University of Saskatchewan
College of Engineering

EE 342: Power Systems I
Mid-term Examination

A formula sheet is allowed

Instructor: S.O. Faried **October 2008**
Duration: 2 hours

1. A 60-Hz, 500-kV, 3-phase transmission line is 320 km long. The distributed line parameters are: $r = 0.01864\ \Omega/km$, $x_l = j0.3728\ \Omega/km$, $y = j4.4739\ \mu S/km$.
   The transmission line delivers 700 MW at 500 kV with 90% power factor lagging. Find:
   (a) The sending-end voltage and current.
   (b) The transmission line efficiency.
   (c) The voltage regulation.
   (d) It is required to compensate the line by a series capacitor bank. The degree of series compensation is 70%. Find the value of the capacitance per phase of the series capacitor bank.

2. The configuration of a double circuit, bundle conductors, three-phase, 60-Hz, 500 kV, 400 km, transposed line is shown in Fig. 1. The bundle spacing is 45 cm.

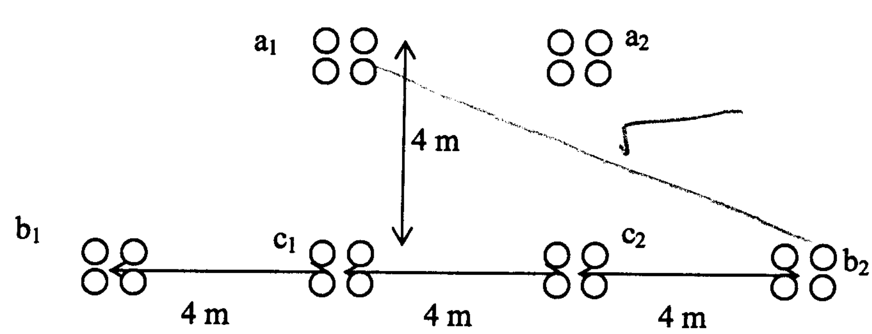


Fig. 1

Each conductor of the bundle is Bluebird with an outside diameter of 1.762 in, a GMR of 0.0586 ft and a resistance of 0.034 ohm/km.

Find:

a) The inductive reactance and shunt admittance of the line per phase per km.

b) The surge impedance loading.

c) The wavelength of the line.

d) The disruptive corona voltage in kV for air temperature of 27° C, a barometric pressure of 740 mm and irregularity factor of 0.85.

1 $\ell = 320\,km$

$R = .01864\,\Omega/km$

$X_L = j.3728\,\Omega/km$

$Y = j4.4739\,\mu℧/km$

delivers: 700 MW, 500 kV, .9 (lagging)

FIND ABCD PARAMETERS:

a) $Z_{series} = (R + jX_L)\ell$

$= (.01864\,\Omega/km + j.3728\,\Omega/km)(320\,km)$

$Z_{series} = 122.1231\angle 77.6477°\,\Omega$

$Y = (j(4.4739 \times 10^{-6}\,℧/km)(320\,km))$

$Y = .001432\angle 90°\,℧$

$Z_c = \sqrt{\dfrac{Z}{Y}} = 292.0300\angle -6.1762°$

$\gamma = \sqrt{ZY} = .4182\angle 83.8239°$ ✓

$A = D = \cosh(\gamma)$

$= .9159\angle 1.1372°$

$B = Z_c \sinh\gamma$

$B = 118.6801\angle 78.0091°$

$C = \sinh(\gamma)/Z_c$

$C = .001392\angle 90$

$V_{Rph} = \dfrac{500kV}{\sqrt{3}}\angle 0°$

$P = \sqrt{3}\,|V_L|\,|I_L|\cos\phi$

$|I_R| = \dfrac{700 \times 10^6\,W}{\sqrt{3}(500 \times 10^3\,V)(.9)}$

$|I_R| = 895.1004\,A$

$\angle I_R = -\cos^{-1}.9$

$= -25.8419°$

$I_R = 895.1004\angle -25.8419°\,A$

$\begin{bmatrix} 4 & 19 \\ 7 & 43 \end{bmatrix}$ $\begin{bmatrix} 23 \\ 59 \end{bmatrix}$

$= 1213$, 2698

$V_{sph} = AV_{Rph} + BI_R$

$V_{sph} = (.9159\angle 1.1372^\circ)\left(\frac{500\times10^3 V}{\sqrt{3}}\angle 0^\circ\right) + (118.6801\angle 78.0911^\circ)(898.1004\angle -25.[illegible]$

$V_{s_{ph}} = 341.634\angle 15.1752^\circ$ kV

$|V_S| = 591.728$ kV

$I_S = (V_{Rph} + DI_R$

$I_S = (.001392\angle 90.3615^\circ)\left(\frac{500\times10^3 V}{\sqrt{3}}\angle 0^\circ\right) + (.9159\angle 1.1372^\circ)(898.1004\angle -25.84[illegible] A)$

$I_S = 747.0065\angle 4.4563^\circ$ A

b) $\eta = \frac{700\times10^6 W}{3(341.634\times10^3 V)(747.0065 A)(\cos(15.1752^\circ - 4.4563^\circ))} \times 100\%$

$\eta = 93.05\%$ or $.9305$

c) $\epsilon = \frac{\frac{591.728\times10^3 V}{.9159} - 500\times10^3 V}{500\times10^3 V} \times 100\%$

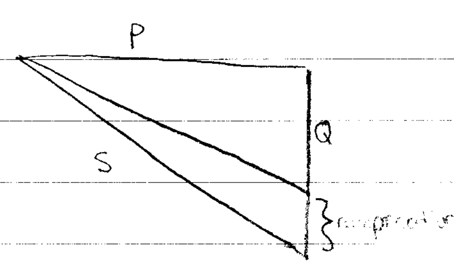
$\epsilon = 29.21\ \%$

d) New A, New B

$$\begin{bmatrix} A_{eq} & B_{eq} \\ C_{eq} & D_{eq} \end{bmatrix} = \begin{bmatrix} 1 & -jX_c \\ 0 & 1 \end{bmatrix}\begin{bmatrix} A & B \\ C & D \end{bmatrix} = \begin{bmatrix} A - C(jX_c) & B - D(jX_c) \\ C & D \end{bmatrix}$$

$.7\times 100 - 90\%$

$= 7\%$



old: $I_S = 747.0065 \angle 4.4563° A$ $V_{R_{ph}} = \frac{500}{\sqrt{3}} \times 10^3 V \angle 0°$

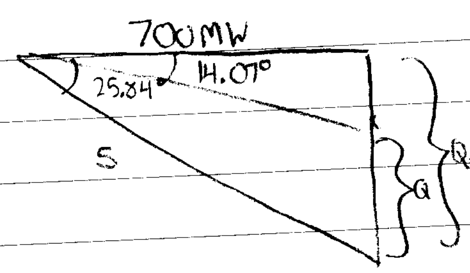
$V_S = (A - C j Y_c) V_{Rph} + (B - D j Y_c) I_R$ $I_R = 898.1004 \angle -\cos^{-1}(.97)$

$I_R = 898.1004 \angle -14.0699°$

$I_S = C V_{Rph} + D I_R$

$I_S = 828.2985 \angle 15.2402° A$

S = ??



$Q = Q_{tot} - Q_1$

$Q = 305.10$ VAR $- 170.18$ VAR

$Q = 134.92$ VAR

~~$Q = V I$~~

$Q = \frac{V^2}{X_c}$

$Y_c = \frac{(500 kV)^2}{134.92 \text{ VAR}}$

$V_s = AV_{Rph} - CjY_c V_{Rph} + BI_R - DjY_c I_R$

$jX_c((V_{Rph} + DI_R) = AV_{Rph} + BI_R - V_s$

$$jY_c = \frac{AV_{Rph} + BI_R - V_s}{(V_{Rph} + DI_R}$$

$X_c = 394.5964\Omega$

$\therefore X_c = \frac{1}{2\pi fC}$

$$C_{ph} = \frac{1}{2\pi f X_c}$$

$$\boxed{C_{ph} = 6.7229 \times 10^{-6}\ F}$$

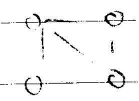
45cm = 1.4764 ft

$D_s = .0586$ ft $\quad D_{s\,bundle} = \sqrt[4]{(.0586\,ft)(1.4764\,ft)^3\sqrt{2}}$

$D_{s\,bundle} = .7186$ ft

$D_{ab} = \sqrt[4]{(\sqrt{2}\,4m)\sqrt{4^2+8^2}\;\sqrt{4^2+8^2}\;\sqrt{2}\,4m}$

$D_{ab} = 7$



[2] $D_s = .0586\,ft = .01786\,m$

a) $D_{s\,bundle} = \sqrt[4]{(.01786m)(.45m)^3\sqrt{2}}$

$= .2190m$

$D_{ab} = \sqrt[4]{(\sqrt{2}\,4m)^2(4^2+8^2)}$

$D_{ab} = 7.1131m$

$D_{bc} = \sqrt[4]{(4m)(8m)(8m)(4m)}$

$D_{bc} = 5.6569m$

$D_{ac} = \sqrt[4]{(4m)(4\sqrt{2}\,m)(4m)(4\sqrt{2}\,m)}$

$D_{ac} = 4.7568m$

$D_{eq} = \sqrt[3]{D_{ab}D_{bc}D_{ac}}$

$D_{eq} = 5.7630\,m$

$D_{sa} = \sqrt{D_{sbund}\,(4m)}$

$D_{sa} = .9359m$

$D_{sb} = \sqrt{D_{sbund}\,(12m)}$

$D_{sb} = 1.6211m$

$D_{sc} = \sqrt{D_{sbund}\,(4m)}$

$D_{sc} = .9359\,m$

$D_s = \sqrt[3]{D_{sa}D_{sb}D_{sc}}$

$D_s = 1.1240m$

$L_{ph} = 2\times10^{-7}\ln\left(\frac{5.7630m}{1.1240m}\right) = 3.2691\times10^{-7}\ H/m$

$\boxed{L_{ph} = 3.2691\times10^{-4}\ H/km}$

$\frac{1.762\,in}{12} \;:\; r = .02238\,m$

$D_{sbund} = \sqrt[4]{(.02238m)(.45m)^3\sqrt{2}}$

$= .2317m$

$D_{sa} = \sqrt{D_{sbund} C (4m)}$ $D_{sb} = \sqrt{D_{sbund}(12m)}$ $D_{sc} = \sqrt{D_{sbundle}(4m)}$

$D_{sa} = .9627m$ $D_{sb} = 1.6675m$ $D_{sc} = .9627m$

$D_s = \sqrt[3]{D_{sa} D_{sb} D_{sc}}$

$D_s = 1.1562m$

$C_{ph} = \frac{2\pi \epsilon_0}{\ln\left(\frac{D_{eq}}{D_s}\right)} = 3.4633 \times 10^{-8}$ F/km

$\frac{1}{2\pi fC} = \Omega$ $2\pi fL = \Omega$

$X_{Lph} = 2\pi L_{ph}$

$X_{Lph} = .1232\ \Omega/km$

$Y_{ph} = 1.3056 \times 10^{-5}\ \mho/km$

b) $SIL = \frac{|V_L|^2}{\sqrt{\frac{L}{C}}} = \frac{|500kV|^2}{\sqrt{\frac{3.2691 \times 10^{-4} H/km}{3.4633 \times 10^{-8} F/km}}}$

$SIL = 2573.1847$ MW

c) $\lambda = \frac{2\pi}{\beta}$ $\gamma = \alpha + j\beta$

$Z_s = \left[\frac{.0345\Omega/km + j.1232\Omega/km}{2}\right] 400km$ (p.u./km)

$Z_s = 49.7469\angle 82.1435°\ \Omega$

$Y = jY_{ph}(400km)$

$Y = j.005222$

$\gamma = \sqrt{Z_s Y}$

$\gamma = \alpha + j.5085$

$\lambda = \frac{2\pi}{.5085} = 12.3563m$

d) $V_d = (.85)(21.9kV/cm)\left(\frac{.392(74)}{27+273}\right)(2.2377cm) \ln\left(\frac{400 \times 10^5}{2.2377cm}\right)$ kV

$V_d = 66.952$ kV