EE 340L – Experiment 5: Transmission Lines

Balanced power transmission lines are represented by their π equivalent circuit on a per-phase basis as shown in Fig. 1 below. Herein, Z and Y represent the line series impedance and shunt admittance, respectively, (V_S, I_S) and (V_R, I_R) represent the phase voltage and current and the sending end (left terminal) and receiving end (right terminal).

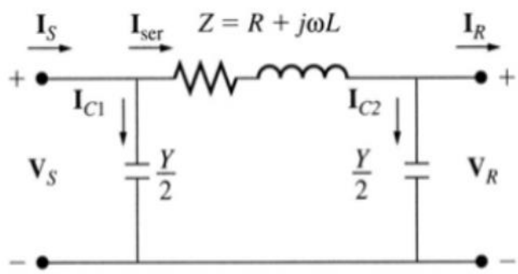

Fig. 1

Through simple KCL/KVL analysis, the sending end quantities are related to the receiving end quantities by what the so-called ABCD line parameters:

$$\boxed{\begin{aligned} V_S &= AV_R + BI_R \\ I_S &= CV_R + DI_R \end{aligned}} \qquad A = \frac{ZY}{2} + 1 \qquad B = Z \qquad C = Y\left(\frac{ZY}{4} + 1\right) \qquad D = \frac{ZY}{2} + 1$$

Note that is real transmission lines, the series impedance is very small relative to the shunt impedance, i.e., Z << (1/Y). The values of Z and Y can be determined from the open-circuit and short-circuit tests.

1. Open-Circuit Test

Under open-circuit conditions, i.e., I_R = 0 A,

$$V_S = AV_R, \quad I_S = CV_R \approx YV_S, \quad P_S \approx 0W, \quad Q_S \approx -YV_S^2.$$

If one measures the voltage and current (V_S, I_S) and real and reactive power (P_S, Q_S) at the sending end, the shunt admittance Y can be computed by

$$Y \approx \frac{I_S}{V_S}, \quad or \quad Y \approx -\frac{Q_S}{V_S^2}.$$

<u>Experiment:</u> Locate the 3-phase transmission line module. Connect one end of the module to a 3-phase 208/120 V supply through a multi-meter, and leave the other end open. Measure the (V_S, I_S, P_S, Q_S) and the voltage V_R at the receiving end using a second multi-meter. Record your measurements below.

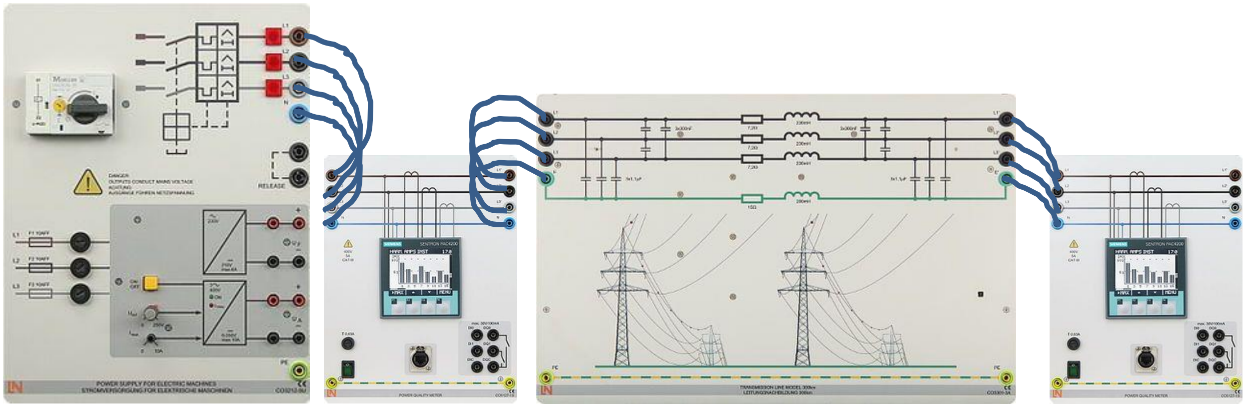

Fig. 1: Open-Circuit Test

$$V_S = \text{........}V, \quad I_S = \text{........}A, \quad P_S \approx \text{.........}W, \quad Q_S \approx \text{.........}VAR, \quad V_R = \text{..........}V.$$

Then calculate the line admittance using the above equations

$$Y \approx \frac{I_S}{V_S} = \text{............}S, \quad or \quad Y \approx -\frac{Q_S}{V_S^2} = \text{...............}S$$

2. Short-Circuit Test

Under short-circuit conditions, i.e., V_R = 0 V,

$$V_S = BI_R = ZI_R, \quad I_S = DI_R, \quad P_S \approx RI_R^2 \; W, \quad Q_S = XI_R^2 - \frac{Y}{2}V_S^2.$$

If one measures the voltage and current (V_S, I_R) and real and reactive power (P_S, Q_S) at the sending end, the real and reactive elements of Z can be computed by

$$R = \frac{P_S}{I_R^2}, \quad X = (Q_S + \frac{Y}{2}V_S^2)/I_R^2.$$

<u>Experiment:</u> Connect one end of the module to a 3-phase 208/120 V supply, and short out the line terminals at the other end (see Fig. 2 below). Measure the (V_S, I_S, P_S, Q_S) and the current I_R at the receiving end.

$$V_S = \text{........}V, \quad I_S = \text{........}A, \quad P_S \approx \text{.........}W, \quad Q_S \approx \text{.........}VAR, \quad V_R = \text{..........}V.$$

Then compute the real and imaginary part of the series impedance:

$$R = \frac{P_S}{I_R^2} = \text{.............}\Omega, \quad X = (Q_S + \frac{Y}{2}V_S^2)/I_R^2 = \text{...........}\Omega.$$

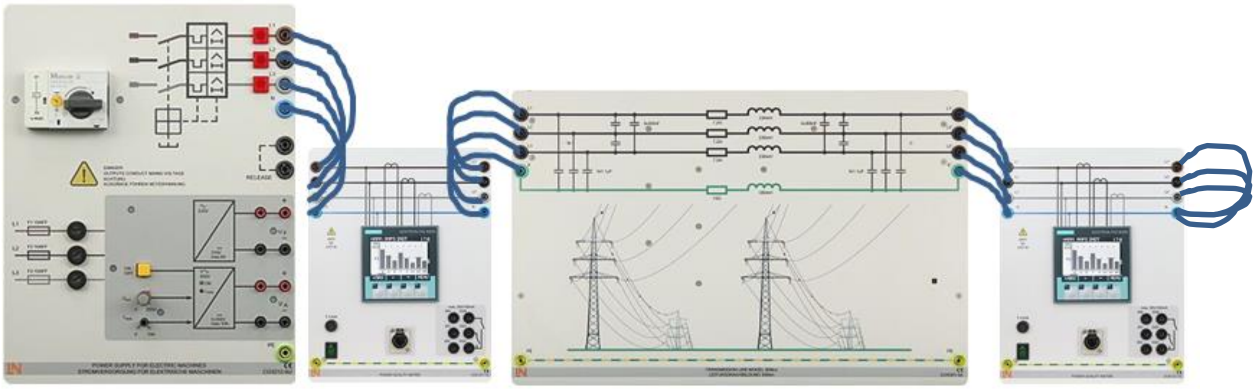

Fig. 2: Short-Circuit Test

Note: Unlike the case of a transformer, the series impedance of a long line is sufficiently large, so applying full voltage will not cause excessive currents. Verify the following:

$$V_S = ZI_R = \ldots\ldots\ldots\ldots V, \quad I_S = DI_R = \ldots\ldots\ldots\ldots A$$

Under the open-circuit test, verify that

$$V_R = V_S / A = \ldots\ldots\ldots\ldots\ldots V$$

3. Load Test

Now connect a resistive load (i.e., with unity power factor) on each phase of the receiving end terminals the right of the meter. The adjustable 3-phase resistive load is shown in Fig. 3 below.

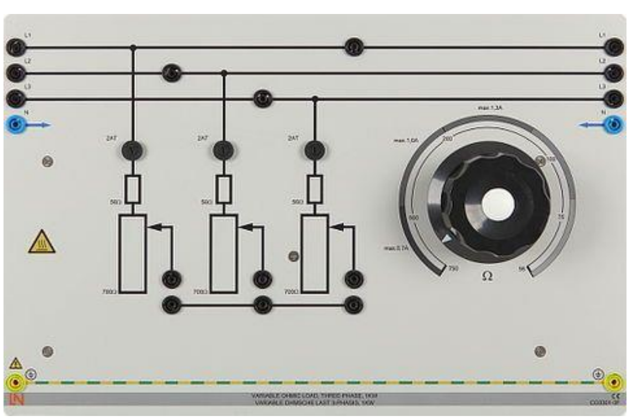

Fig. 3: Variable Resistive Load Bank.

Start with the largest resistance value that will draw the least current (i.e., maximum position in the counter-clockwise direction). Then record (V_S, I_S, P_S, Q_S) and (V_R, I_R, P_S) in the first row of the table below. Then decrease the load resistance in increments that result in the load current to increase in increments of 0.15 A, and repeat the measurements. For each load, calculate the line efficiency and voltage regulation. Fill in the Table below.

I_S (A)	V_S (A)	P_S (W)	Q_S (VAR)	I_R (A)	V_R (V)	P_R (W)	η (%)	VR (%)
				0.15				
				0.30				
				0.45				
				0.60				
				0.75				
				0.90				
				1.05				
				1.20				
				1.35				
				1.50				
				1.65				
				1.80				
				1.95				

Finally, Plot the line efficiency and voltage regulation as a function of power delivered to the load.