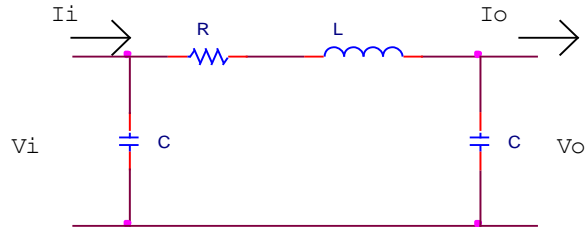


Transmission Lines Lab

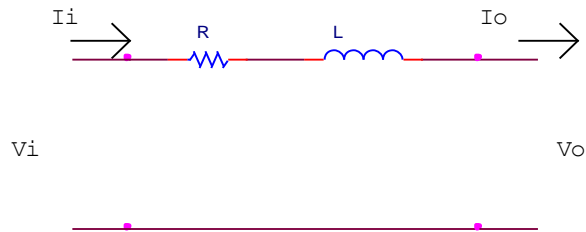
For this lab we will use a model of a 19 mile 15 kV transmission line. Using a short line model we get something like this (for each phase):



But in this experiment the capacitances are very small, on the order of $0.15 \mu\text{F}$, using the equation for the reactance of a capacitor:

$$X_C = \frac{1}{j\omega C}$$

This gives an impedance of about $-j17.7 \text{ K}\Omega$ which can be considered an open since it is much greater than any other impedances in this experiment, so the previous diagram reduces to:



From this it can be seen that input current (I_i) must be equal to output current (I_o)

Parts 2 and 4 of the procedure:

In these sections you collect data, which allow you compute values for L and R using the following equations:

Measured values: I_{exc} , V_i , I_i , P_i , $\angle V_i - I_i$, V_o , I_o , P_o , $\angle V_o - I_o$, Q_o , $\angle V_i - V_o$

Time delay to angle (in degrees) conversion: $\theta = t * f * 360^\circ$

Method 1:

$$S = VI$$

$$S^2 = P^2 + Q^2$$

$$P_{LOSS} = P_i - P_o$$

$$Q_{LOSS} = Q_i - Q_o$$

$$R = \frac{P_{LOSS}}{I^2}$$

$$X_L = \frac{Q_{LOSS}}{I^2}$$

Method 2:

$$\bar{V}_i = \sqrt{2}V_i \angle \theta_i$$

$$\bar{V}_o = \sqrt{2}V_o \angle \theta_o$$

$$\bar{I} = \sqrt{2}I \angle \theta_i$$

$$\bar{Z}_L = \frac{\bar{V}_i - \bar{V}_o}{\bar{I}}$$

$$\bar{Z}_L = R + jX_L$$

T Line Notes

Both one of these methods will give you R and X_L from the collected data, Method 1 however is much easier to use since it does not deal with phasors and delay angles. Once X_L has been found L can be determined from the inductive impedance formula:

$$X_L = \omega L = 2\pi f L$$

so

$$L = \frac{X_L}{2\pi f}$$

Part 3:

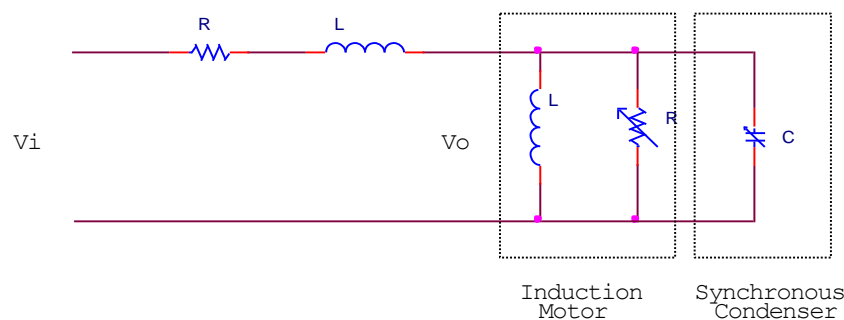
In this section you determined the voltage regulation of the transmission line. Ideally a transmission line should hold the same output voltage regardless of the load that is attached to it; voltage regulation is a measure of its ability to do that. The formula for voltage regulation follows:

$$VR = \frac{V_{nl} - V_{fl}}{V_{fl}} * 100\%$$

The no load voltage you measured in the lab was the output voltage when the load was disconnected while the full load voltage was with the load connected. In an ideal case with no load voltage equal to full load voltage the VR would be 0% (this very rarely occurs in practical applications), in this experiment you should get a voltage regulation of about 55%-65%.

Part 5:

This part of the lab deals with power factor correction, to accomplish pf correction a synchronous condenser was used to balance an induction motor. As is implied from its name an induction motor is an inductive element and can be modeled as an inductor. Most loads on the power system are inductive in nature and thus draw reactive power. The other device we had on the output of the transmission line was an unloaded synchronous motor (or synchronous condenser) this in effect acts like a variable capacitor which has increasing capacitance as its rotor excitation current is increased (we will get to how and why in a future lab). So the per phase circuit can be represented like this:



Since an Inductor absorbs Q and a Capacitor absorbs $-Q$ (or supplies) if the capacitor is sized correctly it will supply the reactive power that the inductor draws, meaning that the transmission line will only see the resistor as a load and will not supply any reactive power. So to the line the load power factor appears to be unity. As you increased the

T Line Notes

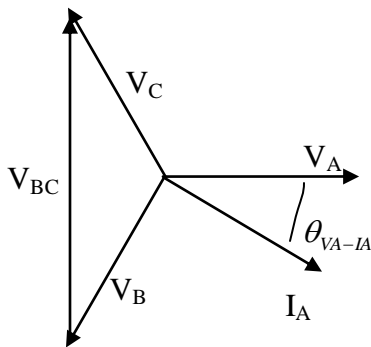
excitation current to the rotor you should have seen the voltage, current, reactive power, and angle values in the transmission line falling. This is because the increasing capacitance is balancing the inductance and the power factor is approaching unity.

Reactive power meter:

In the experiment an analog wattmeter was used to measure reactive power, here is how it works:

Meter measures: $P = V I \cos(\theta_{VI})$

Meter inputs for this experiment are V_{BC} and I_A



From the phasor diagram it can be seen that:

$$V_{BC} = \sqrt{3}V_A \angle (\theta_{VA} + 90)$$

Putting this into the meter we get

$$\begin{aligned} P &= V_{BC} I_A \cos(\theta_{VBC-IA}) \\ &= \sqrt{3}V_A \angle (\theta_{VA} + 90) I_A \cos(\theta_{VBC-IA}) \\ &= \sqrt{3}V_A I_A \cos((\theta_{VA} + 90) + (\theta_{VA-IA})) \\ &= \sqrt{3}V_A I_A \cos(\theta_{VI} + 90) \\ &= \sqrt{3}V_A I_A \sin(\theta_{VI}) \\ \text{since } Q &= VI \sin(\theta_{VI}) \\ &= \sqrt{3}Q_A \end{aligned}$$

So the output Q is the reading on the meter divided by the square root of 3

*Note this trick only works on balanced systems