6/15/12 PER-UNIT

IDEA: use normalized values so

1. It's easier to compare devices of different ratings
2. Reduce range of values to improve accuracy of numerical calculations

Quantity in pu = $\frac{\text{physical (SI) quantity}}{\text{base "reference" value of quantity}}$

1ϕ $I_b = \frac{S_b}{V_b} = \frac{VA_{1\phi,\,base}}{V_{LN,\,base}}$

where $S_b = P_b = Q_b = V_b I_b = V_{LN,b} I_b$

$Z_b = R_b = X_b = \frac{V_b}{I_b} = \frac{V_{LN,b}}{I_b} = \frac{V_b}{S_b/V_b} = \frac{V_b^2}{S_b} =$

3ϕ - A little trickier

$S_{b3\phi} = 3 S_{b1\phi}$ $\qquad V_{LL,b} = \sqrt{3} V_{LN,b}$

$P_{b3\phi} = 3 P_{b1\phi}$

$Q_{b3\phi} = 3 Q_{b1\phi}$

$I_b = \frac{S_{3\phi,b}}{3 V_{LN,b}}$ $\qquad Z_b = \frac{(V_{LL,b}/\sqrt{3})^2}{S_{3\phi,b}/3} = \frac{V_{LL,b}^2}{S_{3\phi,b}}$

$= \frac{S_{3\phi,b}}{\sqrt{3} V_{LL,b}}$

Show: $\vec{V}_{AB} = \sqrt{3}\,V_A$ =

$= |\vec{V}_A - \vec{V}_B|$

$= |V_A\angle 0° - V_A\angle -120°|$

$= |V_A - [V_A\cos(-120°) + jV_A\sin(-120°)]|$

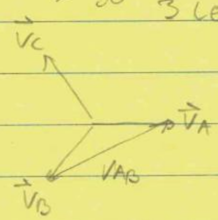
$= |V_A + \frac{1}{2}V_A + j\frac{\sqrt{3}}{2}V_A|$

$= \left|\frac{3}{2} + j\frac{\sqrt{3}}{2}\right| V_A$

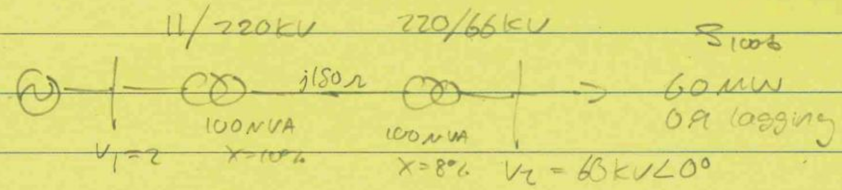
$$|V_{AB}| = \sqrt{\left(\frac{3}{2}\right)^2 + \left(\frac{\sqrt{3}}{2}\right)^2} = \sqrt{\frac{12}{4}} = \sqrt{3}$$

$$\phi_{AB} = \cos^{-1}\frac{Re\,V_{AB}}{|V_{AB}|} = \cos^{-1}\left(\frac{3/2}{\sqrt{3}}\right) = \cos^{-1}(\sqrt{3})$$

$= 30°$ 3 leads by 30



example



$Z_{b,line} = \frac{(220kV)^2}{100MVA} = 484\ \Omega$ ⇐ $S_b = 100 MVA$

$V_{b,gen} = 11 kV$

$V_{b,line} = 220kV$

$X_{line} = \frac{180\Omega}{484\ \Omega} = 0.31\ pu$

$S_{load} = 60 + j60 \sin(\cos^{-1}(.9))$ MVA

$= .6 + j0.262$ pu

$I_{load} = \frac{S_{load}^*}{V_2} = .6 - j0.262$ pu $= .66 - j.29$

$V_2 = \frac{60kV}{66kV} = 0.91$ pu

$Z_{eq} = X_{xf_1} + X_{line} + X_{xf_2}$

$= j0.1 + j0.08 + j0.31$

$= j0.489$ pu

$V_1 = V_2 + Z_{eq} I_{load}$

$= 0.91 + (j0.489)(0.6 - j0.262)$

$= 1.1\ \angle -3.052°$

$V_{1,SI} = (11kV)(1.1) = 1.21 kV$

<u>Change-of-base</u> Idea: express as ratio wrt new re

$$Z_{pu,new} = Z_{pu,old} \left(\frac{S_{b,new}}{S_{b,old}}\right)\left(\frac{V_{b,old}}{V_{b,new}}\right)^2$$

$$(S,P,Q)_{pu,new} = (S,Q,P)_{pu,old} \left(\frac{S_{b,new}}{S_{b,old}}\right)$$

$$V_{pu,new} = V_{pu,old} \left(\frac{V_{b,old}}{V_{b,new}}\right)$$