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1. ZADATAK

$U_1 = 10{,}5 \angle 0^\circ \text{ kV} = 1 \angle 0^\circ \text{ p.u.}$

$U_2 = 107{,}3 \angle -4{,}3^\circ \text{ kV} = 0{,}97545 \angle -4{,}3^\circ \text{ p.u.}$

$U_3 = 103{,}6 \angle -7^\circ \text{ kV} = 0{,}94182 \angle -7^\circ \text{ p.u.}$ $\quad S_B = 100 \text{ MVA}$

$$Z_T = \frac{S_B}{U_n^2} \cdot \frac{U_n^2}{S_n} \cdot j u_k \quad \Rightarrow \quad Y_T = -j\frac{1}{u_k} = -j\,8{,}33333 \text{ p.u.}$$

$$Y_{01} = Y_{02} = 0 \text{ p.u.}$$

$$Z_V = (R_1 + jX_1)\cdot l = (0{,}15 + j0{,}40)\cdot 50 = 7{,}5 + j20\ \Omega$$

$$Z_V = 0{,}06198 + j\,0{,}16529 \text{ p.u.}$$

$$Y_V = \frac{1}{Z_V} = 1{,}98894 - j\,5{,}30416 \text{ p.u.}$$

$$\frac{Y_{0V}}{2} = j\,\frac{B_1}{2}\,l \cdot \frac{U_n^2}{S_B} = j \cdot \frac{2{,}7\cdot 10^{-6}}{2} \cdot 50 \cdot \frac{110^2}{100} = j\,0{,}0081675 \text{ p.u.}$$

$$Y = \begin{bmatrix} Y_T & -Y_T & 0 \\ -Y_T & Y_T + 2Y_V + 2\cdot\frac{Y_{0V}}{2} & -2Y_V \\ 0 & -2Y_V & 2Y_V + 2\cdot\frac{Y_{0V}}{2} \end{bmatrix}$$

$$Y = \begin{bmatrix} -j\,8{,}33333 & j\,8{,}33333 & 0 \\ j\,8{,}33333 & 3{,}97788 - j\,18{,}92532 & -3{,}97788 + j\,10{,}60832 \\ 0 & -3{,}97788 - j\,10{,}60832 & 3{,}97788 - j\,10{,}59199 \end{bmatrix}$$

$$\begin{vmatrix} I_1 \\ I_2 \\ I_3 \end{vmatrix} = Y \cdot \begin{vmatrix} U_1 \\ U_2 \\ U_3 \end{vmatrix}$$

$$I_1 = -j\,8{,}33333 \cdot 1 + j\,8{,}33333 \cdot 0{,}97545 \angle -43^\circ + 0$$

$$I_1 = 0{,}60948 - j\,0{,}22746 = 0{,}65055 \angle -20{,}466^\circ \;\; p.u$$

$$I_2 = j\,8{,}33333 \cdot 1 + (3{,}97788 - j\,18{,}92532) \cdot 0{,}97545 \angle -43^\circ$$
$$+ (-3{,}97788 + j\,10{,}60832) \cdot 0{,}94182 \angle -7^\circ$$

$$I_2 = -0{,}01577 + j\,0{,}006889 \;\; p.u$$

$$I_3 = (-3{,}97788 + j\,10{,}60832) \cdot 0{,}97545 \angle -43^\circ$$
$$+ (3{,}97788 - j\,10{,}59199) \cdot 0{,}94182 \angle -7^\circ$$

$$I_3 = -0{,}59065 + j\,0{,}25172 \;\; p.u$$

$$S_1 = U_1 \cdot I_1^* = 1 \cdot I_1^* = 0{,}60948 + j\,0{,}22746 \;\; p.u$$

$$\boxed{S_1 = 60{,}948 + j\,22{,}746 \;\; MVA}$$

$$S_2 = U_2 \cdot I_2^* = 0{,}97545 \angle -43 \cdot (-0{,}01577 - j\,0{,}006889)$$
$$= -0{,}01584 - j\,0{,}005548 \;\; p.u$$

$$\boxed{S_2 = -1{,}1584 - j\,0{,}5548 \;\; MVA}$$

$$S_3 = U_3 \cdot I_3^* = 0{,}94182 \angle -7 \cdot (-0{,}59065 - j\,0{,}25172)$$
$$= -0{,}58103 - j\,0{,}16751$$

$$\boxed{S_3 = -58{,}103 - j\,16{,}751 \;\; MVA}$$

$$\boxed{\Delta S = S_1 + S_2 + S_3 = 1{,}6866 + j\,5{,}4402 \;\; MVA}$$

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2 ZADATAK

$$Y_v = 1,98894 - j\,5,30416 \text{ p.u.}$$

$$\frac{Y_{0v}}{2} = j\,0,0081675 \text{ p.u.}$$

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$$Y = \begin{bmatrix} Y_v + \frac{Y_0}{2} & -Y_v & 0 \\ -Y_v & 2Y_v + 2\frac{Y_0}{2} & -Y_v \\ 0 & -Y_v & Y_v + \frac{Y_0}{2} \end{bmatrix}$$

$$Y = \begin{bmatrix} 1,98894 - j5,29599 & -1,98894 + j5,30416 & 0 \\ -1,98894 + j5,30416 & 3,97788 - j10,59199 & -1,98894 + j5,30416 \\ 0 & -1,98894 + j5,30416 & 1,98894 - j5,29599 \end{bmatrix}$$

$$KL_1 = \frac{S_1^*}{Y_{11}} = \frac{-0,1 + j0,04}{1,98894 - j5,29599} = -0,01283 - j\,0,01406$$

$$KL_2 = \frac{S_2^*}{Y_{22}} = \frac{-0,5 + j\,0,15}{3,97788 - j10,59199} = -0,02795 - j\,0,03671$$

$$YL_{12} = \frac{Y_{12}}{Y_{11}} = \frac{-1,98894 + j5,30416}{1,98894 - j5,29599} = -1,00135 + j\,0,00051$$

$$YL_{21} = YL_{23} = \frac{-1,98894 + j5,30416}{3,97788 - j10,59199} = -0,50068 + j\,0,00025$$

$$U_i^{(k+1)} = \frac{KL_i}{\left(U_i^{(k)}\right)^*} - \sum_{j=1}^{i-1} YL_{ij}\,U_j^{(k+1)} - \sum_{j=i+1}^{n} YL_{ij}\,U_j^{(k)}$$

$U_1^{(0)} = 1 \text{ p.u.} \qquad U_2^{(0)} = 1 \text{ p.u.} \qquad U_3^{(0)} = 1 \text{ p.u.}$

$$U_1^{(1)} = \frac{KL_1}{U_1^{(0)}} - YL_{12} \cdot U_2^{(0)} - \overbrace{YL_{13} \cdot U_3^{(0)}}^{0}$$

$$= \frac{-0{,}01283 - j\,0{,}01406}{1} - (-1{,}00135 + j\,0{,}00051)$$

$$= 0{,}98852 - j\,0{,}01457 = 0{,}98863 \angle{-0{,}844}$$

$$\boxed{U_1^{(1)} = 108{,}7493 \angle{-0{,}844^\circ}}$$

$$U_2^{(1)} = \frac{KL_2}{U_2^{(0)}} - YL_{21} \cdot U_1^{(1)} - YL_{23} \cdot U_3^{(0)}$$

$$= \frac{-0{,}02795 - j\,0{,}03671}{1} - (-0{,}50068 + j\,0{,}00025) \cdot (0{,}98852 - j\,0{,}01457)$$

$$- (-0{,}50068 + j\,0{,}00025) \cdot 1$$

$$= 0{,}96766 - j\,0{,}044502 = 0{,}96868 \angle{-2{,}633^\circ}$$

$$\boxed{U_2^{(1)} = 106{,}55495 \angle{-2{,}633^\circ}}$$

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3. ZADATAK

$$X_g = \frac{x_d''}{100} \cdot \frac{U_n^2}{S_n} = 0,19 \cdot \frac{10,5^2}{35} = 0,5985\ \Omega$$

$$X_g = j\,0,54286 \quad \Rightarrow \quad Y_g = -j\,1,842096 \text{ p.u.}$$

$$Z_T = \frac{S_B}{U_n^2} \cdot \frac{U_n^2}{S_n} \cdot j u_k = \frac{100}{35} \cdot j\,0,11 = j\,0,31429 \text{ p.u.}$$

$$Y_T = -j\,3,18177 \text{ p.u.}$$

$$Z_V = \frac{S_B}{U_n^2} \cdot j x_1 \cdot l = \frac{100}{110^2} \cdot j \cdot 0,41 \cdot 30 = j\,0,10165 \text{ p.u.}$$

$$Y_V = -j\,9,83768$$

$$Y = \begin{bmatrix} Y_g + Y_T & -Y_T & 0 \\ -Y_T & Y_T + Y_V & -Y_V \\ 0 & -Y_V & Y_V \end{bmatrix}$$

$$Y = -j \begin{vmatrix} 5,02387 & -3,18177 & 0 \\ -3,18177 & 13,01945 & -9,83768 \\ 0 & -9,83768 & 9,83768 \end{vmatrix}$$

$$Z = j \begin{vmatrix} 0,54286 & 0,54286 & 0,54286 \\ 0,54286 & 0,85714 & 0,85714 \\ 0,54286 & 0,85714 & 0,9588 \end{vmatrix}$$

$$\begin{vmatrix} {}^dU_1^k \\ {}^dU_2^k \\ {}^dU_3^k \end{vmatrix} = \begin{vmatrix} {}^dU_1^z \\ {}^dU_2^z \\ {}^dU_3^z \end{vmatrix} + |Z| \begin{vmatrix} 0 \\ 0 \\ {}^dI_3 \end{vmatrix}$$

$U_1 = 1 \; p.u$

$U_2 = 1{,}04636 \angle -5{,}7°$

$U_3 = 1{,}04364 \angle -7{,}5$

$${}^dU_3^k = 0 = {}^dU_3^z + Z_{33} \cdot {}^dI_3 = 1{,}04364 \angle -7{,}5 + j\,0{,}9588 \cdot {}^dI_3$$

$$I_3^d = \frac{-1{,}04364 \angle -7{,}5}{j\,0{,}9588} = -0{,}14208 - j\,1{,}07917$$

$$I_{kv} = -I_3^d = 0{,}14208 + j\,1{,}07917$$

$$I_{pu} = I \cdot \frac{\sqrt{3}\,U_n}{S_B} \Rightarrow I = \frac{I_{pu} \cdot S_B}{\sqrt{3}\,U_n}$$

$$I_{kv} = (0{,}14208 + j\,1{,}07917) \cdot \frac{100 \cdot 10^6}{\sqrt{3} \cdot 110 \cdot 10^3}$$

$$I_{kv} = 74{,}57266 + j\,566{,}41735 = \underline{571{,}30526 \angle 82{,}5° \; A}$$

$${}^dU_2^k = {}^dU_2^z + Z_{23} \cdot {}^dI_3 = 1{,}04636 \angle -5{,}7 + j\,0{,}85714 \cdot (-0{,}14208 - j\,1{,}07917)$$

$${}^dU_2^k = 1{,}96619 - j\,0{,}22571 = 217{,}70131 \angle -6{,}55°$$

$$I_{2k} = \left(\frac{S_{2k}}{{}^dU_2^k}\right)^* \quad \frac{j20}{217{,}70131 \angle -6{,}55} = 10{,}47952 + j\,91{,}26959$$

$$= 91{,}86399 \angle -83{,}45°$$