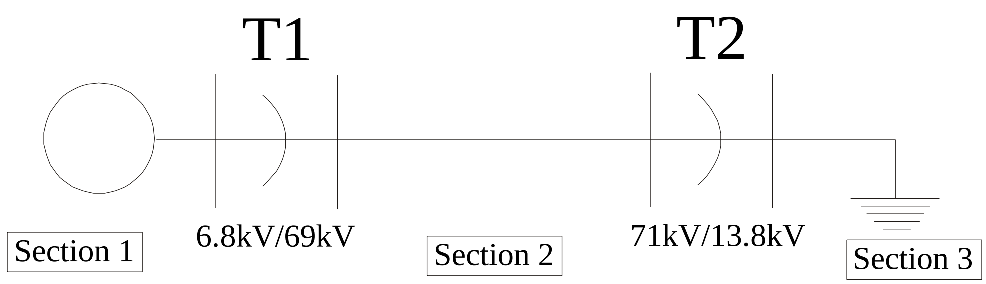
Module B4

Problem 1

Consider the power system shown below. Choose a system power base 100MVA and a line-to-line voltage base for section 1 as 6.9kV. The load in section 3 consumes 10MVA at 0.8pf leading when the line-to-line voltage at the load is 13.8kV

(a) Determine the ohmic value of a R+jX load (R and X connected in series, as shown) in section 3 that consumes this same amount of power at the specified voltage level (i.e., that consumes 10 MVA at 0.8 pf leading at 13.8kV line-to-line).

(b) Compute the impedance base for the section 3 load.



Solution to problem 1

(a) $S=\frac{V_{LL}^2}{Z^*}\Rightarrow Z=\frac{V_{LL}^2}{S^*}=\frac{\left(13.8\times10^3\right)^2}{10\times10^6\left(0.8+j0.6\right)}=\underline{\underline{15.235-j11.426\,\Omega}}$

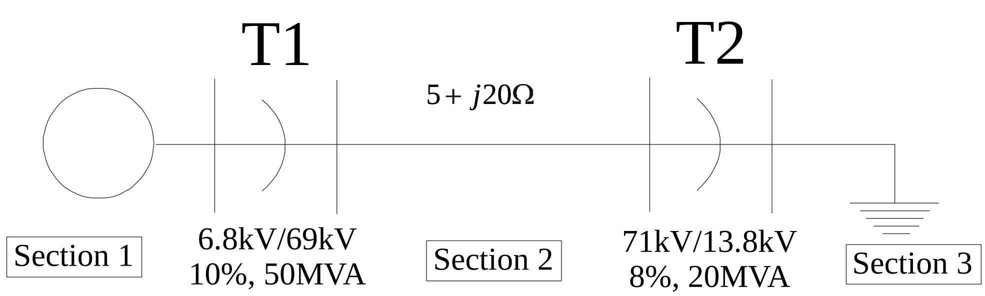
(b) $V_{\underset{2}{BASE}}=6.9\left[\frac{6.9}{6.8}\right]=70.015$

$V_{\underset{3}{BASE}}=70.015\left[\frac{13.8}{71}\right]=13.608$

$Z_{BASE}=\frac{\left(V_{\underset{3}{BASE}}\right)^2}{S_{BASE}}=\frac{\left(13.608\times10^3\right)^2}{S_{BASE}}=1.8519\,\Omega$

Problem 2

Consider the power system shown below. Choose a system power base of 100MVA and a line-to-line voltage base for section 1 as 6.9kV. Determine the appropriate values of per unit impedance for transformers T1, T2, ad the transmission line.



Solution to problem 2

$$V_{base,2} = 6.9 \cdot \left(\frac{69}{6.8}\right) = 70.015, \quad V_{base,3} = 70.015 \cdot \left(\frac{13.8}{71}\right) = 13.61\,p.u.$$

$$X_{T1,new} = 0.10 \cdot \left(\frac{6.8}{6.9}\right)^2 \cdot \left(\frac{100}{50}\right) = \underline{\underline{0.1942}}$$

$$X_{T2,new} = 0.08 \cdot \left(\frac{71}{70.015}\right)^2 \cdot \left(\frac{100}{20}\right) = 0.08 \cdot \left(\frac{13.8}{13.61}\right)^2 \cdot \left(\frac{100}{20}\right) = \underline{\underline{0.4112}}$$

$$Z_{base,2} = \frac{\left(70.015 \times 10^3\right)^2}{100 \times 10^6} = 49.021\Omega \quad \Rightarrow X_L = \frac{5 + j20}{49.021} = \underline{\underline{0.102 + j0.4081}}$$

Problem 3

A generator is connected to a transmission line through a transformer having a rated turns ratio (ratio of line to line voltages) of:

20 kV (generator side) to 100 kV (transmission line side).

The generator has a per unit reactance of 0.08 pu on a 19 kV, 50 MVA base.

Select the base voltage on the transmission line side to be 110 kV.

a. Compute the base voltage on the generator side.
b. Compute the pu reactance of the generator using a 100 MVA system power base.

Solution to problem 3

(a)

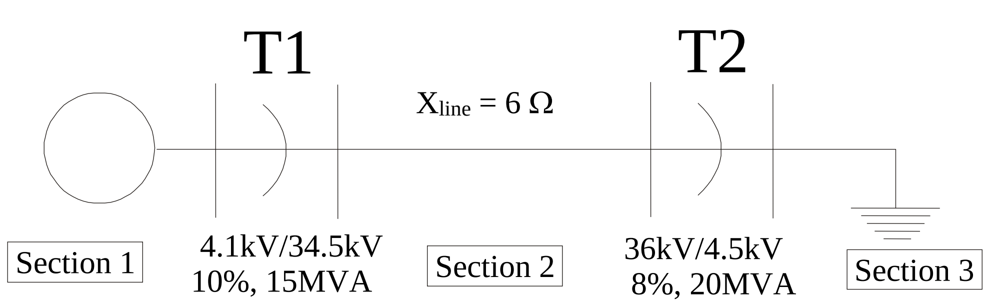
$$V_{basegen} = 110kV \cdot \left[\frac{20kV}{100kV}\right] = 22kV$$

(b)

$$X_{pu2} = X_{pu1} \cdot \left[\frac{V_{base1}}{V_{base2}}\right]^2 \cdot \left[\frac{S_{base2}}{S_{base1}}\right] = 0.08 \cdot \left[\frac{19kV}{22kV}\right]^2 \cdot \left[\frac{100MVA}{50MVA}\right] = 0.11934$$

Problem 4

Choose a system MVA base of 100 MVA and a voltage base of 4.0 kV for the load portion of the system. Find per-unit values of impedances for both transformers and the transmission line.



Solution to problem 4

$$V_{base2} = (4.0kV)\cdot\left(\frac{36kV}{4.5kV}\right) = 32kV$$

$$V_{base2} = (32kV)\cdot\left(\frac{4.1kV}{34.5kV}\right) = 3.803kV$$

$$T1: X_{T1} = X_{puT1}\cdot\left[\frac{V_{baseold}}{V_{basenew}}\right]^2\cdot\left[\frac{S_{basenew}}{S_{baseold}}\right] = 0.10\cdot\left[\frac{4.1kV}{3.803kV}\right]^2\cdot\left[\frac{100MVA}{15MVA}\right] = 0.7749$$

$$T2: X_{T2} = X_{puT2}\cdot\left[\frac{V_{baseold}}{V_{basenew}}\right]^2\cdot\left[\frac{S_{basenew}}{S_{baseold}}\right] = 0.08\cdot\left[\frac{4.5kV}{4.0kV}\right]^2\cdot\left[\frac{100MVA}{20MVA}\right] = 0.506$$

$$Line: Z_{base} = \frac{(32kV)^2}{100MVA} = 10.24\Omega \Rightarrow Z_{pu} = \frac{6\Omega}{10.24\Omega} = 0.586$$

Problem 5

1. B4: You receive the following data from a manufacturer regarding a new three phase transformer:

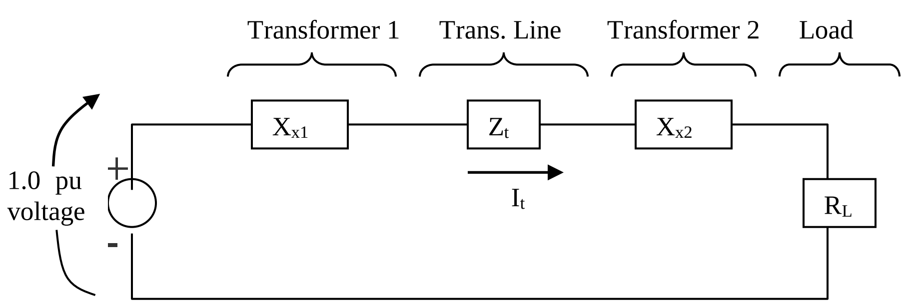
Ratio of line-line voltages:	13.8kV/225kV
Power rating:	400 MVA
Per unit reactance on component base:	8%

You are considering replacement of an existing transformer in your three-phase system with this new one, and you want to see how it would affect the currents. Below is a circuit of your system. All data is in per unit on a 100 MVA base. The voltage base for the transmission line is 230 kV and the voltage base for the low side of transformer 1 is 14.1067 kV. The per unit impedances of the transmission line, transformer 2, and the load are:

Z_t=0.0004+j0.005 pu X_{X2}=0.02 pu R_L=0.8 pu

a. Compute the per unit reactance of the transformer on the system bases.

b. Compute the magnitude of the current I_t in the transmission line, in per unit, and in amperes.



Solution to problem 5

a.

$$X_{x1} = 0.08\left(\frac{225}{230}\right)^2\left(\frac{100}{400}\right) = 0.0191\,\text{pu}$$

b.

$$I_{t,pu} = \frac{1.0}{X_{x1} + Z_t + X_{x2} + R_L} = \frac{1.0}{j0.0191 + 0.0004 + j0.005 + j0.02 + 0.8} = \frac{1.0}{0.8004 + j0.0441} = 1.2456 - j0.0686$$

And the current magnitude, in per unit, is given by $|I_t|=\sqrt{(1.2456)^2+(0.0686)^2}=1.2475$ pu

To get amperes, we need the current base for the transmission line section of the system. This is:

$$I_{base} = \frac{100\times10^6}{\sqrt{3}(230\times10^3)} = 251 \;\Rightarrow\; I_t = 1.2475(251) = 313.1\,\text{amperes}$$