29. 由于三台机组完全相同

28. 向1注入电流： $Z_{11} = \frac{1}{j1+j3+j2} = -j\frac{1}{6} = -j0.1667$

$Z_{21} = \frac{1}{j3+j2} = -j\frac{1}{5} = -j0.2 = Z_{61}$

$Z_{31} = Z_{41} = \frac{1}{j2} = -j\frac{1}{2} = -j0.5 = Z_{51}$

向2注入电流： $Z_{22} = \frac{1}{j2+j3} = -j\frac{1}{5} = -j0.2 = Z_{62}$

$Z_{32} = \frac{1}{j2} = -j\frac{1}{2} = -j0.5 = Z_{42} = Z_{52}$

向3注入电流： $Z_{33} = \frac{1}{j5+j2} = -j\frac{1}{7} = -j0.1429$

$Z_{43} = \frac{1}{j2} = -j\frac{1}{2} = -j0.5 = Z_{53} = Z_{63}$

向4注入电流： $Z_{44} = \frac{1}{j2} = -j0.5 = Z_{54} = Z_{64}$

向5注入电流： $Z_{55} = \frac{1}{j4+j2} = -j\frac{1}{6} = -j0.1667$，$Z_{65} = \frac{1}{j2} = -j0.5$

向6注入电流： $Z_{66} = \frac{1}{j2+j3+j2} = -j\frac{1}{7} = -j0.1429$

由Z矩阵对称性得：

$$Z = \begin{bmatrix} -j0.1667 & -j0.2 & -j0.5 & -j0.5 & -j0.5 & -j0.2 \\ -j0.2 & -j0.2 & -j0.5 & -j0.5 & -j0.5 & -j0.2 \\ -j0.5 & -j0.5 & -j0.1429 & -j0.5 & -j0.5 & -j0.5 \\ -j0.5 & -j0.5 & -j0.5 & -j0.5 & -j0.5 & -j0.5 \\ -j0.5 & -j0.5 & -j0.5 & -j0.5 & -j0.1667 & -j0.5 \\ -j0.2 & -j0.2 & -j0.5 & -j0.5 & -j0.5 & -j0.1429 \end{bmatrix}$$

29. (1) 由于三台机组完全相同 $\therefore P_{G10} = P_{G20} = P_{G30} = \frac{1}{3}P_{D0} = 60\,MW$

$\Delta P_{G1} = \frac{1}{3}\Delta P_{D1} = \frac{1}{3}\times 32 = 10.67\,MW$

各台机组功频静特性系数：$K_{Gi} = \frac{1}{\delta_{i*}} \cdot \frac{P_{GN}}{f_N} = \frac{1}{2.5\%} \times \frac{100}{50} = 80\,MW/Hz$

$\therefore \Delta f_1 = -\frac{\Delta P_{G1}}{K_{Gi}} = -\frac{10.67}{80} = -0.1334\,Hz$

(2) $\Delta P_{G2} = \frac{1}{2}\Delta P_{D1} = 16\,MW$，$\Delta f_2 = -\frac{\Delta P_{G2}}{K_{Gi}} = -0.2\,Hz$

(3) 改变 K_{G1}

$\Delta f_3 = \frac{1}{2}\Delta f_1 = -0.0667\,Hz$ ~~$\Delta P_{G3} = \Delta P_{G1}$~~

$-\Delta f_3 (K_{G1} + 2K_{Gi}) = \Delta P_{G1} \Delta P_{D1}$ $\therefore K_{G1} = 320.0\,MW/Hz$

$\therefore \delta_1^* = \frac{1}{K_{G1}} \cdot \frac{P_{GN}}{f_N} = \frac{1}{320.0} \times \frac{100}{50} = 0.625\%$

再代入 $\left[\frac{\Delta Q}{U}\right] = B'' [\Delta U]$ 求出 $\Delta U^{(0)}$，修正电压 $U^{(1)} = U^{(0)} - \Delta U^{(0)}$，返回计算 ΔP，ΔQ

如此反复

(6) 可以调低①点电压或升高周围节点（例如④）的电压

$\widetilde{X}_2 = (X_2 + X_{T1}) // (\frac{1}{2}X_{L1} + X_{T2}) = 0.2363$

$\widetilde{X}_{\text{零}0} = X_{T1} // (\frac{1}{2}X_{L0} + X_{T2}) = 0.09551$

$\therefore \dot{I}_{a1} = \dfrac{\dot{E}}{j(\widetilde{X}_1 + \widetilde{X}_2 // X_0)} = 6.275\angle -66.09°$

$\therefore \dot{I}_{a0} = -\dot{I}_{a1} \cdot \dfrac{\widetilde{X}_2}{\widetilde{X}_2 + \widetilde{X}_0} = 4.469\angle 113.9°$

$\dot{I}_{aT10} = $ 对 $- \dfrac{\frac{1}{2}X_{L0} + X_{T2}}{X_{T1} + \frac{1}{2}X_{L0} + X_{T2}} \cdot \dot{I}_{a0} = 4.268\angle -66.09°$

$\therefore \dot{I}_{T10} = 3\dot{I}_{aT0} = 12.80\angle -66.09°$

(3) 系 $X_{\text{I}} = X_d' + X_{T1} + \frac{1}{2}X_{L1} + X_{T2} = $ ~~1.495~~ 1.175 $\quad E' = 1.55 \quad U = 1$

$X_\Delta = \widetilde{X}_0 = $ ~~0.2363~~ $\dfrac{\widetilde{X}_2\widetilde{X}_0}{\widetilde{X}_2 + \widetilde{X}_0} = 0.06880$

$X_{\text{II}} = (X_d' + X_{T1}) + (\frac{1}{2}X_{L1} + X_{T2}) + \dfrac{(X_d' + X_{T1}) + (\frac{1}{2}X_{L1} + X_{T2})}{X_\Delta} = $ ~~2.487~~ 5.681

$X_{\text{III}} = X_d' + X_{T1} + X_{L1} + X_{T2} = 1.85$

$P_{\text{II}M} = \dfrac{E'U}{X_{\text{II}}} = 0.6232 \qquad P_{\text{III}M} = \dfrac{E'U}{X_{\text{III}}} = 0.8378$

$P_0 = \dfrac{E'U}{X_{\text{I}}}\sin\delta_0 = \dfrac{1.55}{1.175} \times \sin(25.6°) = $ ~~0.560~~ 0.5700

$\delta_h = 180° - \delta_0 = 154.4°$

$\therefore \delta_{cr} = \cos^{-1}\left(\dfrac{P_0(\delta_h - \delta_0) + P_{\text{II}M}\cos\delta_h - P_{\text{III}M}\cos\delta_0}{P_{\text{II}M} - P_{\text{III}M}}\right) = $ ~~82.82°~~ 62.82°

(4) $X_\Delta = X_2$ 增大 $\quad X_{\text{II}}$ 减小 $\quad \because P_{\text{II}M}, P_{\text{III}M}$ 增大 $\quad \therefore \delta_{new}$ 更大一些

3. (1) $X_{dz} = 0.62 + 0.1 + \frac{1}{2} \times 1.35 + 0.4 = 0.62 + 0.875 = 1.495$

$X_{qz} = 0.48 + 0.875 = 1.355$

$X'_{dz} = 0.3 + 0.875 = 1.175$

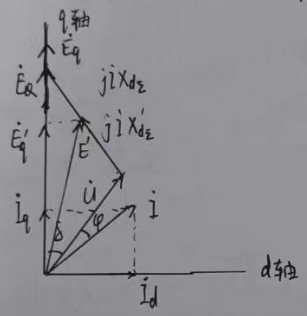
$\dot{U} = 1.0 \angle 0°$ $\therefore \dot{I} = \frac{\dot{E}' - \dot{U}}{jX'_{dz}} = 0.6630 \angle -30.71°$ $\therefore \varphi = 30.71°$

$\therefore \dot{E}_Q = \dot{U} + j\dot{I}X_{qz} = 1.651 \angle 27.90°$ $\therefore \delta = 27.90°$

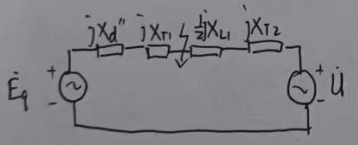
$I_d = I \sin(\delta + \varphi) = 0.5659$, $I_q = I \cos(\delta + \varphi) = 0.3454$

$E_q = U \cdot \cos\delta + I_d \cdot X_{dz} = 1.730$

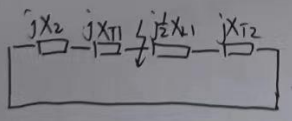
$\therefore \dot{E}_q = 1.730 \angle 27.90°$, $\dot{I}_d = 0.5659 \angle -62.1°$, $\dot{I}_q = 0.3454 \angle 27.90°$



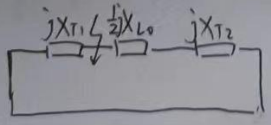
(2) 正序网



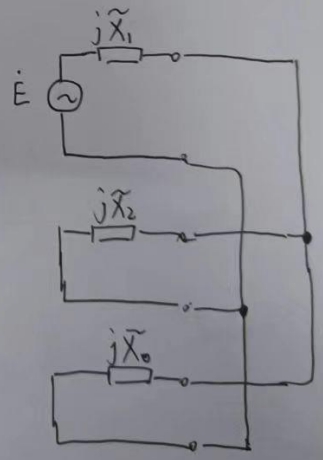
负序网



零序网



$\Rightarrow$



$\tilde{X}_1 = \left[(X_d'' + X_{T1}) /\!/ (\frac{1}{2}X_{L1} + X_{T2}) \right] \frac{S_N}{S_B} = 0.1774$

$\dot{E} = \left(\frac{\dot{E}_q}{X_d'' + X_{T1}} + \frac{\dot{U}}{X_{L1} + X_{T2}} \right) \tilde{X}_1 = 1.540 \angle 23.91°$

30. (1) ① PV节点 ② VS节点(平衡节点) ③ PQ节点

(2) $Y_{11} = jB_{10} + \frac{1}{\frac{1}{jB_{12}} + \frac{1}{jB_{20}} /\!/ (t^2 \cdot \frac{1}{jB_{23}})} = jB_{10} + \frac{t^2 B_{12}(B_{20}+B_{23})}{t^2(B_{20}+B_{23}) + B_{12}}$

(2) $Y_{11} = jB_{10} + jB_{12} = j(B_{10}+B_{12})$

$Y_{12} = -jB_{12}$ $Y_{13} = 0$,

$Y_{22} = jB_{12} + jB_{20} + jt^2B_{23} = j(B_{12} + B_{20} + t^2B_{23})$

$Y_{23} = -jt^2B_{23}$, $Y_{33} = jB_{23}$

$$Y = \begin{bmatrix} j(B_{10}+B_{12}) & -jB_{12} & 0 \\ -jB_{12} & j(B_{12}+B_{20}+t^2B_{23}) & -jt^2B_{23} \\ 0 & -jt^2B_{23} & jB_{23} \end{bmatrix}$$

(3) $\Delta P_1 = P_1 - U_1(U_2 B_{12}\sin\delta_{12}) = P_1 + U_1U_2B_{12}\sin(\delta_1-\delta_2)$

$\Delta P_3 = -P_3 - U_3(U_2 B_{32}\sin\delta_{32}) = -P_3 + U_2U_3t^2B_{23}\sin(\delta_3-\delta_2)$

$\Delta Q_3 = -Q_3 - U_3(-U_2B_{32}\sin\delta_{32}) = -Q_3 - U_2U_3t^2B_{23}\sin(\delta_3-\delta_2)$

(4) $$\begin{bmatrix} \Delta P_1 \\ \Delta P_3 \\ \Delta Q_3 \end{bmatrix} = \begin{bmatrix} +U_1U_2B_{12}\cos\delta_{12} & 0 & 0 \\ 0 & U_2U_3t^2B_{23}\cos\delta_{32} & U_2U_3t^2B_{23}\sin\delta_{32} \\ 0 & U_2U_3t^2B_{23}\sin\delta_{32} & -U_1U_3t^2B_{23}\cos\delta_{32} + 2B_{23}U_3^2 \end{bmatrix} \begin{bmatrix} \Delta\delta_1 \\ \Delta\delta_3 \\ \frac{\Delta U_3}{U_3} \end{bmatrix}$$

(5) $B' = \begin{bmatrix} B_{10}+B_{12} & 0 \\ 0 & B_{23} \end{bmatrix}$ $B'' = \begin{bmatrix} B_{23} \end{bmatrix}$

给定初值 $\delta^{(0)}$、$U^{(0)}$，计算 $\Delta P^{(0)}$ 和 $\left[\frac{\Delta P}{U}\right]^{(0)}$ 代入 $\left[\frac{\Delta P}{U}\right] = B'[U\delta]$ 求出 $\Delta\delta^{(0)}$，修正相角 $\delta^{(1)} = \delta^{(0)} - \Delta\delta^{(0)}$

代入 $\left[\frac{\Delta Q}{U}\right] = B''[\Delta U]$ 求出 $\Delta U = \frac{\Delta Q}{U}$ 由无功功率方程求出 $\Delta Q^{(0)}$，计算 $\left[\frac{\Delta Q}{U}\right]^{(0)}$