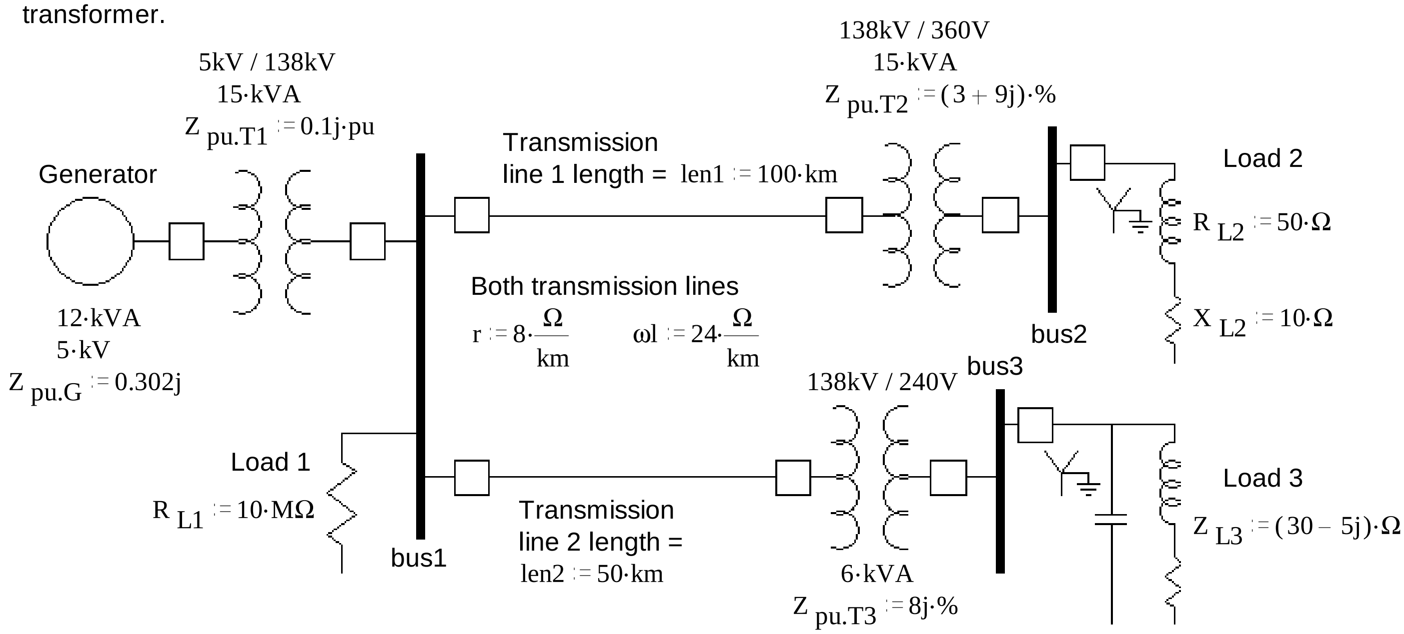
Like problem 4 on homework Zoom Example

4. A one-line diagram of a 3ϕ system is shown below. Manufacturer's information is shown for the generator and each transformer.



a) Choose an S_{base} to minimize the per-unit base conversions. Then choose regions and a V_{base} for each region.

$S_{base} := 15 \cdot kVA$

Region 1	The generator	$V_{base1} := 5 \cdot kV$
Region 2	Bus1, Load 1 and the transmission lines	$V_{base2} := 138 \cdot kV$
Region 3	Bus2 and Load 2	$V_{base3} := 360 \cdot V$
Region 4	Bus2 and Load 3	$V_{base4} := 240 \cdot V$

b) Find I_{base} and Z_{base} in each of the regions.

Region 1 $I_{base1} := \frac{S_{base}}{\sqrt{3} \cdot V_{base1}}$ $I_{base1} = 1.732 \cdot A$ $Z_{base1} := \frac{V_{base1}^2}{S_{base}}$ $Z_{base1} = 1.667 \cdot k\Omega$

Region 2 $I_{base2} := \frac{S_{base}}{\sqrt{3} \cdot V_{base2}}$ $I_{base2} = 0.063 \cdot A$ $Z_{base2} := \frac{V_{base2}^2}{S_{base}}$ $Z_{base2} = 1.27 \cdot 10^3 \cdot k\Omega$

Region 3 $I_{base3} := \frac{S_{base}}{\sqrt{3} \cdot V_{base3}}$ $I_{base3} = 24.056 \cdot A$ $Z_{base3} := \frac{V_{base3}^2}{S_{base}}$ $Z_{base3} = 8.64 \cdot \Omega$

Region 4 $I_{base4} := \frac{S_{base}}{\sqrt{3} \cdot V_{base4}}$ $I_{base4} = 36.084 \cdot A$ $Z_{base4} := \frac{V_{base4}^2}{S_{base}}$ $Z_{base4} = 3.84 \cdot \Omega$

c) Make the necessary per-unit S_{base} conversions.

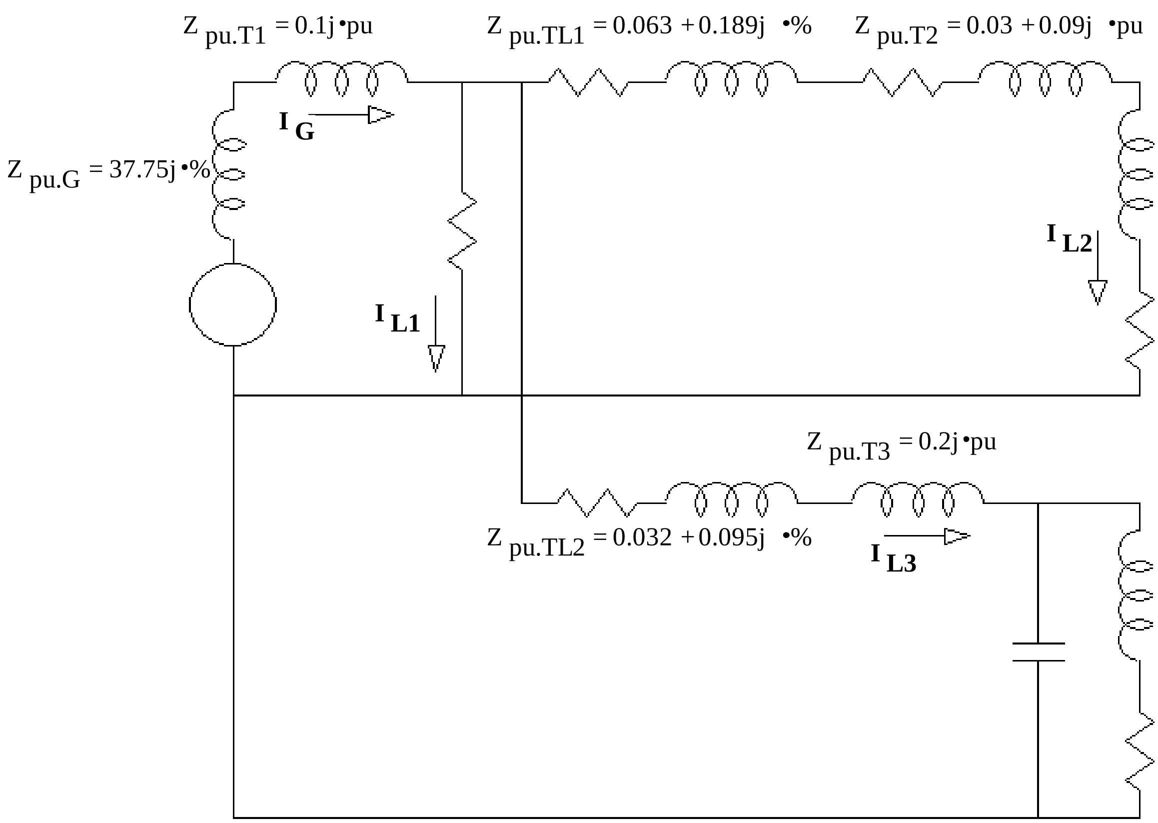
$Z_{pu.G} := Z_{pu.G} \cdot \frac{S_{base}}{12 \cdot kVA}$ $Z_{pu.G} = 0.378j \cdot pu$ $Z_{pu.T3} := Z_{pu.T3} \cdot \frac{S_{base}}{6 \cdot kVA}$ $Z_{pu.T3} = 0.2j \cdot pu$

d) Find the impedances of the two transmission lines and convert to pu.

$$Z_{TL1} := (8 + 24j)\cdot\frac{\Omega}{km}\cdot len1 \qquad Z_{TL1} = 800 + 2400i \;\bullet\Omega \qquad Z_{TL2} := (8 + 24j)\cdot\frac{\Omega}{km}\cdot len2 \qquad Z_{TL2} = 400 + 1.2\bullet 10^{3}j \;\bullet\Omega$$

$$Z_{pu.TL1} := \frac{Z_{TL1}}{Z_{base2}} \qquad Z_{pu.TL1} = 0.063 + 0.189j \;\bullet\% \qquad Z_{pu.TL2} := \frac{Z_{TL2}}{Z_{base2}} \qquad Z_{pu.TL2} = 0.032 + 0.095j \;\bullet\%$$

e) Draw the per-phase diagram showing all the per-unit numbers found or given so far.



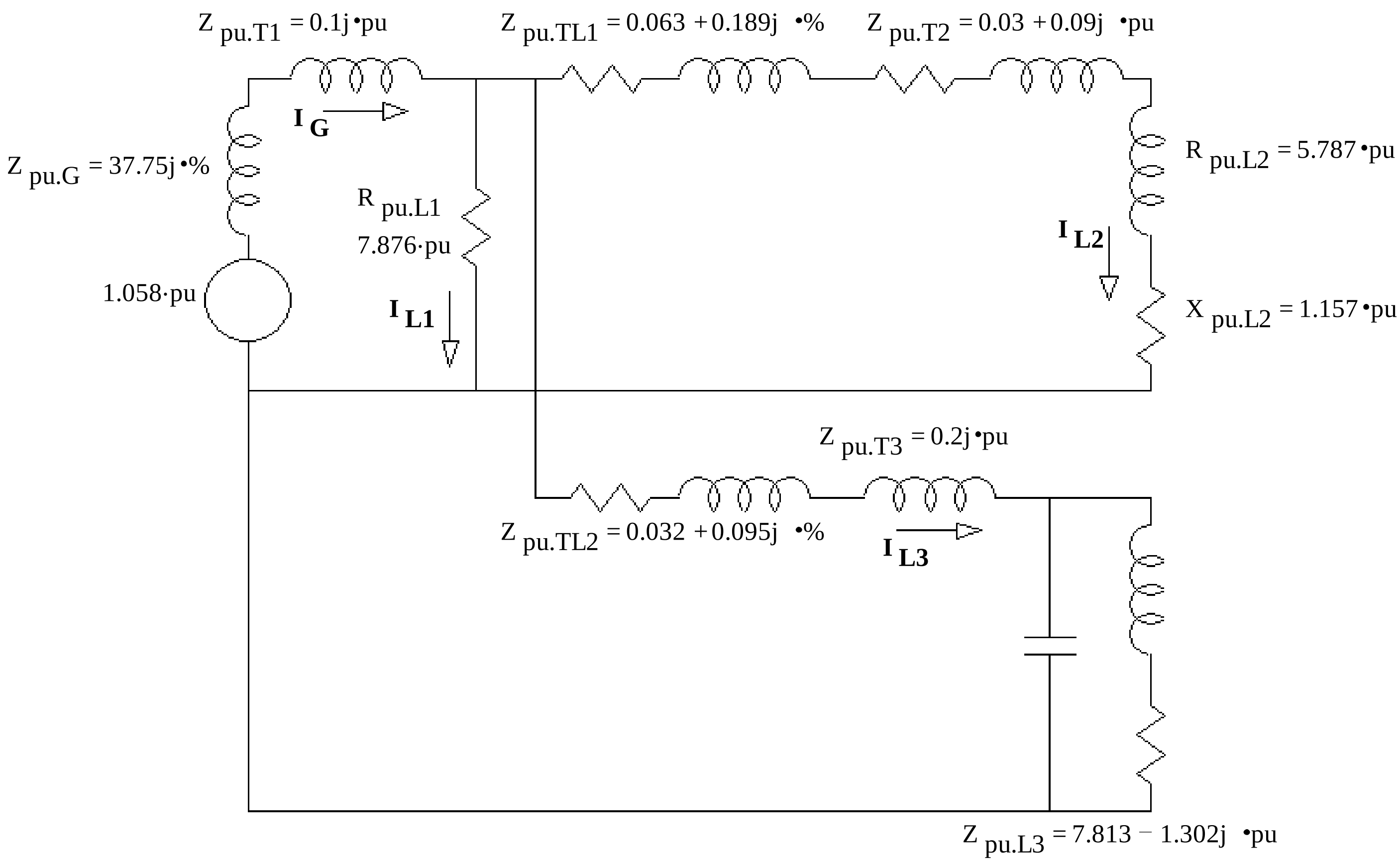
ALL calculations made to this point **ONLY need to be made ONCE** for this system and S_{base} **!!**

f) Find the pu values of the 3 loads and add that information to the per-phase diagram.

$R_{pu.L1} := \frac{R_{L1}}{Z_{base2}}$ $\quad R_{pu.L1} = 7.876 \cdot pu$

$R_{pu.L2} := \frac{R_{L2}}{Z_{base3}}$ $\quad R_{pu.L2} = 5.787 \cdot pu$ $\quad X_{pu.L2} := \frac{X_{L2}}{Z_{base3}}$ $\quad X_{pu.L2} = 1.157 \cdot pu$

$Z_{pu.L3} := \frac{Z_{L3}}{Z_{base4}}$ $\quad Z_{pu.L3} = 7.813 - 1.302j \cdot pu$



g) The line voltage at bus1 is measured and found to be $V_{bus1} := 146 \cdot kV$ Assume the phase angle is 0º.

Find all 3 load line-current magnitudes and the magnitude of the generator line-current. Please remember that you can't add magnitudes, so may need some complex values.

$V_{pu.bus1} := \frac{146 \cdot kV}{V_{base2}}$ $\quad V_{pu.bus1} = 1.058 \cdot pu$

$\mathbf{I}_{pu.L1} := \frac{1 \cdot pu}{R_{pu.L1}}$ $\quad \mathbf{I}_{pu.L1} = 0.127 \cdot pu$ $\quad \left|\mathbf{I}_{pu.L1}\right| \cdot I_{base2} = 7.967 \cdot mA$

$\mathbf{I}_{pu.L2} := \frac{V_{pu.bus1}}{Z_{pu.TL1} + Z_{pu.T2} + \left(R_{pu.L2} + X_{pu.L2} \cdot j\right)}$ $\quad \mathbf{I}_{pu.L2} = 0.174 - 0.037j \cdot pu$ $\quad \left|\mathbf{I}_{pu.L2}\right| \cdot I_{base3} = 4.277 \cdot A$

$\mathbf{I}_{pu.L3} := \frac{V_{pu.bus1} \cdot pu}{Z_{pu.TL2} + Z_{pu.T3} + Z_{pu.L3}}$ $\quad \mathbf{I}_{pu.L3} = 0.133 + 0.019j \cdot pu$ $\quad \left|\mathbf{I}_{pu.L3}\right| \cdot I_{base4} = 4.839 \cdot A$

$\mathbf{I}_{pu.G} := \mathbf{I}_{pu.L1} + \mathbf{I}_{pu.L2} + \mathbf{I}_{pu.L3}$ $\quad \mathbf{I}_{pu.G} = 43.358 - 1.862j \cdot \%$ $\quad \left|\mathbf{I}_{pu.G}\right| \cdot I_{base1} = 0.752 \cdot A$

h) Find the power delivered to Load 2, both in pu and in kW.

$P_{pu.L2} := \left(\left|\mathbf{I}_{\mathbf{pu.L2}}\right|\right)^2 \cdot R_{pu.L2}$ $\quad P_{pu.L2} = 0.183 \cdot pu$ $\quad P_{L2} := P_{pu.L2} \cdot S_{base}$ $\quad P_{L2} = 2.744 \cdot kW$

i) Find the line voltage at Load 2 (magnitude).

$V_{Load2} := \left|\mathbf{I}_{\mathbf{pu.L2}}\right| \cdot \sqrt{R_{pu.L2}^{\;2} + X_{pu.L2}^{\;2}} \cdot V_{base3}$ $\quad V_{Load2} = 377.8 \cdot V$

j) Find the line voltage at the generator (magnitude).

$\mathbf{V}_{\mathbf{pu.G}} := 1 \cdot pu + \mathbf{I}_{\mathbf{pu.G}} \cdot \left(Z_{pu.G} + Z_{pu.T1}\right)$ $\quad \mathbf{V}_{\mathbf{pu.G}} = 100.889 + 20.703j \cdot \%$ $\quad \left|\mathbf{V}_{\mathbf{pu.G}}\right| \cdot V_{base1} = 5.15 \cdot kV$

k) The line voltage at the generator drops by 8% to: $\quad 146 \cdot kV \cdot 0.92 = 134.32 \cdot kV$

Find the magnitude of Load-3 line current and repeat parts h) and i) for this new generator voltage.

Note: It may be helpful to realize that if one voltage in the system drops by 8%, so do all the rest, and so do all the currents. Drop by 8% means multiply by 0.92. All powers drop too, but use $(0.92)^2$ as the factor.

$\left|\mathbf{I}_{\mathbf{pu.L3}}\right| \cdot I_{base4} \cdot 0.92 = 4.5 \cdot A$ = new I_{Load3}

$P_{L2} \cdot 0.92^2 = 2.323 \cdot kW$ = new P_{L2}

$V_{Load2} \cdot 0.92 = 347.5 \cdot V$ = new V_{Load2}