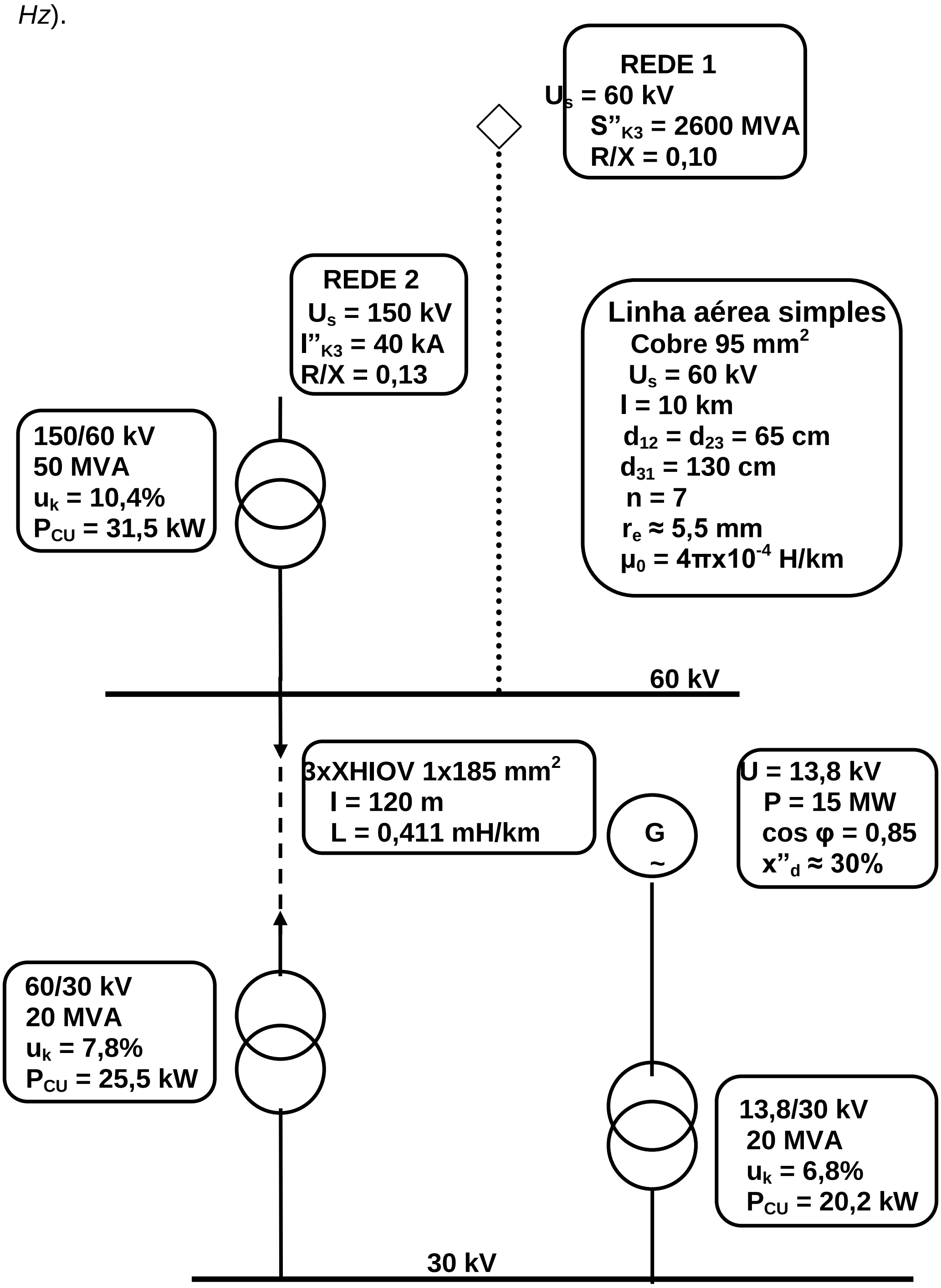
CONCEITOS DE SUBESTAÇÕES DE MUITO ALTA, ALTA E MÉDIA TENSÃO

Fascículo 5 – Cálculos e Dimensionamentos

DESAFIO – RESOLUÇÃO

Calcule o *valor* da **corrente de curto-circuito** no *barramento* de **60 kV** (*f = 50 Hz*).



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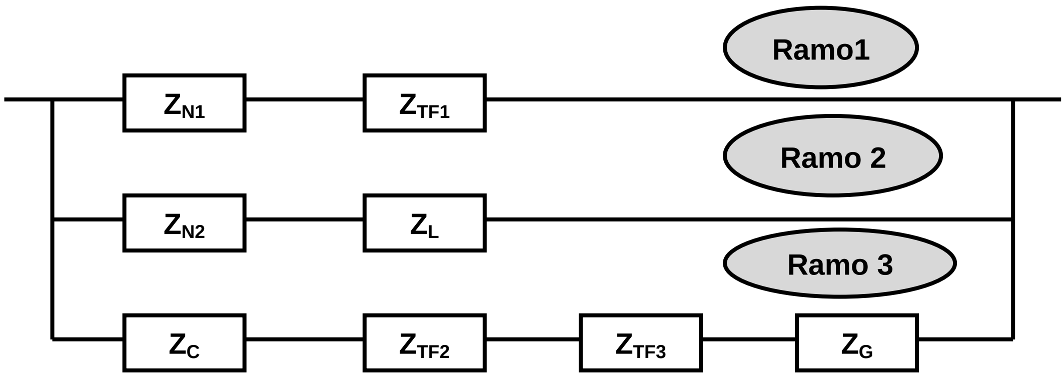
1) Diagrama equivalente de impedâncias



2) Cálculo das impedâncias equivalentes dos equipamentos

2.1) Rede 1

$(1{,}1x60x10^3) / (\sqrt{}3x40x10^3) = 0{,}952\ \Omega$

$X_{N1}^2 = (Z_{N1}^2 – R_{N1}^2) = (Z_{N1}^2 – 0{,}13^2 x X_{N1}^2)$

$X_{N1}^2 + 0{,}13^2 x X_{N1}^2 = Z_{N1}^2$

$X_{N1}^2 (1+0{,}13^2) = Z_{N1}^2$

$X_{N1} = \sqrt{}(Z_{N1}^2/(1+0{,}13^2)) = \sqrt{}(0{,}952^2/(1+0{,}13^2)) = 0{,}944\ \Omega$

$R_{N1} = 0{,}13x0{,}944 = 0{,}123\ \Omega$

2.2) Rede 2

$Z_{N2} = (1{,}1x(60x10^3)^2) / (2600x10^6) = 1{,}523\ \Omega$

$X_{N2} = \sqrt{}(Z_{N2}^2/(1+0{,}13^2)) = \sqrt{}(1{,}523^2/(1+0{,}1^2)) = 1{,}515\ \Omega$

$R_{N2} = 0{,}1x1{,}515 = 0{,}087\ 0{,}152\ \Omega$

2.3) TF1

- Corrente nominal primária: $I_{n1} = 50x10^6 /(\sqrt{}3x60x10^3) = 481$ A
- Corrente nominal secundária: $I_{n2} = 50x10^6 /(\sqrt{}3x30x10^3) = 962$ A

$Z_{TF1} = (10{,}4x(60x10^3)^2) / (100x50x10^6) = 7{,}488\ \Omega$

$R_{TF1} = 31.500 / (3x481^2) = 0{,}046\ \Omega$

$X_{TF1} = \sqrt{}(Z_{TF1}^2 – R_{TF2}^2) = \sqrt{}(7{,}488^2 – 0{,}046^2) = 7{,}488\ \Omega$

2.4) Linha aérea

$R_L = (1/56)$ x $(10.000/95) = 1{,}880\ \Omega$

$X_L = 2x\pi x50$ x $((4x\pi x10^{-4})/(2x\pi))$ x $(\ln ((818{,}9/5{,}5) + (1/(4x7))) = 0{,}317\ \Omega/km$

$X_L = 0{,}317x\ 10 = 3{,}17\ \Omega$

$d = \sqrt[3]{}(650x650x1300) = 818{,}9$ mm

2.5) TF2

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- Corrente nominal primária: $I_{n1} = 20x10^6 /(\sqrt{3}x60x10^3) = 192$ A
- Corrente nominal secundária: $I_{n2} = 20x10^6 /(\sqrt{3}x30x10^3) = 385$ A

$Z_{TF2} = (7{,}8x(60x10^3)^2) / (100x20x10^6) = 14{,}040\ \Omega$

$R_{TF2} = 25.500 / (3x192^2) = 0{,}231\ \Omega$

$X_{TF2} = \sqrt{(Z_{TF1}^2 – R_{TF2}^2)} = \sqrt{(14{,}040^2 – 0{,}231^2)} = 14{,}038\ \Omega$

2.6) Cabo

$R_C = 0{,}012 \times (60x10^3/30x10^3)^2 = 0{,}048\ \Omega$

$X_C = 0{,}015 \times (60x10^3/30x10^3)^2 = 0{,}060\ \Omega$

2.7) TF3

- Corrente nominal primária: $I_{n1} = 20x10^6 /(\sqrt{3}x13{,}8x10^3) = 837$ A
- Corrente nominal secundária: $I_{n2} = 50x10^6 /(\sqrt{3}x30x10^3) = 385$ A

$Z_{TF3} = (6{,}8x(60x10^3)^2) / (100x20x10^6) = 12{,}240\ \Omega$

$R_{TF3} = 0{,}045 \times (60x10^3/30x10^3)^2 = 0{,}180\ \Omega$

$X_{TF3} = \sqrt{(Z_{TF3}^2 – R_{TF}^2)} = \sqrt{(12{,}24^2 – 0{,}18^2)} = 12{,}139\ \Omega$

2.8) Gerador

$S_G = 15/0{,}85 = 17{,}6$ MVA

$X_G \approx Z_G = (30x(13{,}8x10^3)^2) / (100x17{,}6x10^6) = 3{,}246\ \Omega$

- Ponto B:

$X_G = 3{,}246 \times (30x10^3/13{,}8x10^3)^2 = 15{,}340\ \Omega$

3) Cálculo das impedâncias equivalentes no ponto de defeito

Sendo:

Z_1: impedância equivalente do Ramo 1

$Z_1 = Z_{N1} + Z_{TF1} = (0{,}087 + j0{,}944) + (0{,}046 + j1{,}872) = (0{,}169 + j2{,}816)$

$|Z_1| = \sqrt{(0{,}169^2 + 2{,}816^2)} = 2{,}821\ \Omega$

Z_2: impedância equivalente do Ramo 2

$Z_2 = Z_{N2} + Z_L = (0{,}123 + j1{,}515) + (1{,}880 + j3{,}17) = (2{,}003 + j4{,}685)$

$|Z_2| = \sqrt{(2{,}003^2 + 4{,}685^2)} = 5{,}095\ \Omega$

Z_3: impedância equivalente do Ramo 3

$Z_3 = Z_C + Z_{TF2} + Z_{TF3} + Z_G = (0{,}048 + j0{,}060) + (0{,}231 + j14{,}308) + (0{,}180 + j12{,}139) + j61{,}\ 363 = (0{,}048 + 0{,}231 + 0{,}180) + j(0{,}060 + 14{,}038 + 12{,}139 + 61{,}363) = 0{,}459 + j87{,}600$

$|Z_3| = \sqrt{(0{,}459^2 + 87{,}600^2)} = 87{,}601\ \Omega$

A impedância equivalente no ponto de defeito é:

$Z_d = Z_1//Z_2//Z_3 \approx (Z_1 \times Z_2 \times Z_3) / (Z_2 x Z_3 + Z_1 x Z_3 + Z_1 x Z_2)$ – *simplificação*

$|Z_d| = (2{,}821x5{,}095x87{,}601) / (5{,}095x87{,}601 + 2{,}821x87{,}601 + 2{,}821x5{,}095)$

$|Z_d| = 1{,}779\ \Omega$

4) Cálculo da corrente de curto-circuito

$I''_{k3} = 1{,}1xUn / (\sqrt{3}xZ_d) = 1{,}1x60x10^3 / (\sqrt{3}x1{,}779)$

$I''_{k3} \approx 21{,}4$ kA