

The diagram shows a power system with three buses (bus1, bus2, bus3) and two transmission lines. A generator is connected to bus1. Load 1 is connected to bus1. Transmission line 1 connects bus1 and bus2. Load 2 is connected to bus2. Transmission line 2 connects bus1 and bus3. Load 3 is connected to bus3. The diagram includes the following parameters and components:

- Generator:** 12·kVA, 5·kV, $Z_{puG} := 0.302j$
- Transformer 1:** 5kV / 138kV, 15·kVA, $Z_{pu.T1} := 0.1j \cdot pu$
- Transmission line 1:** length = $len1 := 100 \cdot km$
- Transmission line 2:** length = $len2 := 50 \cdot km$
- Both transmission lines:** $r := 8 \cdot \frac{\Omega}{km}$, $\omega l := 24 \cdot \frac{\Omega}{km}$
- Transformer 2:** 138kV / 360V, 15·kVA, $Z_{pu.T2} := (3 + 9j) \cdot \%$
- Transformer 3:** 138kV / 240V, 6·kVA, $Z_{pu.T3} := 8j \cdot \%$
- Load 1:** $R_{L1} := 10 \cdot M\Omega$
- Load 2:** $X_{L2} := 10 \cdot \Omega$, $R_{L2} := 50 \cdot \Omega$
- Load 3:** $Z_{L3} := (30 - 5j) \cdot \Omega$

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|-------------------|----------|---|-----------------------------|
| S _{base} | Region 1 | The generator | V _{base1} |
| | Region 2 | Bus1, Load 1 and the transmission lines | V _{base2} |
| | Region 3 | Bus2 and Load 2 | V _{base3} := 360·V |
| | Region 4 | Bus2 and Load 3 | V _{base4} := 240·V |

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|----------|---|--|--|--|
| Region 1 | $I_{\text{base1}} =$ | $Z_{\text{base1}} =$ | | |
| Region 2 | $I_{\text{base2}} =$ | $Z_{\text{base2}} =$ | | |
| Region 3 | $I_{\text{base3}} := \frac{S_{\text{base}}}{\sqrt{3} \cdot V_{\text{base3}}}$ | $I_{\text{base3}} = 24.056 \cdot \text{A}$ | $Z_{\text{base3}} := \frac{V_{\text{base3}}^2}{S_{\text{base}}}$ | $Z_{\text{base3}} = 8.64 \cdot \Omega$ |
| Region 4 | $I_{\text{base4}} := \frac{S_{\text{base}}}{\sqrt{3} \cdot V_{\text{base4}}}$ | $I_{\text{base4}} = 36.084 \cdot \text{A}$ | $Z_{\text{base4}} := \frac{V_{\text{base4}}^2}{S_{\text{base}}}$ | $Z_{\text{base4}} = 3.84 \cdot \Omega$ |

- $$Z_{\text{pu.G}} = \quad \quad \quad Z_{\text{pu.T3}} =$$

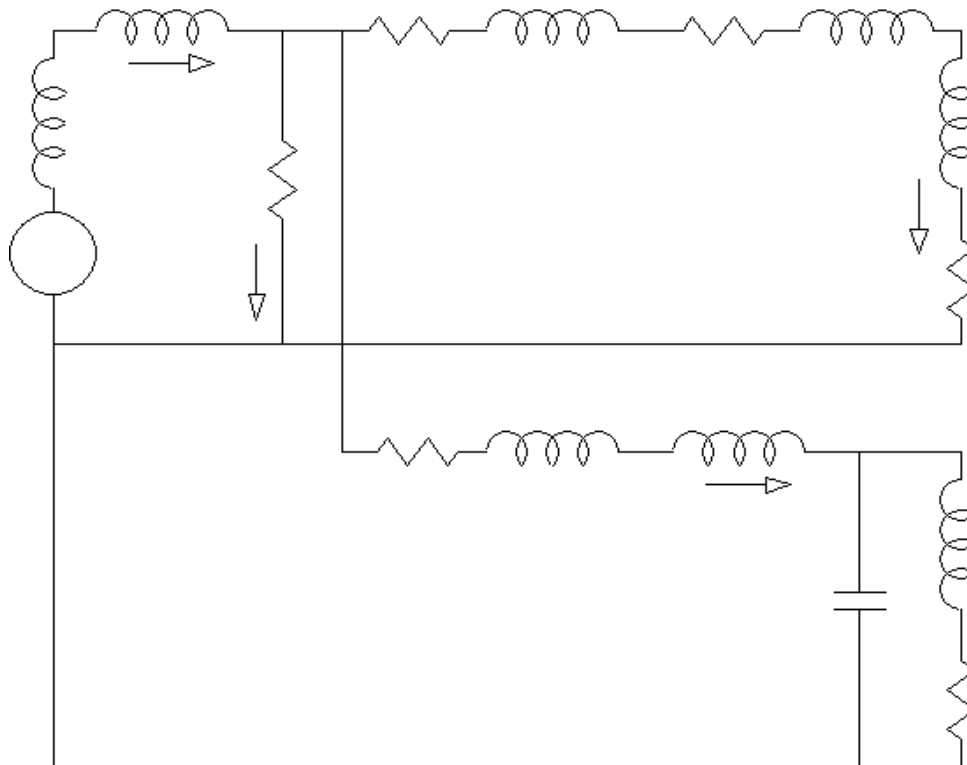
d) Find the impedances of the two transmission lines and convert to pu.

$$Z_{TL1} =$$

$$Z_{pu.TL1} =$$

$$Z_{TL2} := (8 + 24j) \cdot \frac{\Omega}{\text{km}} \cdot \text{len2} \quad Z_{TL2} = 400 + 1.2 \cdot 10^3 j \cdot \Omega \quad Z_{pu.TL2} := \frac{Z_{TL2}}{Z_{base2}} \quad Z_{pu.TL2} = 0.032 + 0.095j \cdot \%$$

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



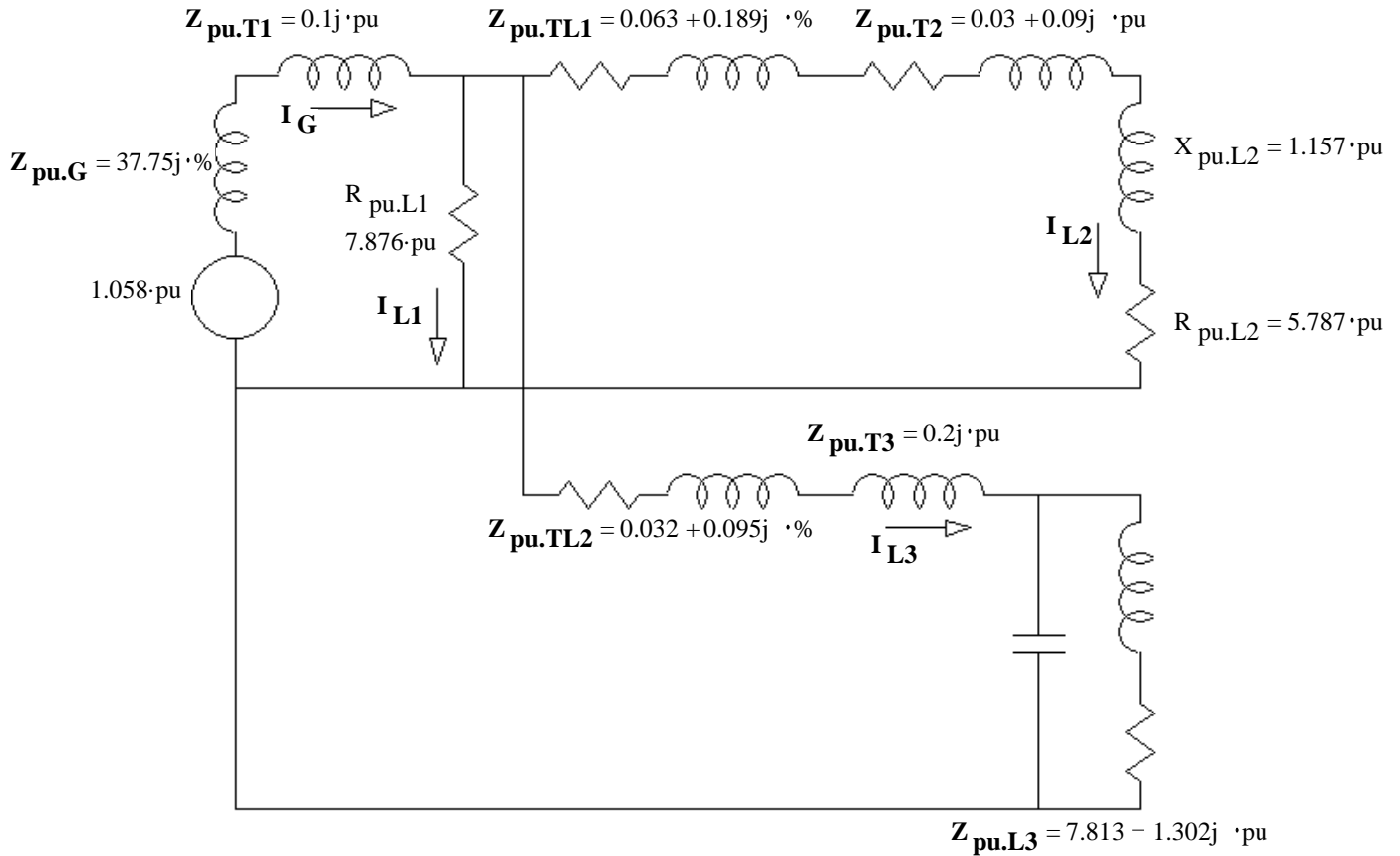
ALL calculations made to this point **ONLY need to be made ONCE** for this system and S_{base} !!

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

$$R_{pu.L1} =$$

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

$$Z_{pu.L3} =$$



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

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.

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

$$I_{pu.L1} =$$

$$I_{L1} =$$

$$I_{pu.L2} = \frac{V_{pu.bus1}}{Z_{pu.TL1} + Z_{pu.T2} + (R_{pu.L2} + X_{pu.L2} \cdot j)}$$

$$= \frac{1.058 \cdot pu}{(6.301 \cdot 10^{-4} + 1.89 \cdot 10^{-3} \cdot j) + (0.03 + 0.09 \cdot j) + (5.787 + 1.157 \cdot j) \cdot pu}$$

$$I_{L2} =$$

$$I_{pu.L3} := \frac{V_{pu.bus1}}{Z_{pu.TL2} + Z_{pu.T3} + Z_{pu.L3}}$$

$$I_{pu.L3} = 0.133 + 0.019j \text{ pu}$$

$$|I_{pu.L3}| \cdot I_{base4} = 4.839 \cdot A$$

$$I_{pu.G} := I_{pu.L1} + I_{pu.L2} + I_{pu.L3}$$

$$I_{pu.G} = 44.094 - 1.862j \text{ pu}$$

$$|I_{pu.G}| \cdot I_{base1} = 0.764 \cdot A$$

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

$$P_{pu.L2} =$$

$$P_{L2} =$$

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

$$V_{Load2} =$$

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

$$V_{pu.G} =$$

$$V_G =$$

k) The line voltage at bus1 drops by 8% to:

$$146 \cdot kV \cdot 0.92 = 134.32 \cdot kV$$

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.

$$\text{new } I_{Load3} =$$

$$\text{new } P_{L2} =$$

$$\text{new } V_{Load2} =$$