Homework 3 Haocong Wang mw814

Q1. $(3-\varphi)\ P = \sqrt{3}\, V_L I \cos\varphi \Rightarrow (3-\varphi)\ S = \sqrt{3}\, V_L I$

$\Rightarrow I = S/\sqrt{3}V_L = \dfrac{100 \times 10^6}{\sqrt{3} \times 220 \times 10^3} = 262.43$ A

total (I^2R) ~~l~~oss $=$ max (3%) of rated MVA $= \left(100 \times \frac{3}{100}\right) = 3$ MVA

$\Rightarrow (I^2R$ - loss) per phase $= 1$ MVA $= 10^6$ VA

$\therefore R/ph = \left[\dfrac{10^6}{262.43^2}\right] = 14.52\ (\Omega/ph)$

$\because R/ph = \rho\dfrac{l}{a} \Rightarrow a = \dfrac{\rho \times l}{(R/ph)} = \dfrac{2.84 \times 10^{-8} \times 100 \times 10^3}{14.52}$

$= 1.956 \times 10^{-4}\ m^2 = \pi r^2$

$\Rightarrow r = 7.89 \times 10^{-3}$ m $\Rightarrow D = 0.0157$ m $= 15.7$ (mm)

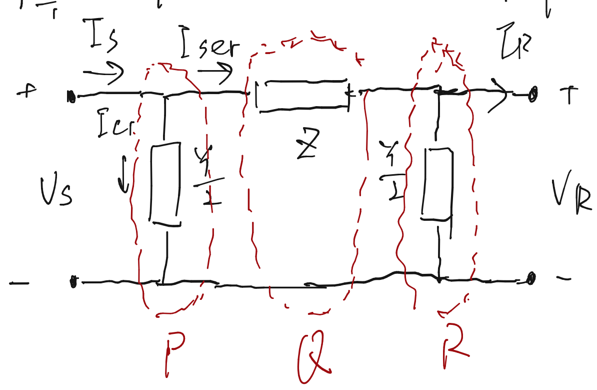
Q2. $Z = 0.05 + j0.45\ (\Omega/km/ph) = 0.4527 \angle 83.66°$

$y = 3.4 \times 10^{-6} \angle 90°$, $l = 80$ km

(a) $Z_T = 0.4527 \times 80\ \Omega/ph = 36.216\ (\Omega/ph) \Rightarrow Z_T = 36.216 \angle 83.66°$

$Y_T = 2.72 \times 10^{-4}\ (\Omega^{-1}/ph) \Rightarrow Y/2 = 1.36 \times 10^{-4} \angle 90°$

(b)



for P: ~~AB~~CD $= \begin{bmatrix} 1 & 0 \\ Y/2 & 1 \end{bmatrix}$

for Q: $\begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}$

for R: $\begin{bmatrix} 1 & 0 \\ Y/2 & 1 \end{bmatrix}$

$\Rightarrow$ Total (ABCD) - constant $=$ cascading of P. Q. R

$= \begin{bmatrix} 1 & 0 \\ Y/2 & 1 \end{bmatrix} \begin{bmatrix} 1 & Z_T \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ Y/2 & 1 \end{bmatrix} = \begin{bmatrix} 1 + \frac{YZ}{2} & Z \\ Y\left(1 + \frac{YZ}{4}\right) & 1 + \frac{YZ}{2} \end{bmatrix}$

$\Rightarrow A = D = 0.995 \angle 0.0314°$

$B = 36.216 \angle 83.66°$, $C = 2.713 \times 10^{-4} \angle 90.0156°$

(c) 1. $V_R(ph) = \dfrac{220}{\sqrt{3}} \times 10^3 = 127.017 \times 10^3 \angle 0°$, $P_o = \sqrt{3}\, V_R I_R \cos\varphi_o$

$\Rightarrow I_R$ (ph = line) $= \left[\dfrac{200 \times 10^6}{\sqrt{3} \times 220 \times 10^3 \times 0.8}\right] = 656.08$ A

$\Rightarrow I_R(ph) = 656.68 \angle -\cos^{-1}(0.8) = 656.68 \angle -36.86°$

$\Rightarrow V_S = AV_R + BI_R = 143.7 \angle 6.95$ kV (ph)

$V_S(L\text{-}L) = V_S(ph) \times \sqrt{3} = 248.9 \angle 6.95°$ kV

2. $P_0 = 306\ MVA = \sqrt{3} \times 220 \times 10^3 \times I_R$

$\Rightarrow I_R = \left(\frac{306 \times 10^6}{\sqrt{3} \times 220 \times 10^3} \right) = 803.0417 \Rightarrow I_R = 803.0417 \angle 0^\circ$

$\therefore V_s(ph) = AV_R + BI_R = 132.793 \angle 12.6^\circ$ kV

$V_s(l-l) = 230 \angle 12.6^\circ$ kV

Q3. (a) $\underline{1.7414 \times 10^{-19} (\Omega^{-1} \cdot m)}$ (b) $\underline{3.292 \times 10^{-4}\ \Omega/m}$

Q4. (a) per-unit value of the power $= \frac{30}{30} = 1$ pu

- - - - - - voltage $= \frac{26}{26} = 1$ pu

(b) $\frac{E \cdot V}{X_s} \sin\delta = 0.32 \Rightarrow \delta = \sin^{-1}\left(\frac{0.32 \times 8}{1.3}\right) = 11.354^\circ$

$Q = \frac{V}{X_s}[E\cos\delta - V] = 0.343$ pu

$S = 0.32 + j0.343$

(c) $\tan\varphi = \frac{Q}{P} \Rightarrow \phi = 46.98^\circ \Rightarrow$ power factor $= 0.68$ lag

(d) Real power $= 1.50 \times 0.32 = 0.48$ pu

$P = \frac{E \cdot V}{X_s} \sin\delta \Rightarrow \delta = 17.18$

Reactive power $= 0.343$ pu

Power factor : $\tan^{-1}\left(\frac{0.343}{0.48}\right) = 35.54 = \varphi \Rightarrow \cos\varphi = 0.81$ lag

$Q = \frac{-V^2}{X_s} + \frac{VE}{X_s}\cos\delta = 0.293$

$S = 4.8 + j0.293$

(e) We can change the DC field excitation :

$E\uparrow \Rightarrow$ power angle $\delta\downarrow \Rightarrow \cos\delta\uparrow, \sin\delta\downarrow \Rightarrow$ decrease the power factor

(f) $|E_{new}| = 1.3 \times 1.15 = 1.495$ pu, $P_e = \frac{|V| \cdot |E_{new}|}{X_a} \cdot \sin(\delta'_{new}) = 0.32$

$\Rightarrow \sin|\delta'_{new}| = 0.171 \Rightarrow \delta'_{new} = 9.846^\circ$

$\Rightarrow Q_e = \frac{|V|\ |E_{new}|}{X_a} \cdot \cos(\delta'_{new}) - \frac{|V|^2}{X_a} = 0.59$ pu

$|S| = \sqrt{P_e^2 + Q_e^2} = 0.67$ pu, $pf = \frac{P_e}{|S|} = 0.48$