z_2)} \\
 &= \frac{j3,22 \cdot j0,174}{j0,329} \\
 &= \underline{j1,73 \text{ pu}}
 \end{aligned}$$

$$\begin{aligned}
 I_{a_2} &= \frac{-\bar{I}_{a_1} z_0}{z_0 + z_2} \\
 &= \frac{j3,22 \cdot j0,15}{j0,329} \\
 &= j1,49 \text{ pu}
 \end{aligned}$$

Arus gangguan pada fasa b.

$$\begin{aligned}
 I_b &= I_{a_0} + a^2 I_{a_1} + a I_{a_2} \\
 &= j1,73 + (-0,5 - j0,866)(-j3,22) + (-0,5 + j0,866)(j1,49) \\
 &= j1,73 + j1,61 + 2,79 - j0,745 - 1,29 \\
 &= (-4,08 + j2,59) \text{ pu}
 \end{aligned}$$

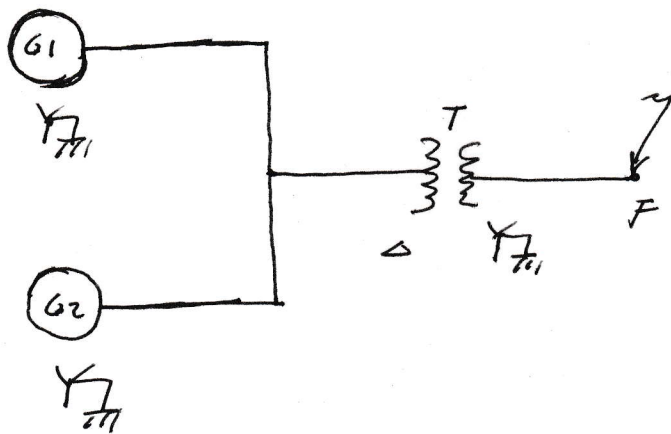
Arus gangguan pada fasa c.

$$\begin{aligned}
 I_c &= I_{a_0} + a I_{a_1} + a^2 I_{a_2} \\
 &= j1,73 + (-0,5 + j0,866)(-j3,22) + (-0,5 - j0,866)(j1,49) \\
 &= j1,73 + j1,61 + 2,79 - j0,745 + 1,29 \\
 &= (4,08 + j2,59) \text{ pu}
 \end{aligned}$$

Arus gangguan kutub:

$$\begin{aligned}
 I_f &= 3 I_{a_0} \\
 &= 3 \cdot j1,73 \\
 &= \underline{j5,19 \text{ pu}}
 \end{aligned}$$

Contoh:



Data ?

G1 dan G2

$$20 \text{ MVA}, 11 \text{ kV}, X_1 = X_2 = 13\% \rightarrow X'' = X_d = X_1$$

$$X_0 = 5\%$$

Trafo

$$50 \text{ MVA}, 13,8 / 33 \text{ kV}$$

$$X_1 = X_2 = X_0 = 12\%$$

Hitung arus gangguan pada titik F, bila terjadi gangguan satu phase ketanah (SLGF), L.L.F dan gangguan hubung ringkat 3 ϕ (3 ϕ F).

Jawab:

$$\text{Kita pilih MVA dasar} = 50 \text{ MVA}$$

$$\text{kV dasar} = 13,8 \text{ kV}$$

$$\text{Tegangan dasar di F} = \frac{33}{13,8} \cdot 13,8 = 33 \text{ kV}$$

Reaktansi Generator:

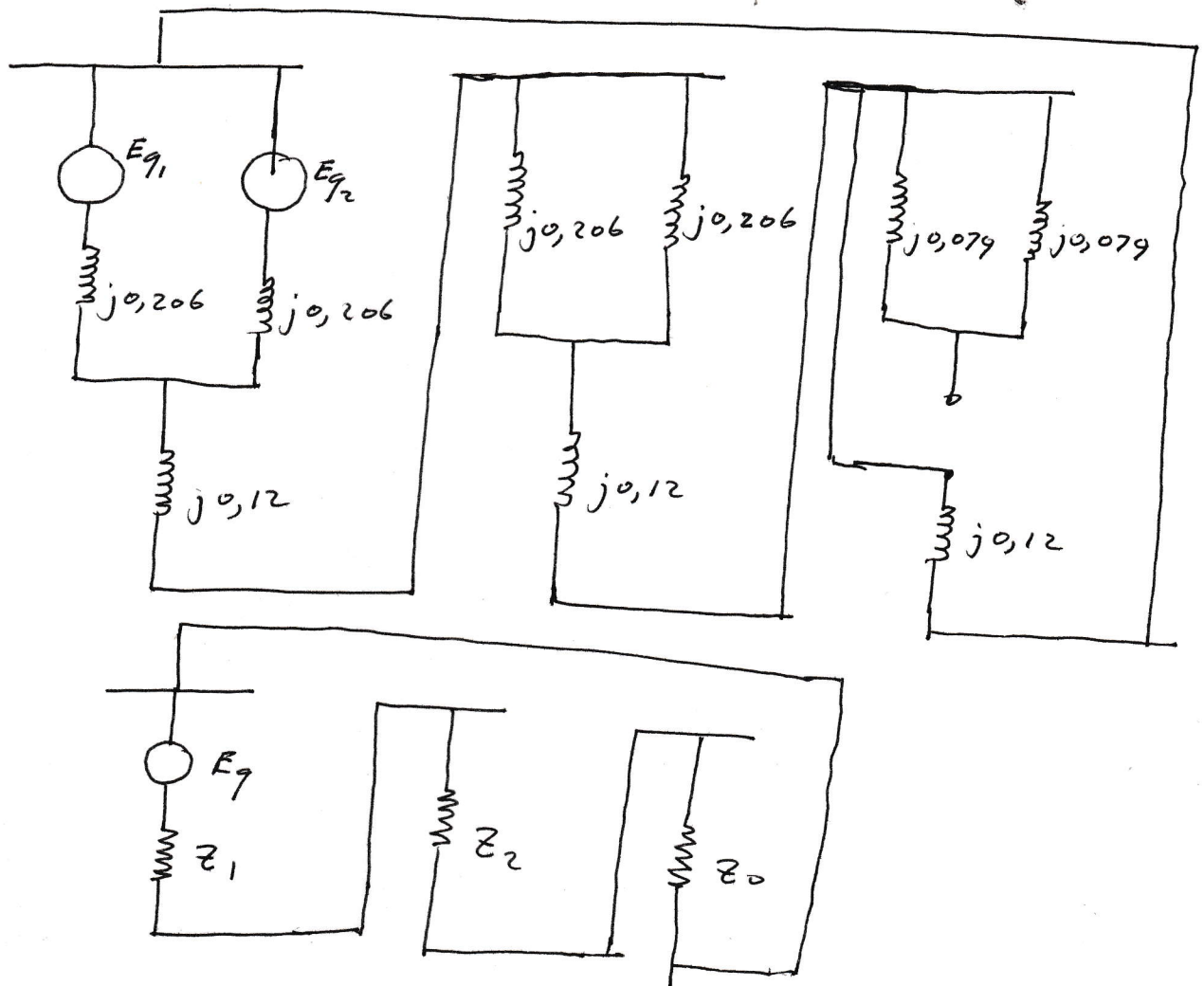
$$X_1 = X_2 = X\% \cdot \frac{\text{MVA}_B}{\text{MVA}} \cdot \left(\frac{\text{kV}}{\text{kV}_B} \right)^2 = 0,13 \cdot \frac{50}{20} \left(\frac{11}{13,8} \right)^2 = j 0,206 \text{ pu}$$

$$X_0 = X\% \cdot \frac{\text{MVA}_B}{\text{MVA}} \cdot \left(\frac{\text{kV}}{\text{kV}_B} \right)^2 = 0,05 \cdot \frac{50}{20} \left(\frac{11}{13,8} \right)^2 = j 0,0794 \text{ pu}$$

Reactansi Transformator :

151

$$X_1 = X_2 = X_0 = 0,12 \cdot \frac{50}{50} \left(\frac{13,8}{13,8} \right)^2 = j0,12 \text{ pu}$$



$$Z_1 = \frac{j0,206}{2} + j0,12 = j0,223 \text{ pu}$$

$$Z_2 = \frac{j0,206}{2} + j0,12 = j0,223 \text{ pu}$$

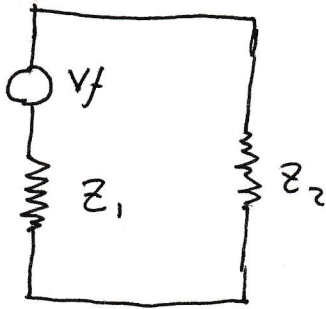
$$Z_0 = j0,12 \text{ pu}, V_f = \frac{11}{13,8} = 0,797 \text{ pu}$$

$$I_{a1} = \frac{V_f}{Z_1 + Z_0 + Z_2} = \frac{0,797 \angle 0}{j0,223 + j0,223 + j0,12} = -j1,40813 \text{ pu}$$

$$I_{\text{dasar}} = \frac{MVA_B}{\sqrt{3} \cdot kV_{\text{das}}} = \frac{50.000}{\sqrt{3} \cdot 33} = 879,773 \text{ A}$$

$$I_a = I_f = 3 I_{a1} = 3 \cdot -j1,40813 \text{ pu} = -j4,22439 \text{ pu}$$

$$I_a = I_f = 4,22439 \cdot 879,773 = 3695,3823 \text{ A (SLGP)}$$

L-L-F :

$$I_{a1} = \frac{V_f}{Z_1 + Z_2} = \frac{0,797}{j0,223 + j0,223} = -j1,787 \text{ pu}$$

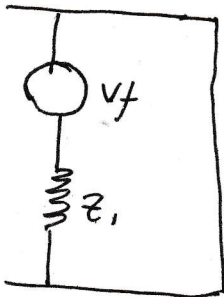
$$I_{a1} = -I_{a2} \rightarrow I_{a2} = j1,787 \text{ pu}; I_{a0} = 0$$

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

$$I_b = 0 + (-0,5 - j0,866)(-j1,787) + (-0,5 + j0,866)(j1,787) \\ = j0,893 - 1,547 - j0,893 - 1,547 = -3,094 \text{ pu}$$

$$I_b = -I_e = I_f = 3,094 \text{ pu}$$

$$I_F = 3,094 \cdot 874,773 = 2706,547 \text{ Amp}$$

3 ϕ F

$$Z_1 = j0,223 \text{ pu}$$

$$I_{a1} = \frac{V_f}{Z_1} = \frac{0,797}{j0,223} = -j3,574 \text{ pu}$$

$$I_{a1} = I_F = -j3,574 \text{ pu}$$

$$I_F = 3,574 \cdot 874,773 = 3126,431 \text{ Amp}$$

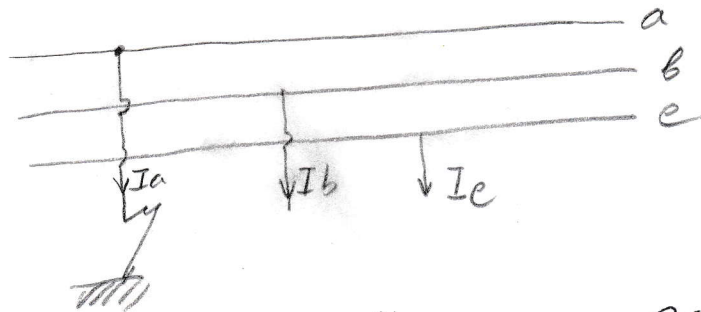
GANGGUAN PADA JALA-JALA JARINGAN.

153

Gangguan pada jala? jaringan dapat berupa:

1. gangguan satu fase ke tanah
2. gangguan dua fase
3. gangguan dua fase ke tanah
4. gangguan tiga fase
5. gangguan melalui impedansi:
 - a. gangguan satu fase ke tanah.
 - b. gangguan dua fase
 - c. gangguan dua fase ke tanah
 - d. gangguan tiga fase

1. gangguan satu fase ke tanah ($\phi-G$).



Kondisi pada saat gangguan satu fase ke tanah

$$V_a = 0$$

$$I_b = 0$$

$$I_c = 0$$

Berdasarkan komponen simetris:

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

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

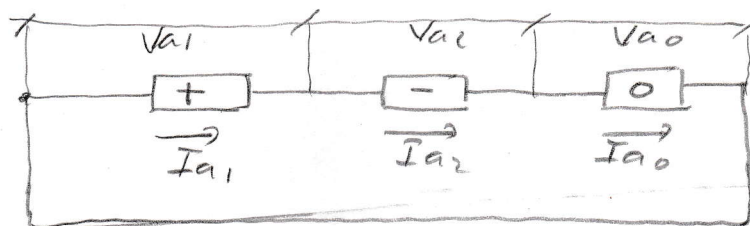
$$I_{a2} = \frac{1}{3}(I_a + a^2 I_b + a I_c) = \frac{1}{3} I_a$$

Biarli:

$$I_{a0} = I_{a1} = I_{a2} = \frac{1}{3} I_a \dots (A)$$

$$V_a = V_{a1} + V_{a2} + V_{a0} = 0 \dots (B)$$

Dari persamaan (A) dan (B) akan didapat sirkuit ekuivalen



Bila fase a sebelum gangguan satu fase terjadi:

$V_f = E_f$ nolah - olah sebagai ggl (emf) yg ditimbulkan jadi:

$$V_{a1} = V_f - I_{a1} \cdot Z_1$$

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

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

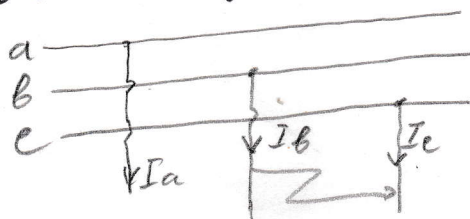
$$V_a = V_{a1} + V_{a2} + V_{a0}$$

$$0 = V_f - I_{a1} (Z_1 + Z_2 + Z_0)$$

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

$$\text{jadi : } I_a = I_f = \frac{3V_f}{Z_1 + Z_2 + Z_0}$$

2. Gangguan 2 fase



Gangguan terjadi di fase b dan c.

Kondisi pada saat gangguan: $I_a = 0$; $I_c = -I_b$; $V_b = V_c$
Komponen simetris:

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

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

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

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

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

$$= \frac{1}{3}(a^2 - a) I_b.$$

Dari persamaan 2 diatas didapat bahwa:

$$I_{a1} = -I_{a2} \dots \dots (A)$$

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

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

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

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

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

Dari kedua dan persamaan 3 juga didapat:

$$V_{a1} = V_{a2} \dots \dots (B)$$

$$V_{a1} = V_f - I_{a1} \cdot Z_1$$

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

$$-I_{a2} \cdot Z_2 = V_f - I_{a1} \cdot Z_1$$

$$V_f = I_{a1} \cdot (Z_1 + Z_2)$$

$$I_{a1} = \frac{V_f}{Z_1 + Z_2}$$

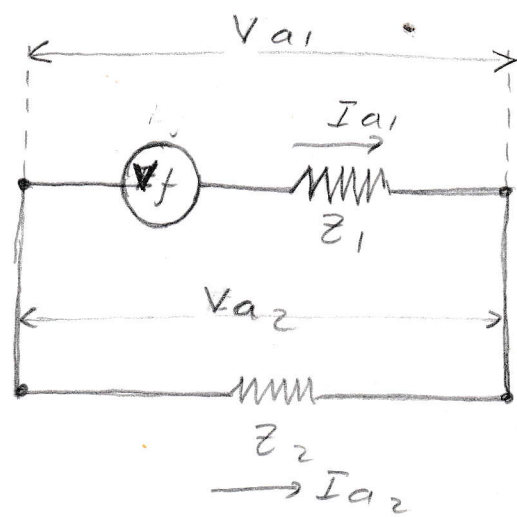
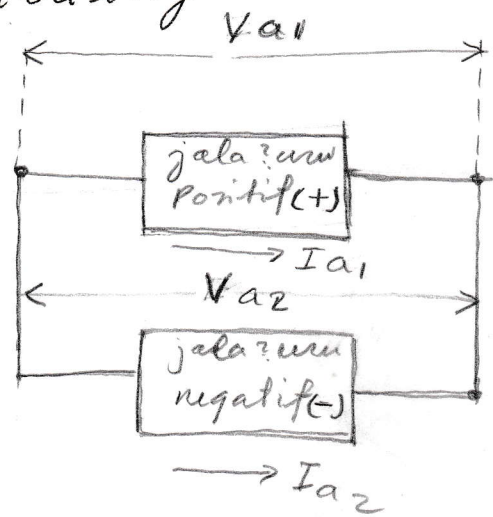
Assume (as); $I_a = 0 \rightarrow$

$$I_b = -j\sqrt{3} \frac{V_f}{Z_1 + Z_2}$$

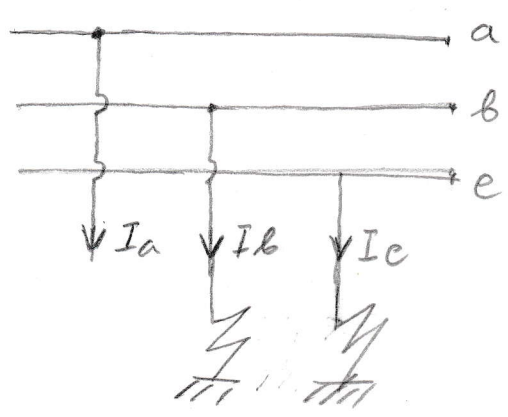
$$I_c = j\sqrt{3} \frac{V_f}{Z_1 + Z_2}$$

jadi: $I_f = I_c = -I_b$.

Dari persamaan (A) dan (B) didapat rangkaian listriknya :



3. Gangguan dua fase ke tanah :



gangguan fase b dan c ke tanah.
kondisi pada saat gangguan:

$$I_a = 0$$

$$V_b = V_c = 0$$

$$I_a = 0$$

$$I_b = -j\sqrt{3} \cdot V_f \cdot (Z_0 + a Z_2) / (Z_1 + Z_2 + Z_2 \cdot Z_0 + Z_0 \cdot Z_1)$$

$$I_c = j\sqrt{3} \cdot V_f (Z_0 + a Z_2) / (Z_1 \cdot Z_2 + Z_2 \cdot Z_0 + Z_0 \cdot Z_1)$$

$$I_f = I_c = -I_b$$

lirkit ekrivaleu gangguan dua fase ke tanah :