

**ERCIYES UNIVERSITY FACULTY OF ENGINEERING
DEPARTMENT OF ENERGY SYSTEMS ENGINEERING
ENERGY SYSTEMS ENGINEERING LABORATORY**



EXPERIMENT MANUAL

EXPERIMENT TITLE

**VOLTAGE DROP AND POWER FACTOR IN ELECTRICAL TRANSMISSION
LINES EXPERIMENT**

COURSE INSTRUCTOR

LABORATORY INSTRUCTOR

EXPERIMENT GROUP:

EXPERIMENT DATE :

SUBMISSION DATE :

EXPERIMENT-12

VOLTAGE DROP AND POWER FACTOR IN ELECTRICAL TRANSMISSION LINES

OBJECTIVE OF THE EXPERIMENT: Observation and measurement of the voltage drop and power factor of a short transmission line.

Equipment Used:

Power Supply Unit
Adjustable Transformer
Line Model
Resistive Load Bank, R
Inductive Load Bank, X_L
Capacitive Load Bank, X_C
Cos ϕ meter
Switch, S
Multimeters

THEORY OF THE EXPERIMENT:

Electrical equivalent circuits are employed in the analysis of energy transmission lines, which are of vital importance for the utilization of electrical energy. These equivalent circuits consist of R, L and C elements whose values vary in proportion to the length of the line. R represents the ohmic resistance of the line, L represents the inductance of the line, and C represents the sum of the capacitances between the line conductors and the capacitances of the line with respect to ground.

Series impedance of the single-phase equivalent circuit of the line: $Z = R + j2\pi fL$

Total admittance of the single-phase equivalent circuit of the line: $Y = G + j2\pi fC$

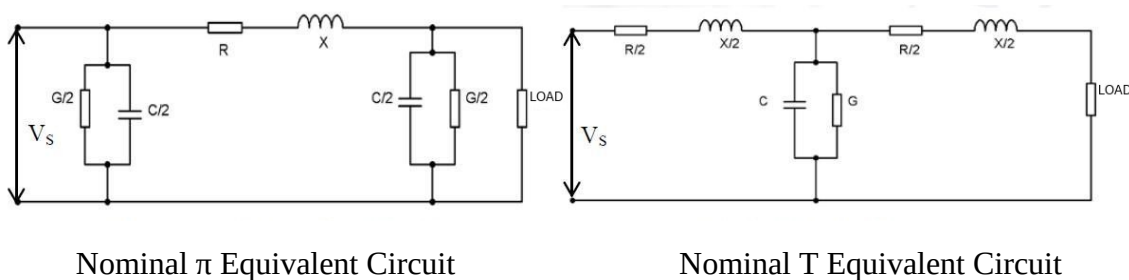


Figure 1. Nominal π and T Equivalent Circuits of a Transmission Line

G denotes the leakage conductance of the line. Since the current flowing due to the conductance is very small compared with the current passing through the equivalent capacitance C of the line, the parameter G in the equivalent circuit is generally neglected. The values of R, L and C increase in proportion to the length of the line.

SHORT TRANSMISSION LINES

These are transmission lines with a length of 0–80 km. Since the equivalent capacitance C of the line is proportional to the length of the line, this value is small enough to be negligible in short transmission lines and is therefore neglected. In this case, the equivalent circuit of the short transmission line is as shown in the figure below.

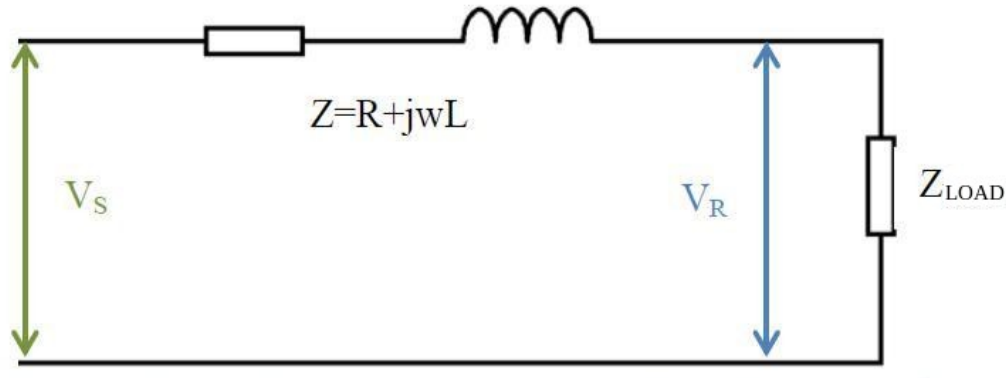


Figure 2. Equivalent Circuit of the Short Transmission Line

$$Z = R + jX_L = r_l + jx_l = z_l$$

$$V_S = V_R + ZI_R$$

$$I_S = I_R$$

$$\text{Line Efficiency } \eta = P_R / P_S$$

$$P_R = \sqrt{3} \cdot U \cdot I \cdot \cos\theta_R$$

$$Q_R = \sqrt{3} \cdot U \cdot I \cdot \sin\theta_R$$

$$S_R = \sqrt{3} \cdot U \cdot I_R^*$$

$$\cos\theta_R = P_R / S_R$$

$$P_S = \sqrt{3} \cdot U \cdot I \cdot \cos\theta_S$$

$$Q_S = \sqrt{3} \cdot U \cdot I \cdot \sin\theta_S$$

$$S_S = \sqrt{3} \cdot U \cdot I_S^*$$

$$\cos\theta_S = P_S / S_S$$

The MV 2222 Line Model represents a 5 km long overhead power transmission line designed for a nominal voltage of 11 kV and a nominal current of 219 A. This line has a cross-sectional area of 120 mm². The power rating of the line is,

$$S_n = \sqrt{3} \cdot 11 \cdot 10^3 \cdot 219 \cong 5 \text{ MVA}$$

Model nominal values: **3x400 V, 2 A**

Values/Parameters:

Quantity	Actual Line	Model Line
U	11 kV	400 V
I	219 A	2 A
S	5 MVA	1386 VA
l	5 km	-
Area	120 mm ²	-
R	0.71 ohm	2.4 ohm
L	5 mH	17 mH
C+	120 nF	30 nF
C0	75 nF	20 nF

Table 2. Required Data for the Short Transmission Line

This line model consists of resistors, inductors and capacitors. In reality, the capacitances, resistances, etc. are fully distributed along the line. However, emulating this in a model would be difficult. Therefore, the line capacitance has been lumped at each end of the line as half of the total capacitance. Moreover, theoretical calculations become highly complex when distributed capacitance is used. For this reason, this simpler method is also employed for this purpose.

Resistive Load:

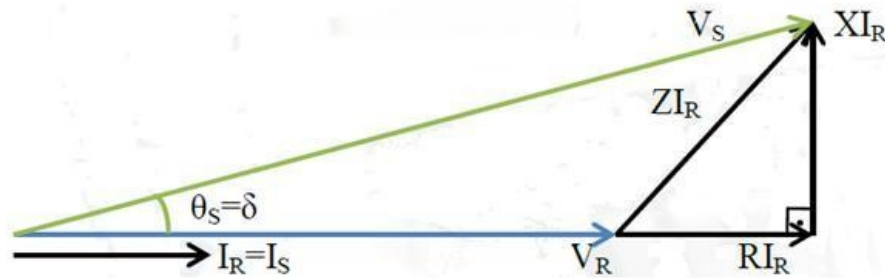


Figure 3. Phasor Diagram for Resistive Load

Inductive Load:

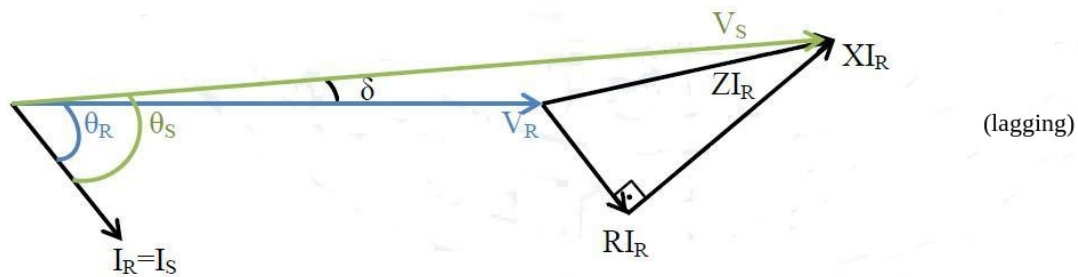


Figure 4. Phasor Diagram for Inductive Load

Capacitive Load:

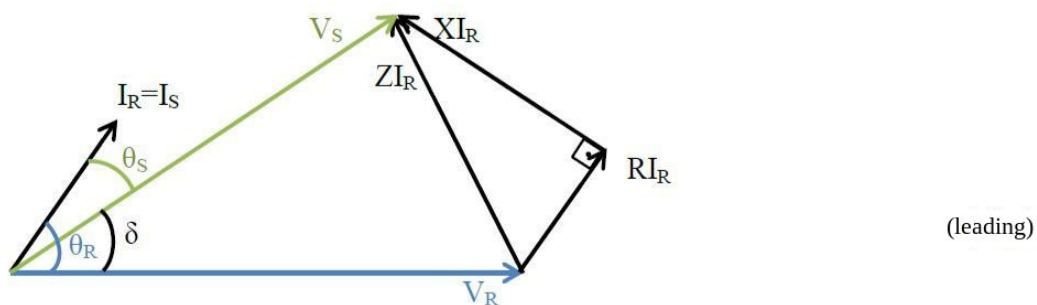


Figure 5. Phasor Diagram for Capacitive Load

EXPERIMENTAL PROCEDURE:

1. Connect the circuit according to Figure 6:

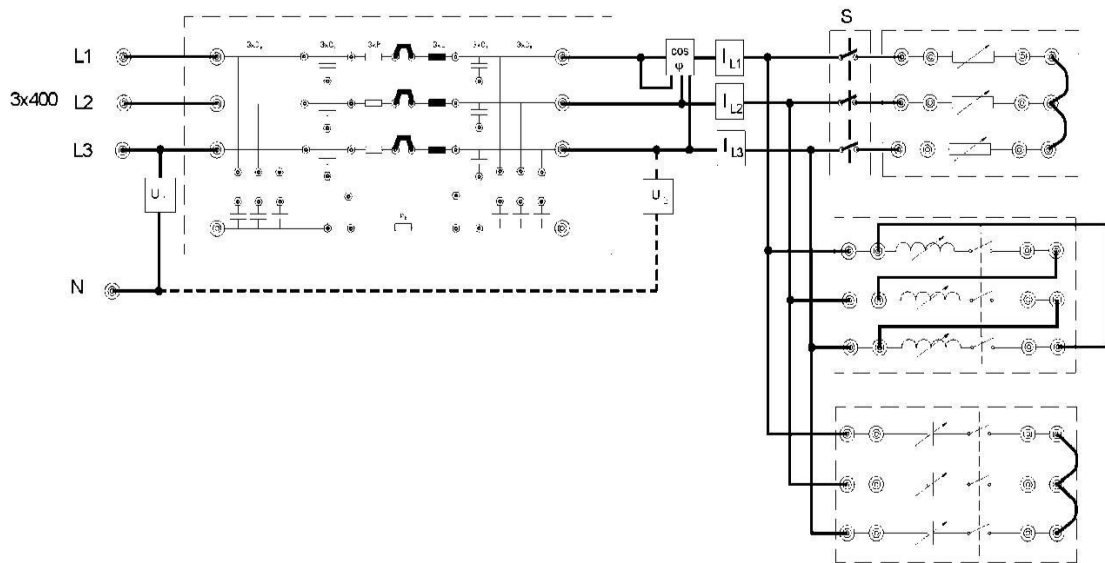


Figure 6. Connections Required for the Experiment

1.1. Resistive Load

- Connect the three-phase voltage and set V_S to 230 V.
- After setting the resistive load bank for minimum current, close switch S and set I_R to 1.00 A.
- Check whether V_S is still 230 V and readjust it if necessary.
- Move the voltmeter to the output and measure V_R .
- Measure the $\cos\phi$ values at the sending end and at the receiving end of the line.

1.2. Inductive Load

- Connect the three-phase voltage and set V_S to 230 V.
- Make the inductive load connection and, while increasing the inductive load value, record the sending-end and receiving-end voltages, currents, $\cos\phi$ values and the voltage drop in the table.

EQUATIONS:

Using the V_R and I_R values to be given in Table 3, the value of V_S can be calculated by means of Equation (1):

$$V_S = V_R + Z \cdot I_R \quad (1)$$

In order to measure the voltage drop of the line, i.e., the difference between the input and output voltages, Equation (2) can be used with acceptable accuracy:

$$\Delta V = V_S - V_R \quad (2)$$

RESULTS AND EVALUATION:

Using the values obtained above, determine the relevant entries in the given table.

	V_S	V_R	I_S	I_R	$\cos\phi_R$	$\cos\phi_S$	ΔV
Resistive Load							
Inductive Load							

Table 3. Measurement and Calculation Results for the Short Transmission Line

- Taking the receiving-end voltage as reference, draw the phasor diagram to scale for both load cases.
- Calculate the receiving-end voltage.