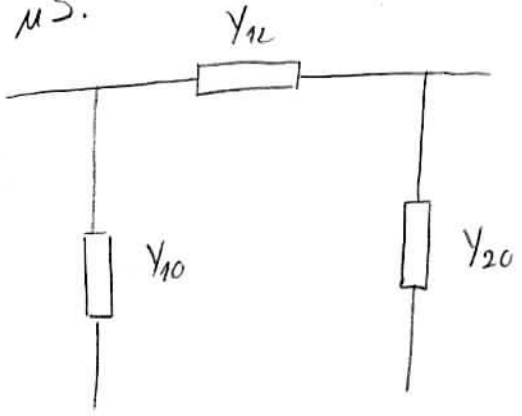
1.) Odredite parametre π - sheme (na 220kV strani) transformatora za kojeg su zadani sljedeći podatci: $S_n = 400\,MVA$, $u_k = 11{,}5\%$, $i_0 = 1\%$, $P_k = 600\,kW$, $P_0 = 130\,kW$. Prijenosni omjer transformatora je $400/220\,kV$ (nazivni prijenosni omjer, $a = 1$). 3 boda.

Izraziti u μS.



$$Z_T = \frac{U_n^2}{S_n}\left[\frac{P_k}{S_n} + j\sqrt{u_k^2 - \left(\frac{P_k}{S_n}\right)^2}\right] =$$

$$= \frac{220^2}{400}\left[\frac{0{,}6}{400} + j\sqrt{0{,}115^2 - \left(\frac{0{,}6}{400}\right)^2}\right] = 0{,}1815 + j\,13{,}914$$

$$Y_T = \frac{1}{Z_T} = 0{,}93734 - j\,71{,}8578\ mS$$

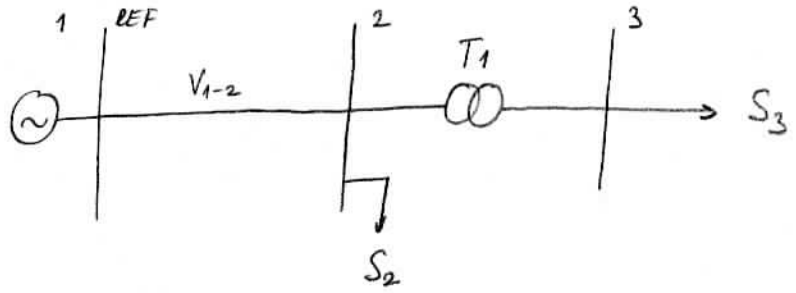
$$Y_{12} = \frac{Y_T}{a} = \frac{Y_T}{1} = Y_T$$

$$Y_0 = \frac{S_n}{U_n^2}\left[\frac{P_0}{S_n} - j\sqrt{i_0^2 - \left(\frac{P_0}{S_n}\right)^2}\right] = \frac{400}{220^2}\left[\frac{0{,}130}{400} - j\sqrt{0{,}01^2 - \left(\frac{0{,}13}{400}\right)^2}\right]$$

$$= 2{,}6859 - 82{,}601\ \mu S$$

$$Y_{10} = Y_{20} = \frac{Y_0}{2} = 1{,}3429 - j\,41{,}3\ \mu S$$

2.) Za mrežu prikazanu slikom odredite koeficijente KL_i i YL_{ij} (u p.u.) koji se koriste za proračun tokova snaga metodom GS-Y. Čvorište 1 je referentno. Koristiti $S_B = 100\,MVA$. 6 bodova.



Poznati su sljedeći podatci:

Vod V_{1-2}	Transformator T1
$U_n = 110\,kV$	$S_n = 150\,MVA$
$X_1 = 0{,}41\,\Omega/km$	$u_k = 11\%$
$\ell = 100\,km$	$U_{n1}/U_{n2} = 110/220\,kV$

Snage potrošača u čvorištima 2 i 3 su također zadane te iznose: $S_{2T} = 20 + j5\,MVA$

$S_{3T} = 80 + j20\,MVA$

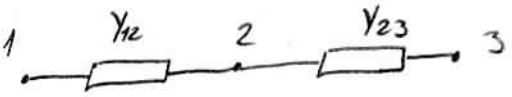
Napomena: Snage potrošača su zadane u apsolutnim iznosima. Potrebno je uzeti u obzir odgovarajući predznak.

$$Z_V\,[p.u.] = \frac{S_B}{U_n^2} \cdot \left(j\,0{,}41 \cdot 100 \right) = j0{,}3388$$

$$Y_{12} = Z_V^{-1} = -j\,2{,}9512 \quad p.u$$

$$Z_T\ [p.u] = \frac{100}{U_n^2}\ \frac{U_n^2}{150}\left[j\sqrt{0{,}11^2} \right] = j0{,}0733$$

$$Y_{23} = Z_T^{-1} = -j\,13{,}6364 \quad p.u.$$



$$[Y] = \begin{bmatrix} Y_{12} & -Y_{12} & 0 \\ -Y_{12} & Y_{12}+Y_{23} & -Y_{23} \\ 0 & -Y_{23} & Y_{23} \end{bmatrix}$$

$$S_{T2} = \frac{-20-j5}{100} = -0{,}2 - j0{,}05$$

$$S_{T3} = \frac{-80-j20}{100} = -0{,}8 - j0{,}2$$

$$KL_2 = \frac{S_{T2}^*}{Y_{22}} = \frac{-0{,}2+j0{,}05}{-j2{,}9512\ j13{,}6364} = 0{,}003 - j0{,}012$$

$$KL_3 = \frac{S_{T3}^*}{Y_{33}} = \frac{-0{,}8+j0{,}2}{-13{,}6364} = -0{,}01467 - j\,0{,}05867$$

$$YL_{2,1} = \frac{Y_{2,1}}{Y_{2,2}} = \frac{+j\,2{,}9512}{-j16{,}5876} = -0{,}1779$$

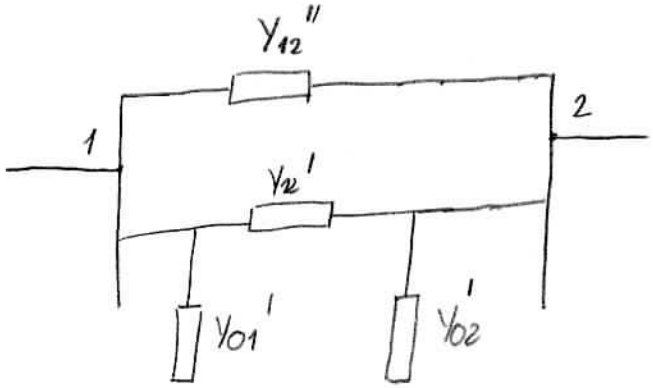
$$YL_{2,3} = \frac{Y_{2,3}}{Y_2} = \frac{j13{,}6364}{-j16{,}5876} = 0{,}8221$$

$$YL_{3,2} = \frac{Y_{3,2}}{Y_{3,3}} = \frac{j13{,}6364}{-j13{,}6364} = -1$$

3.) U transformatorskoj stanici su paralelno spojena dva transformatora sa sljedećim podatcima:

T1	T2
$S_n = 150$ MVA	$S_n = 150$ MVA
$u_k = 11{,}5\%$	$u_k = 11{,}5\%$
420 / 220 kV	400 / 220 kV

Transformatori se nalaze u praznom hodu. Odrediti napon na sekundaru (u kV) ako je napon primara $U_1 = 415$ kV. Koristiti $S_B = 100$ MVA. 5 bodova.



$$Z_T' [p.u.] = \frac{S_B}{U_n^2} \frac{U_n^2}{S_n} \left[j \sqrt{u_k^2} \right] = \frac{100}{150} j\,0{,}115 = j\,0{,}0766 \text{ p.u.}$$

$$a_1 = \frac{\frac{420}{220}}{\frac{400}{220}} = 1{,}05$$

$$Y_T' = \frac{1}{Z_T} = -j13{,}0434 \text{ p.u.}$$

$$Y_{12}' = \frac{Y_T'}{a_1} = -j12{,}4223$$

$$Y_{01}' = \frac{Y_T}{a_1}\left(\frac{1}{a_1} - 1\right) = j\,0{,}59151 \; ; \; Y_{02}' = Y_T\left(1 - \frac{1}{a_1}\right) = -0{,}62111$$

$$Y_{12}'' = Y_T' = -j\,13{,}0434$$

$$[Y] = \begin{bmatrix} -j13{,}0434 - j12{,}4223 - j0{,}59151 & j13{,}0434 + j12{,}4223 \\ j13{,}0434 + j12{,}4224 & -j13{,}0434 - j12{,}4223 - j0{,}62111 \end{bmatrix}$$

$$[Y] = \begin{bmatrix} -j26{,}0572 & j25{,}4657 \\ j25{,}4657 & -j26{,}08681 \end{bmatrix}$$

$I_2 = 0$ p.u.

$U_1 = \frac{415}{400} = 1{,}0375$ p.u.

$U_2 = ?$

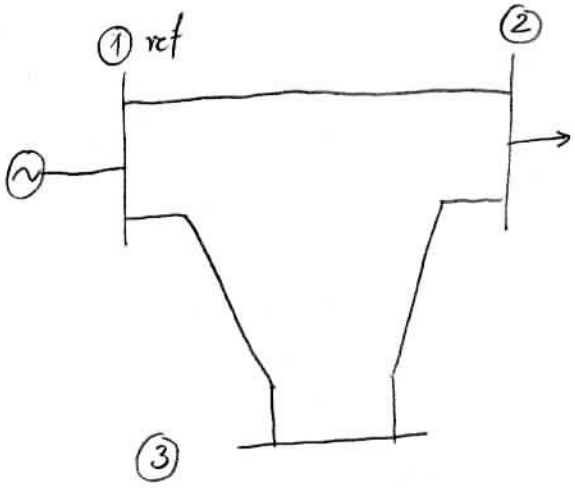
$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = [Y] \begin{bmatrix} U_1 \\ U_2 \end{bmatrix}$$

$$I_2 = Y_{21} \cdot U_1 + Y_{22} \cdot U_2 = j25{,}4657 \cdot 1 - j26{,}08681 \cdot U_2 = 0$$

$$U_2 = \frac{j25{,}4657}{j26{,}08681} = 0{,}9762 \text{ p.u.}$$

$$U_2\,[kV] = 0{,}9762 \cdot 220 = 214{,}76 \text{ kV}$$

4.) Za mrežu zadanu slikom odredite napone u prvoj iteraciji (u kV) koristeći metodu Gauss-Seidel pomoću Z matrice. 6 bodova.



Zadani su tereti u čvorištima:

$S_{2T} = 50 + j\,5$ MVA

$S_{3T} = 150 + j\,30$ MVA

Napon u čvorištu 1 je poznat, iznosi: $\vec{U}_1 = 220\angle 0°$ kV

Podatci o vodovima su dani u tablici:

Vod	R (Ω)	X (Ω)	B (mS)
1-2	0	48	0
1-3	0	20	0
2-3	0	24	0

Koristi $S_B = 100$ MVA. Nazivni napon mreže je $U_n = 220$kV, a naponi u nultoj iteraciji iznose $\vec{U}_2^{(0)} = 220\angle 0°$ kV, $\vec{U}_3^{(0)} = 220\angle 0$ kV

Napomene: → Snage potrošača su dane u apsolutnim iznosima te je prilikom određivanja injekcija u čvorištima potrebno uzeti u obzir odgovarajući predznak.

→ Pretpostaviti da u nultoj iteraciji nije zadovoljen uvjet točnosti. 6 bodova.

$Z_{1,2} = j48\ \Omega$

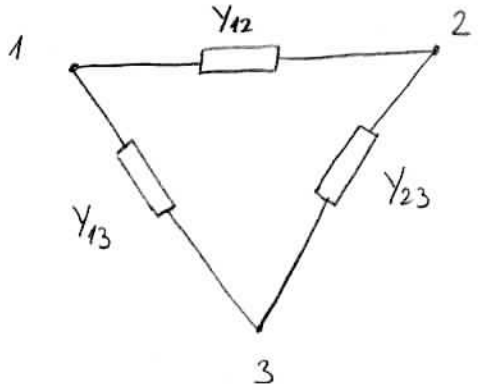
$Z_{13} = j\ 20\ \Omega$

$Z_{23} = j24\ \Omega$

$Z_{12}\ [p.u.] = \frac{100}{220^2} \cdot j48 = 0{,}09917$; $Y_{12}\ [p.u.] = -j\,10{,}083$

$Z_{13}\ [p.u.] = \frac{100}{220^2} \cdot j\,20 = 0{,}04132$; $Y_{13}\ [p.u.] = -j24{,}2$

$Z_{23}\ [p.u.] = \frac{100}{220^2} \cdot j24 = 0{,}04958$; $Y_{23}\ [p.u.] = -20{,}1667$



$$[Y]_{3č} = \begin{bmatrix} Y_{12}+Y_{13} & -Y_{12} & -Y_{13} \\ -Y_{12} & Y_{12}+Y_{23} & -Y_{23} \\ -Y_{13} & -Y_{23} & Y_{13}+Y_{23} \end{bmatrix}$$

$$[Y]_{2č} = \begin{bmatrix} Y_{12}+Y_{23} & -Y_{23} \\ -Y_{23} & Y_{13}+Y_{23} \end{bmatrix} = \begin{bmatrix} -j\,30{,}25 & j\,20{,}1667 \\ j\,20{,}1667 & -j44{,}3667 \end{bmatrix}$$

$$[Z] = [Y]^{-1} = \begin{bmatrix} j\,0{,}04743 & j\,0{,}02156 \\ j\,0{,}02156 & j\,0{,}03234 \end{bmatrix}$$

$$S_2' = \frac{-50 - j5}{100} = -0{,}5 - j0{,}05$$

$$S_3' = \frac{-150 - j30}{100} = -1{,}5 - j0{,}3$$

$$U_1 = 1 \text{ p.u.}$$

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

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

$$I_2^{(0)} = \frac{S_2^*}{U_2^{(0)*}} - \cancel{Y_2' \cdot U_2^{(0)}} = -0{,}5 + j0{,}05 \text{ p.u.}$$

$$I_3^{(0)} = -1{,}5 + j0{,}3 \text{ p.u.}$$

$$I_i^{(k+1)} = \frac{S_i^*}{U_i^{(k+1)*}} - Y' \cdot U_i^{(k+1)}$$

$$U_i^{(k+1)} = U_{REF} + \sum_{\substack{j=1 \\ j \neq ref}}^{i-1} Z_{ij} \cdot I_j^{(k+1)} + \sum_{\substack{j=i \\ j \neq ref}}^{n+1} Z_{ij} \cdot I_j^{(k)}$$

$$U_2^{(1)} = U_1 + Z_{22} \cdot I_2^{(0)} + Z_{23} \cdot I_3^{(0)}$$

$$U_2^{(1)} = 1 + j0{,}04743 \cdot (-0{,}5 + j0{,}05) + j0{,}02156 \cdot (-1{,}5 + j0{,}3) = 0{,}9911 - j0{,}056$$

$$I_2^{(1)} = \frac{S_2^*}{U_2^{(1)*}} = -0{,}5 + j0{,}0787 \text{ p.u.}$$

$$U_3^{(1)} = 1 + Z_{32} \cdot I_2^{(1)} + Z_{33} \cdot I_3^{(0)} = 0{,}9886 - j0{,}0593 \text{ p.u.}$$

$$I_3^{(1)} = \frac{S_3^*}{U_3^{(1)*}} = -1{,}4937 + j0{,}39304 \text{ p.u.}$$

$$U_2^{(1)} = 218{,}39 \angle -3{,}23° \text{ kV}$$

$$U_3^{(1)} = 217{,}88 \angle -3{,}43° \text{ kV}$$