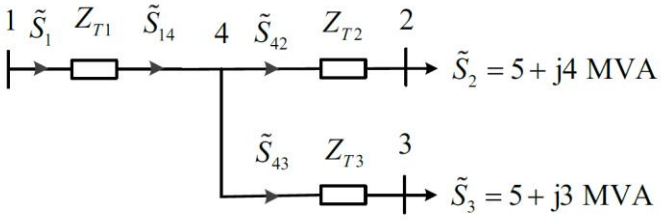
习题 3-5 某变电站安装一台三绕组变压器，运行变比为 110/38.5（1+0.05）/6.6kV，变压器参数折算在高压侧的等值电路如图。若维持变压器低压母线电压为 6kV，则高压母线和中压母线的实际电压为多少？变压器高压侧输入功率为多少？（采用有名值计算）



$Z_{T1} = 0.7 + j65\ \Omega,\ Z_{T2} = 1.47 - j1.51\ \Omega,\ Z_{T3} = 2.47 + j37.8\ \Omega$

答：设低压侧电压为 $6\angle 0^\circ$ kV

在归算后的高压等值电路中 3 点电压为：$V_3 = \frac{V_{低}}{V_{低N}} V_{高N} = \frac{6\angle 0^\circ}{6.6} 110 = 100\angle 0^\circ$ kV

34 支路上的串联损耗：$\Delta S_{Z_{T3}} = \frac{P_3'^2 + Q_3'^2}{|V_3|^2} Z_{T3} = \frac{5^2 + 3^2}{100^2}(2.47+37.8j) = 0.0084+0.1285j$ MVA

所以 $\tilde{S}_{43} = \Delta S_{Z_{T3}} + \tilde{S}_3 = 5.0084 + 3.1285j$ MVA

4 点电压为：

$$V_4 = |V_3| + \frac{P_3' R_{T3} + Q_3' X_{T3}}{|V_3|} + \frac{P_3' X_{T3} - Q_3' R_{T3}}{|V_3|} j = 100 + \frac{5*2.47+3*37.8}{100} + \frac{5*37.8-3*2.47}{100} j = 101.2575+1.8159j$$

$$= 101.2738\angle 1.0256^\circ \text{ kV}$$

为求 2 点电压，需要采用辐射型网络潮流估算方法，过程如下：

取 2 点电压为额定电压：$110\angle 0^\circ$ kV

24 支路上的串联损耗：$\Delta S_{Z_{T2}} = \frac{P_2'^2 + Q_2'^2}{|V_2|^2} Z_{T2} = \frac{5^2 + 4^2}{110^2}(1.47 - 1.51j) = 0.0050 - 0.0051j$ MVA

24 支路近似功率分布：$\tilde{S}_{42} = \Delta S_{Z_{T2}} + \tilde{S}_2 = 5.0050 + 3.9949j$ MVA

24 支路上的电压降落：

$$dV_{24} = \frac{P_{42} R_{T2} + Q_{42} X_{T2}}{|V_4|} + \frac{P_{42} X_{T2} - Q_{42} R_{T2}}{|V_4|} j$$

$$= \frac{5.0050*1.47 - 3.9949*1.51}{100.2738} + \frac{5.0050*(-1.51) - 3.9949*1.47}{100.2738} j$$

$$= 0.0132 - 0.1339j$$

所以迭代一次后：

$$V_2 = V_4 - dV_{24} = 101.2575+1.8159j - (0.0132 - 0.1339j) = 101.2443 + 1.9498j = 101.2588\angle 1.1058^\circ \text{ kV}$$

14 支路末端功率：$\tilde{S}_4 = \tilde{S}_{42} + \tilde{S}_{43} = 5.0050 + 3.9949j + 5.0084 + 3.1285j = 10.0134 + 7.1234j$ MVA

14 支路串联损耗：$\Delta S_{Z_{T1}}=\frac{P_4^{'2}+Q_4^{'2}}{|V_4|^2}Z_{T1}=\frac{10.0134^2+7.1234^2}{101.2738^2}(0.7+65j)=0.0103+0.9570j$ MVA

高压侧输入功率：$\tilde{S}_1=\Delta S_{Z_{T1}}+\tilde{S}_4=0.0103+0.9570j+10.0134+7.1234j=10.0237+8.0804j$ MVA

1 点电压（先以 3 点为参考电压进行计算，然后进行角度修正，实际上本题只需要求幅值，无需求角度）：

$$V_1=|V_4|+\frac{P_4^{'}R_{T1}+Q_4^{'}X_{T1}}{|V_4|}+\frac{P_4^{'}X_{T1}-Q_4^{'}R_{T1}}{|V_4|}j=101.2738+\frac{10.0134*0.7+7.1234*65}{101.2738}+\frac{10.0134*65-7.1234*0.7}{101.2738}j$$

$$=105.9150+6.3776j=106.1068\angle 3.4459^\circ \text{ kV}$$

所以$V_1=106.1068\angle(3.4459^\circ+1.0256^\circ)=106.1068\angle 4.4715^\circ$ kV

将各点电压转化为实际电压：

$V_{低}=6\text{kV}$

$$V_{中}=\frac{|V_3|}{V_{高N}}*V_{中N}=\frac{101.2588}{110}*38.5*(1.05)=37.2126\text{ kV}$$

$$V_{高}=\frac{|V_1|}{V_{高N}}*V_{高N}=106.1068\text{ kV}$$

习题 3-6 某配电线路的电阻与电抗相等，末端电压为 3kV，有功负荷为 600kW。已知当负荷功率因数为 1 时，线路的电压损耗为 10%。若负荷功率因数为 0.8（感性），仍要使线路的电压损耗不大于 10%，这样负荷的有功功率是多少？

答：

设电阻和电抗均为 $x\ \Omega$

功率因数为 1 时

末端功率 S=600kW=0.6MW

$$dV_2=\frac{P_2R+Q_2X}{|V_2|}+\frac{P_2X-Q_2R}{|V_2|}j=\frac{0.6x}{3}+\frac{0.6x}{3}j\ \text{kV}$$

所以 $V_1=V_2+dV_2=3+\frac{0.6x}{3}+\frac{0.6x}{3}j\ \text{kV}$

所以有 $\frac{|V_1|-|V_2|}{3}=\frac{\sqrt{(3+\frac{0.6x}{3})^2+(\frac{0.6x}{3})^2}-3}{3}=0.1$

解得 x=1.4375

所以线路阻抗为：Z=1.4375+1.4375j Ω

设传输的功率为：S'=0.8y+0.6yj MVA

$$dV_2=\frac{P_2R+Q_2X}{|V_2|}+\frac{P_2X-Q_2R}{|V_2|}j=\frac{0.8y*1.4375+0.6y*1.4375}{3}+\frac{0.8y*1.4375-0.6y*1.4375}{3}j=0.6708y+0.0958yj\ \text{kV}$$

$$V_1=V_2+dV_2=3+0.6708y+0.0958yj\ \text{kV}$$

要求电压损耗不超过 10%，有：

$$\frac{|V_1|-|V_2|}{3}=\frac{\sqrt{(3+0.6708y)^2+(0.0958y)^2}-3}{3}\le 0.1$$

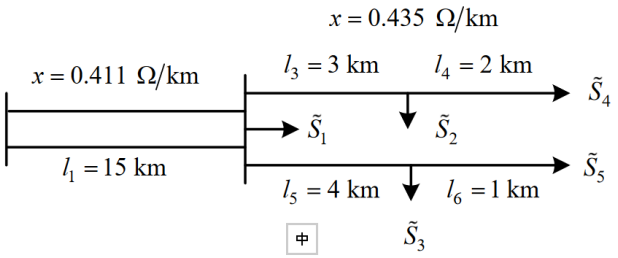
解得：$y\le 0.4421$

所以负荷功率：

S'=0.8*y+0.6*yj=0.3537+0.2653j MVA

习题 3-15 某 35kV 配电系统网络如图，根节点电压运行在 37kV 时，若忽略线路功率损耗，求网络的最大电压损耗。

$\tilde{S}_1 = 6.4 + \mathrm{j}4.8\ \mathrm{MVA}$
$\tilde{S}_2 = 0.04 + \mathrm{j}0.03\ \mathrm{MVA}$
$\tilde{S}_3 = 0.8 + \mathrm{j}0.6\ \mathrm{MVA}$
$\tilde{S}_4 = 0.7 + \mathrm{j}0.714\ \mathrm{MVA}$
$\tilde{S}_5 = 0.03 + \mathrm{j}0.04\ \mathrm{MVA}$



答：

计算线路参数：

$$x_{L1} = \frac{1}{2} \times 0.411 \times 15 = 3.083\ \Omega$$

$$x_{L3} = 0.435 \times 3 = 1.305\ \Omega$$

$$x_{L4} = 0.435 \times 2 = 0.870\ \Omega$$

$$x_{L5} = 0.435 \times 4 = 1.740\ \Omega$$

$$x_{L6} = 0.435 \times 1 = 0.435\ \Omega$$

忽略线路功率损耗（包括有功和无功），计算线路传输功率

$$S_{L4} = S_4 = 0.7 + \mathrm{j}0.714\ \mathrm{MVA}$$

$$S_{L3} = 0.04 + \mathrm{j}0.03 + 0.7 + \mathrm{j}0.714 = 0.74 + \mathrm{j}0.744\ \mathrm{MVA}$$

$$S_{L6} = S_5 = 0.03 + \mathrm{j}0.04\ \mathrm{MVA}$$

$$S_{L5} = 0.8 + \mathrm{j}0.6 + 0.03 + \mathrm{j}0.04 = 0.83 + \mathrm{j}0.64\ \mathrm{MVA}$$

$$S_{L1} = 6.4 + \mathrm{j}4.8 + 0.74 + \mathrm{j}0.744 + 0.83 + \mathrm{j}0.64 = 7.97 + \mathrm{j}6.184\ \mathrm{MVA}$$

计算各条线路上的电压损耗：

$$U_0 = 37\ \mathrm{kV}$$

$$U_1 = \left| 37 - \frac{6.184 \times 3.083}{37} - \mathrm{j}\frac{7.97 \times 3.083}{37} \right| = 36.491\ \mathrm{kV}$$

$$U_2=\left|36.491-\frac{0.744\times1.305}{36.491}-\mathrm{j}\frac{0.74\times1.305}{36.491}\right|=36.464\,\mathrm{kV}$$

$$U_4=\left|36.464-\frac{0.714\times0.870}{36.464}-\mathrm{j}\frac{0.7\times0.870}{36.464}=\right|=36.447\,\mathrm{kV}$$

$$U_3=\left|36.491-\frac{0.64\times1.740}{36.491}-\mathrm{j}\frac{0.83\times1.740}{36.491}\right|=36.461\,\mathrm{kV}$$

$$U_5=\left|36.461-\frac{0.04\times0.435}{36.461}-\mathrm{j}\frac{0.03\times0.435}{36.461}\right|=36.461\,\mathrm{kV}$$

最大电压损耗为 $\frac{U_0-U_4}{U_N}\times100\%=\frac{37-36.447}{35}\times100\%=1.58\%$

（或者，使用近似公式）

$$U_1=37-\frac{6.184\times3.083}{37}=36.485\,\mathrm{kV}$$

$$U_2=36.485-\frac{0.744\times1.305}{36.485}=36.458\,\mathrm{kV}$$

$$U_4=36.458-\frac{0.714\times0.870}{36.458}=36.441\,\mathrm{kV}$$

$$U_3=36.485-\frac{0.64\times1.740}{36.485}=36.454\,\mathrm{kV}$$

$$U_5=36.454-\frac{0.04\times0.435}{36.454}=36.454\,\mathrm{kV}$$

最大电压损耗为 $\frac{U_0-U_4}{U_N}\times100\%=\frac{37-36.441}{35}\times100\%=1.60\%$

如果不忽略无功损耗，首先取各点电压均为 35kV，初步计算功率分布

$$\Delta S_{L4}=\frac{0.7^2+0.714^2}{35^2}\times\mathrm{j}0.870=\mathrm{j}0.00071\,\mathrm{MVA}$$

$$S_{L4}=0.7+\mathrm{j}0.714+\mathrm{j}0.00071=0.7+\mathrm{j}0.715\,\mathrm{MVA}$$

$$\Delta S_{L3}=\frac{(0.7+0.04)^2+(0.715+0.03)^2}{35^2}\times\mathrm{j}1.305=\mathrm{j}0.00117\,\mathrm{MVA}$$

$$S_{L3}=0.7+\mathrm{j}0.715+0.04+\mathrm{j}0.03+\mathrm{j}0.00117=0.74+\mathrm{j}0.746$$

$$\Delta S_{L6}=\frac{0.03^2+0.04^2}{35^2}\times\mathrm{j}0.435=\mathrm{j}8.88\times10^{-7}\,\mathrm{MVA}$$

$$S_{L6}=0.03+\mathrm{j}0.04+\mathrm{j}8.88\times10^{-7}=0.03+\mathrm{j}0.04\,\mathrm{MVA}$$

$$\Delta S_{L5}=\frac{(0.8+0.03)^2+(0.6+0.04)^2}{35^2}\times \mathrm{j}1.740=\mathrm{j}0.00156\,\mathrm{MVA}$$

$$S_{L5}=0.8+\mathrm{j}0.6+0.03+\mathrm{j}0.04+\mathrm{j}0.00156=0.83+\mathrm{j}0.642$$

$$\Delta S_{L1}=\frac{(6.4+0.74+0.83)^2+(4.8+0.746+0.642)^2}{35^2}\times \mathrm{j}3.083=\mathrm{j}0.256\,\mathrm{MVA}$$

$$S_{L1}=6.4+\mathrm{j}4.8+0.74+\mathrm{j}0.746+0.83+\mathrm{j}0.642+\mathrm{j}0.256=7.97+\mathrm{j}6.444\,\mathrm{MVA}$$

回代计算电压：

$$U_0=37\,\mathrm{kV}$$

$$U_1=\left|37-\frac{6.444\times 3.083}{37}-\mathrm{j}\frac{7.97\times 3.083}{37}\right|=36.469\,\mathrm{kV}$$

$$U_2=\left|36.469-\frac{0.746\times 1.305}{36.469}-\mathrm{j}\frac{0.74\times 1.305}{36.469}\right|=36.442\,\mathrm{kV}$$

$$U_4=\left|36.442-\frac{0.715\times 0.870}{36.442}-\mathrm{j}\frac{0.7\times 0.870}{36.442}=\right|=36.425\,\mathrm{kV}$$

$$U_3=\left|36.469-\frac{0.642\times 1.740}{36.469}-\mathrm{j}\frac{0.83\times 1.740}{36.469}\right|=36.438\,\mathrm{kV}$$

$$U_5=\left|36.438-\frac{0.04\times 0.435}{36.438}-\mathrm{j}\frac{0.03\times 0.435}{36.438}\right|=36.438\,\mathrm{kV}$$

最大电压损耗为 $\frac{U_0-U_4}{U_N}\times 100\%=\frac{37-36.425}{35}\times 100\%=1.64\%$

（或者，使用近似公式）

$$U_1=37-\frac{6.444\times 3.083}{37}=36.463\,\mathrm{kV}$$

$$U_2=36.463-\frac{0.746\times 1.305}{36.463}=36.436\,\mathrm{kV}$$

$$U_4=36.436-\frac{0.715\times 0.870}{36.436}=36.419\,\mathrm{kV}$$

$$U_3=36.463-\frac{0.642\times 1.740}{36.463}=36.432\,\mathrm{kV}$$

$$U_5=36.432-\frac{0.04\times 0.435}{36.432}=36.432\,\mathrm{kV}$$

最大电压损耗为$\frac{U_0-U_4}{U_N}\times100\%=\frac{37-36.419}{35}\times100\%=1.66\%$