Experiment 12

VOLTAGE REGULATION OF A TRANSMISSION LINE

Objectives:

1) To observe the flow of real and reactive power in a three phase transmission line with known passive loads
2) To observe the voltage regulation at the receiver end as a function of the type of the load
3) To regulate the receiver voltage
4) To observe the phase angle between the voltages at the sending and receiving end of the transmission line

Introduction:

A transmission line which delivers electric power dissipates heat owing to the resistance of its conductors. It acts, therefore, as a resistance which in some cases is many miles long. The transmission line also behaves like an inductance, because each conductor is surrounded by a magnetic field which also stretches the full length of the line. Finally transmission line behaves like a capacitor, the conductor acting as its more or less widely-separated plates.

The resistance, inductance and capacitance of a transmission line are uniformly distributed over its length, the magnetic field around the conductors existing side by side with the electric field created by the potential difference between them. We can picture transmission line as being made of thousands of elementary resistors, inductors and capacitors as shown in figure 1.

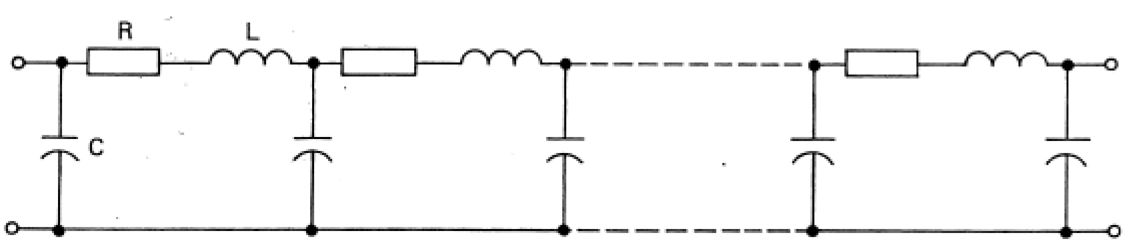

Figure: 1

In high frequency work this is precisely the circuit which has to be used to explain the behavior of a transmission line. Fortunately, at low frequencies of 50Hz or 60Hz, we can simplify most lines so that they comprise one inductance, one resistance and one (or sometimes two) capacitor. Such arrangement is shown in figure 2. Here the inductance L is equal to the sum of the inductors of figure 1, and same is true for the resistance R. The capacitance C is equal to one half of the sum of the capacitors shown in figure 1. Inductance and capacitances are replaced by X_L and X_C in figure 3.

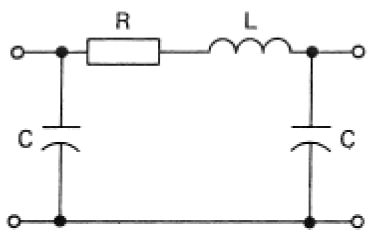

Figure: 2

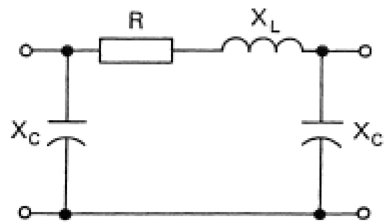

Figure: 3

The relative values of R, X_L and X_C depend upon the type of transmission line. Short, low-voltage lines such as in a house wiring are mainly resistive, and the inductive and capacitive reactance can be neglected (figure 4(a)). Medium-voltage and medium length lines operating say at 100kV and several miles long will have negligible resistance and capacitive reactance compared with the inductive reactance. Such lines can be represented by a single reactance X_L, shown in figure 4(b). Finally very high voltage lines which run for many miles have appreciable capacitive and inductive reactance and may be designated by a circuit similar to figure 4(c).

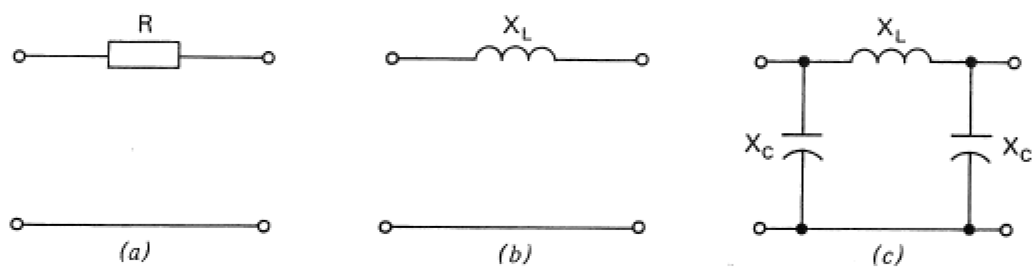

Figure: 4

Most transmission lines can be represented by figure 4(b) and a good understanding of their behavior can be obtained by the simple inductance of figure 4(b). It is this circuit which will be used in this experiment.

Voltage regulation of a transmission line is the rise in voltage at the receiving end, expressed in percent of full-load voltage, when full load at a specified power factor is removed while the sending-end voltage is held constant.

$$\%\text{regulation} = \frac{(V_{nl} - V_{fl})}{V_{nl}} \times 100\% \tag{1}$$

Where, V_{nl} = No load Voltage, V_{fl} = Full load Voltage

A resistive or inductive load at the end of a transmission line produces very large voltage drop, which would be quite intolerable under practical conditions. Motor, relays and electric lights work properly only under stable voltage conditions, close to the potential for which these devices are rated. We must, therefore, regulate the voltage at the receiving end of the transmission line in such a way as to keep it as constant as possible. One approach is to connect capacitors parallel to the load which delivers the required reactive power to the inductive loads thus lowering the need of high line current through the transmission line which results in a lower voltage drop at the load terminals.

Experiment:

Run the LabVIEW program called 'Transmission line voltage regulation'. Perform the following experiments using a simple transmission line having 120Ω per phase line reactance (consisting of only inductive element).

Part 1:

Make a circuit arrangement as shown in figure 5. Set the source panel voltage to $150V_{rms}$. Measure voltage regulation for the following circuit arrangements. Remember that loads are all wye connected.

1. Open circuit
2. Short circuit
3. Resistive load (300Ω/phase) - EMS 8311
4. Capacitive load (300Ω/phase) - EMS 8331
5. Induction Motor - EMS 8241

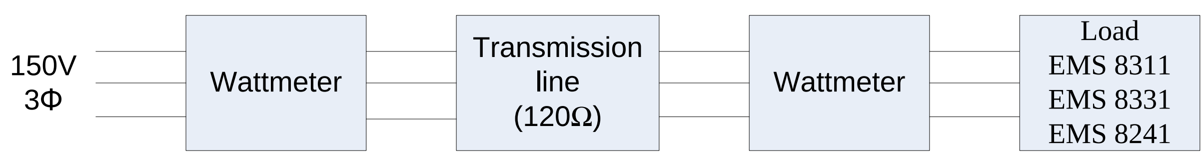

Figure: 5.

Please turn the breaker off after you are done with taking the readings.

Part 2:

In this part, voltage regulation at the receiver end is demonstrated using EMS 8331. EMS 8311 is used to represent a heating load. First output voltage will be recorded for different values of resistance per phase. Next a EMS 8331 is connected parallel to EMS 8311 (follow figure 6). The output voltage is listed for different values of capacitance across the load.

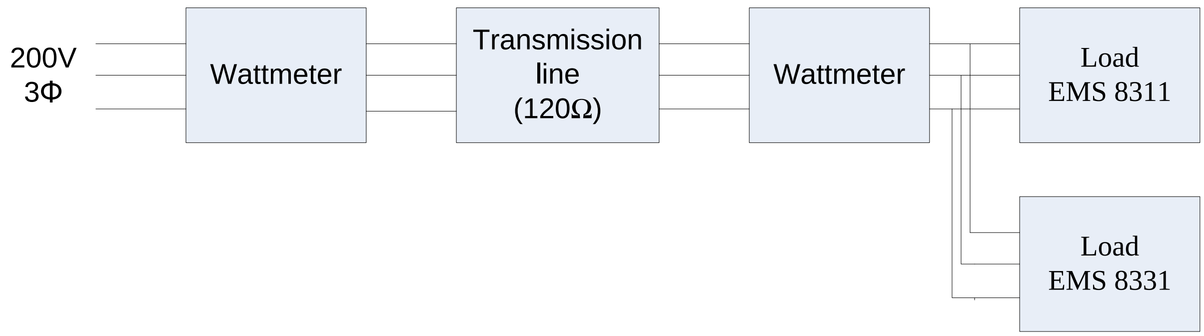

Figure: 6

Table I lists the variation of resistance and capacitive reactance for this experiment

Table I

Resistive load (EMS 8311)		Resistive load with static capacitors in parallel (EMS 8311)‖ (EMS 8331)	
R Ω/phase		R Ω/phase	X_C Ω/phase
∞		∞	∞
1200		1200	∞
600		600	1200
400		400	1200
300		300	600
240		240	600
200		200	400
171.4		171.4	240

Discussion:

1. Find the percent voltage regulation in part 1. What does a positive/negative voltage regulation indicate?
2. Draw the terminal voltage vs. real power at the load terminal of part 2. Indicate the phase angle difference between the sending end and the receiving end in the plot.
3. Discuss the graph obtained in (2)
4. If the transmission line were purely resistive, would it be possible to raise the receiving end voltage by using static capacitors?