

Hanoi University of Science and Technology	Final Examination		
	Course: Power Distribution System	Duration: 90min	No. 1

Item 1 (2 points). Analyse advantages and disadvantages of distribution network configurations and bus schemes at substations and their applications.

Item 2 (4 points). Allocate kVAr compensation in the 10kV industrial distribution system as shown in Fig.

1. Followings are concerned parameters:

$$r_1 = 0.03\Omega ; \quad Q_1 = 600\text{kVAr}$$

$$r_2 = 0.06\Omega ; \quad Q_2 = 500\text{kVAr}$$

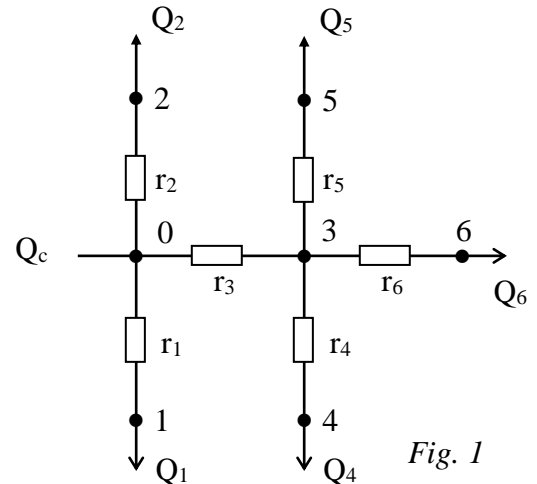
$$r_3 = 0.04\Omega ; \quad Q_4 = 400\text{kVAr}$$

$$r_4 = 0.04\Omega ; \quad Q_5 = 250\text{kVAr}$$

$$r_5 = 0.08\Omega ; \quad Q_6 = 50\text{kVAr}$$

$$r_6 = 0.08\Omega ;$$

Total allocated compensation: $Q_c = 1000\text{kVAr}$.



Item 3 (4 points). Consider a distribution network feeding two factories as Fig. 2. Followings are related parameters

- Factory demands

$$S_1 = 1500\text{kVA}, \cos\phi_1 = 0.8$$

$$S_2 = 3000\text{kVA}, \cos\phi_2 = 0.6$$

- OHL, ACSR-70 conductor, $r_o = 0.46\Omega/\text{km}$, $x_o = 0.38\Omega/\text{km}$

- Distribution substation, two transformers 35/10kV with following ratings

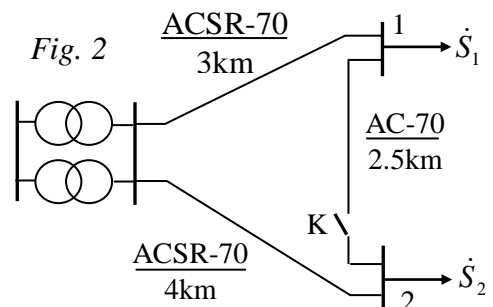
$$S_r = 4000\text{kVA}$$

$$\Delta P_o = 12.5\text{kW}, \Delta P_1 = 42\text{kW}$$

Maximum loss hours of 4000 hour is applicable for both two loads.

Question 1. Determine annual energy loss of the whole distribution network in the case of opening switch K.

Question 2. In the case of closing switch K, how does the voltage of bus 2 change, given the operating voltage at the 10kV bus of distribution substation is 10.5kV?

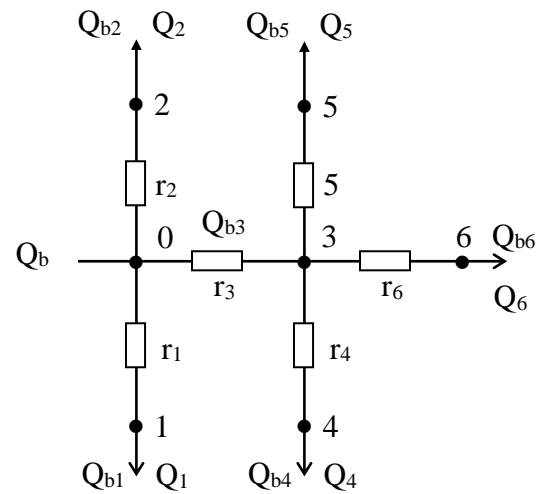


Notes : Open-book exam.

Solution :

Item 2 (4 points):

$r_1 = 0,03\Omega$; $Q_1 = 600 \text{ kVAr}$
 $r_2 = 0,06\Omega$; $Q_2 = 500 \text{ kVAr}$
 $r_3 = 0,04\Omega$; $Q_4 = 400 \text{ kVAr}$
 $r_4 = 0,04\Omega$; $Q_5 = 250 \text{ kVAr}$
 $r_5 = 0,08\Omega$; $Q_6 = 50 \text{ kVAr}$
 $r_6 = 0,08\Omega$;
 compensation amount of : $Q_b = 1000\text{kVAr}$



Solve

$$Q_{03} = Q_4 + Q_5 + Q_6 = 700\text{kVAr}$$

$$Q = Q_{03} + Q_1 + Q_2 = 1800\text{kVAr}$$

$$R_{t@1} = r_4 // r_5 // r_6 = 0,02\Omega$$

$$r_{03} = R_{t@1} + r_3 = 0,06\Omega$$

$$R_{t@} = r_{03} // r_1 // r_2 = 0,015\Omega$$

$$Q_{b1} = Q_1 - \frac{(Q - Q_b) \cdot R_{t@}}{r_1} = 600 - \frac{(1800 - 1000) \cdot 0,015}{0,03} = \underline{200\text{kVAr}}$$

$$Q_{b2} = Q_2 - \frac{(Q - Q_b) \cdot R_{t@}}{R_2} = 500 - \frac{(1800 - 1000) \cdot 0,015}{0,06} = \underline{300\text{kVAr}}$$

$$Q_{b3} = Q_b - Q_{b1} - Q_{b2} = 1000 - 200 - 300 = 500\text{kVAr}$$

$$Q_{b4} = Q_4 - \frac{(Q_{03} - Q_{b3}) \cdot R_{t@1}}{r_4} = 400 - \frac{(700 - 500) \cdot 0,02}{0,04} = \underline{300\text{kVAr}}$$

$$Q_{b5} = Q_5 - \frac{(Q_{03} - Q_{b3}) \cdot R_{t@1}}{r_5} = 250 - \frac{(700 - 500) \cdot 0,02}{0,08} = \underline{200\text{kVAr}}$$

$$Q_{b6} = Q_6 - \frac{(Q_{03} - Q_{b3}) \cdot R_{t@1}}{r_6} = 50 - \frac{(700 - 500) \cdot 0,02}{0,08} = \underline{0\text{kVAr}}$$

Item 3 (4 points) :

$$Z_{H1} = r_o.l_{H1} + j x_o.l_{H1} = 0,46.3 + j 0,38.3 = 1,38 + j.1,14\Omega$$

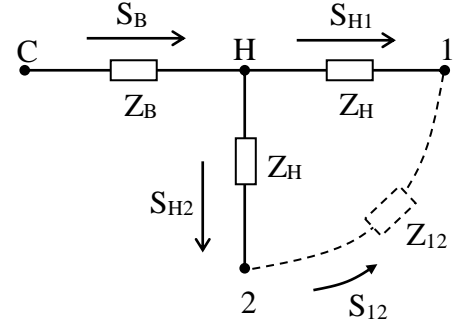
$$Z_{H2} = r_o.l_{H2} + j x_o.l_{H2} = 0,46.4 + j 0,38.4 = 1,84 + j.1,52\Omega$$

$$Z_{12} = r_o.l_{12} + j x_o.l_{12} = 0,46.2,5 + j0,38.2,5 = 1,15 + j0,95\Omega$$

$$S_1 = P_1 + jQ_1 = 2000.0,8 + j2000.0,6 = 1600 + j1200 \text{ kVA}$$

$$S_2 = P_2 + jQ_2 = 3000.0,6 + j3000.0,8 = 1800 + j2400 \text{ kVA}$$

$$\tau = (0,124 + T_{\max} \cdot 10^{-4})^2 \cdot 8760 = (0,124 + 5000 \cdot 10^{-4})^2 \cdot 8760 = 3410 \text{ (hour)}$$



1. K open

$$\dot{S}_{H1} = \dot{S}_1 = \underline{1200 + j900 \text{ (kVA)}}$$

$$\dot{S}_{H2} = \dot{S}_2 = \underline{1800 + j2400 \text{ (kVA)}}$$

$$\dot{S}_B = \dot{S}_1 + \dot{S}_2 = \underline{3000 + j3300 \text{ (kVA)}}$$

$$\Delta P_{H1} = \frac{(P_1^2 + Q_1^2)}{U_{dm}^2} \cdot R_1 = \frac{(1200^2 + 900^2)}{10^2} \cdot 1,38 \cdot 10^{-3} = 31,05 \text{ kW}$$

$$\Delta A_{H1} = \Delta P_{H1} \cdot \tau = 31,05 \cdot 2405 = \underline{\underline{74675 \text{ kWh/year}}}$$

$$\Delta P_{H2} = \frac{(P_2^2 + Q_2^2)}{U_{dm}^2} \cdot R_2 = \frac{(1800^2 + 2400^2)}{10^2} \cdot 1,84 \cdot 10^{-3} = 165,6 \text{ kW}$$

$$\Delta A_{H2} = \Delta P_{H2} \cdot \tau = 165,6 \cdot 2405 = \underline{\underline{389268 \text{ kWh/year}}}$$

$$S_B = \sqrt{P_B^2 + Q_B^2} = \sqrt{3000^2 + 3300^2} = 4460 \text{ kVA}$$

$$\Delta P_B = N_B \cdot \Delta P_{oB} + \frac{1}{N_B} \cdot \left(\frac{S_B}{S_{dmB}} \right)^2 \cdot \Delta P_{nB} = 2.12,5 + \frac{1}{2} \cdot \left(\frac{4460}{4000} \right)^2 \cdot 42 = 51,11 \text{ kW}$$

$$\Delta A_B = N_B \cdot \Delta P_{oB} \cdot T_{nam} + \frac{1}{N_B} \cdot \left(\frac{S_B}{S_{dmB}} \right)^2 \cdot \Delta P_{nB} \cdot \tau = 2.12,5 \cdot 8760 + \frac{1}{2} \cdot \left(\frac{4460}{4000} \right)^2 \cdot 42 \cdot 2405 = 281789 \text{ kWh}$$

$$\Delta A = \Delta A_{H1} + \Delta A_{H2} + \Delta A_B = 74675 + 389268 + 281789 = \underline{\underline{745732 \text{ kWh/year}}}$$

$$\Delta U_{H2} = \frac{P_2 \cdot R_{H2} + Q_2 \cdot X_{H2}}{U_{dm}} = \frac{1800 \cdot 1,84 + 2400 \cdot 1,52}{10} \cdot 10^{-3} = 0,696 \text{ kV}$$

$$U_2 = U_H - \Delta U_{H2} = 10,5 - 0,696 = \underline{\underline{9,804 \text{ kV}}}$$

2. *K close*

$$\dot{S}'_{H2} = \frac{\dot{S}_2 \cdot (Z_{12} + Z_{H1}) + \dot{S}_1 \cdot Z_{H1}}{Z_{H1} + Z_{12} + Z_{H2}} = \frac{\dot{S}_2 \cdot (l_{12} + l_{H1}) + \dot{S}_1 \cdot l_{H1}}{l_{H1} + l_{12} + l_{H2}}$$

$$\dot{S}'_{H2} = \frac{(1800 + j2400) \cdot 5,5 + (1200 + j900) \cdot 3}{9,5} = \underline{1421,05 + j1673,68 \text{ kVA}}$$

$$\Delta U'_{H2} = \frac{P'_{H2} \cdot R_{H2} + Q'_{H2} \cdot X_{H2}}{U_{dm}} = \frac{1421,05 \cdot 1,84 + 1673,68 \cdot 1,52}{10} \cdot 10^{-3} = 0,516 \text{ kV}$$

$$\text{VËy } U'_2 = U_H - \Delta U'_{H2} = 10,5 - 0,516 = 9,984 \text{ kV}$$

Therefore, K close the voltage at node 2 increase from **9,804kV** to **9,984kV**.

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Followings are concerned parameters:

- $r_1 = 0.03\Omega$; $Q_1 = 600\text{kVAr}$
- $r_2 = 0.06\Omega$; $Q_2 = 500\text{kVAr}$
- $r_3 = 0.04\Omega$; $Q_4 = 400\text{kVAr}$
- $r_4 = 0.04\Omega$; $Q_5 = 250\text{kVAr}$
- $r_5 = 0.08\Omega$;

Total allocated compensation: $Q_c = 1000\text{kVAr}$.

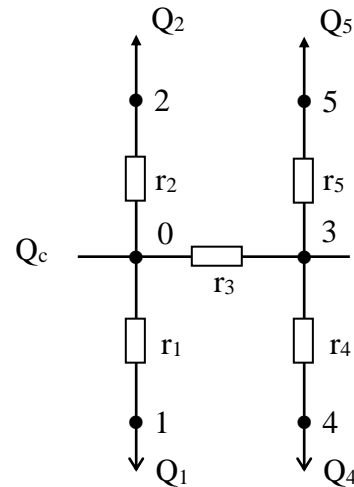


Fig. 1

Item 3. Consider a distribution network feeding two factories as Fig. 2. Followings are related parameters

- Factory demands

$$S_1 = 2000\text{kVA}, \cos\phi_1 = 0.8$$

$$S_2 = 3000\text{kVA}, \cos\phi_2 = 0.6$$

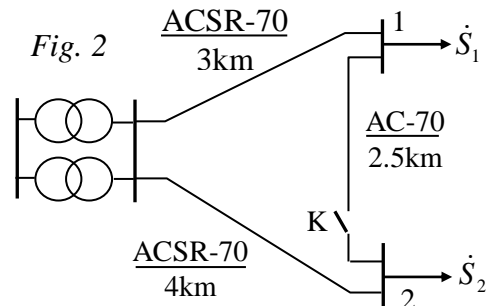
- OHL, ACSR-70 conductor, $r_o = 0.46\Omega/\text{km}$, $x_o = 0.38\Omega/\text{km}$

- Distribution substation, two transformers 35/10kV with following ratings

$$S_r = 4000\text{kVA}$$

$$\Delta P_o = 12.5\text{kW}, \Delta P_1 = 42\text{kW}$$

Maximum loss hours of 5000 hour is applicable for both two loads.



Question 1. Determine annual energy loss of the whole distribution network in the case of opening switch K.

Question 2. In the case of closing switch K, how does the voltage of bus 2 change, given the operating voltage at the 10kV bus of distribution substation is 10.5kV?

Notes : Open-book exam.

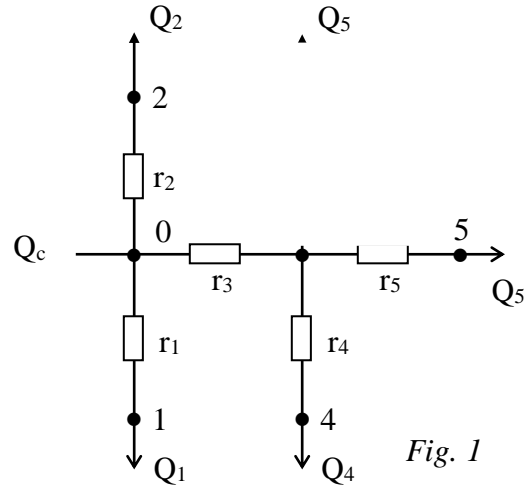
Hanoi University of Science and Technology	Final Examination		
	Course: Power Distribution System	Duration: 90min	No. 2

Item 1. Analyze advantages and disadvantages of distribution network configurations and bus schemes at substations and their applications.

Item 2. Allocate kVAr compensation in the 10kV industrial distribution system as shown in Fig. 1. Followings are concerned parameters:

- $r_1 = 0.03\Omega$; $Q_1 = 600\text{kVAr}$
- $r_2 = 0.06\Omega$; $Q_2 = 500\text{kVAr}$
- $r_3 = 0.04\Omega$; $Q_4 = 400\text{kVAr}$
- $r_4 = 0.04\Omega$; $Q_5 = 50\text{kVAr}$
- $r_5 = 0.08\Omega$;

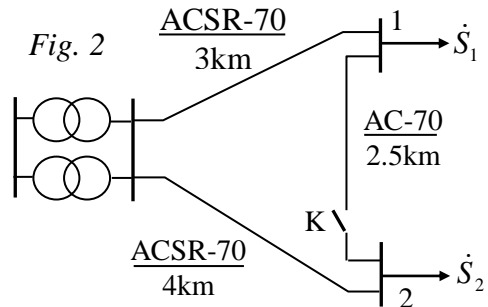
Total allocated compensation: $Q_c = 1000\text{kVAr}$.



Item 3. Consider a distribution network feeding two factories as Fig. 2. Followings are related parameters

- Factory demands
 - $S_1 = 3000\text{kVA}$, $\cos\phi_1 = 0.8$
 - $S_2 = 4000\text{kVA}$, $\cos\phi_2 = 0.6$
- OHL, ACSR-70 conductor, $r_o = 0.46\Omega/\text{km}$, $x_o = 0.38\Omega/\text{km}$
- Distribution substation, two transformers 35/10kV with following ratings
 - $S_r = 5000\text{kVA}$
 - $\Delta P_o = 12.5\text{kW}$, $\Delta P_1 = 42\text{kW}$

Maximum loss hours of 4500 hour is applicable for both two loads.



Question 1. Determine annual energy loss of the whole distribution network in the case of opening switch K.

Question 2. In the case of closing switch K, how does the voltage of bus 2 change, given the operating voltage at the 15kV bus of distribution substation is 16kV?

Notes : Open-book exam.