Date: ______________

Name: ______________________

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LABORATORY EXPERIMENT NO. 4

POWER FLOW AND VOLTAGE REGULATION OF A SIMPLE TRANSMISSION LINE

OBJECT

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 load.

DISCUSSION

TRANSMISSION LINES

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, the transmission line behaves like a capacitor, the conductors 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 a transmission line as being made up of thousands of elementary resistors, inductors and capacitors as shown in *Fig. 4-1.*

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) capacitors (for each phase). Such an arrangement is shown in *Fig. 4-2.*

In *Fig. 4-2*, the inductance L is equal to the sum of the inductances of *Fig. 4-1*, and the same is true for the resistance R. The capacitance C is equal to one half the sum of the capacitors shown in *Fig. 4-1.* The inductance L and capacitance C

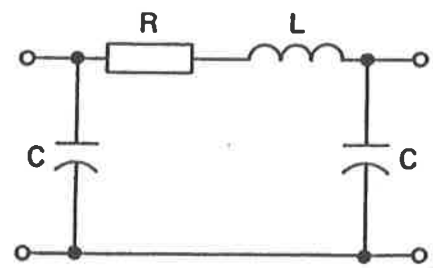

Fig. 4-2

can be replaced by their equivalent reactances X_L and X_C as shown in *Fig. 4-3.*

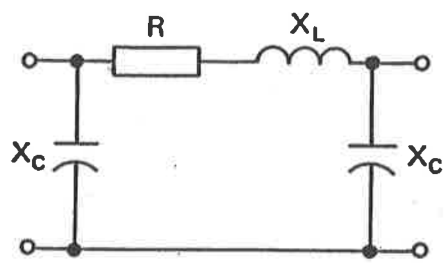

Fig. 4-3

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 reactances can be neglected *(Fig. 4-4a).*

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 *Fig. 4-4(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 *Fig. 4-4(c).*

Most transmission lines can be represented by *Fig. 4-4(b)* or *4-4(c)*, and a good understanding of their behavior can be obtained by the simple

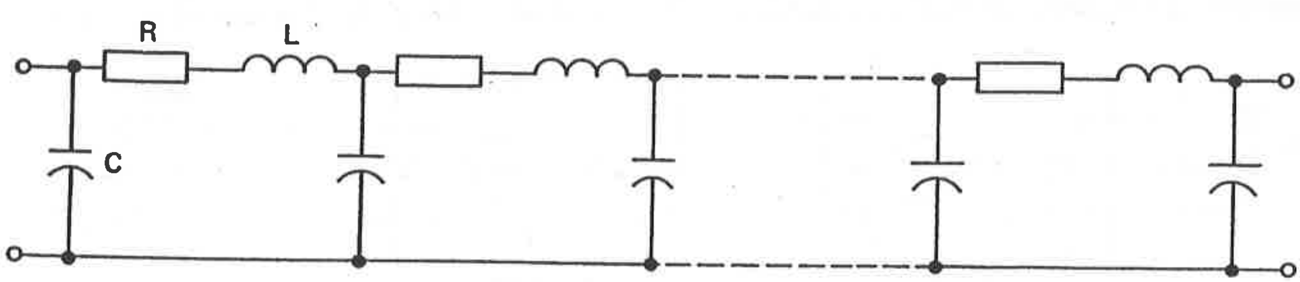

Fig. 4-1

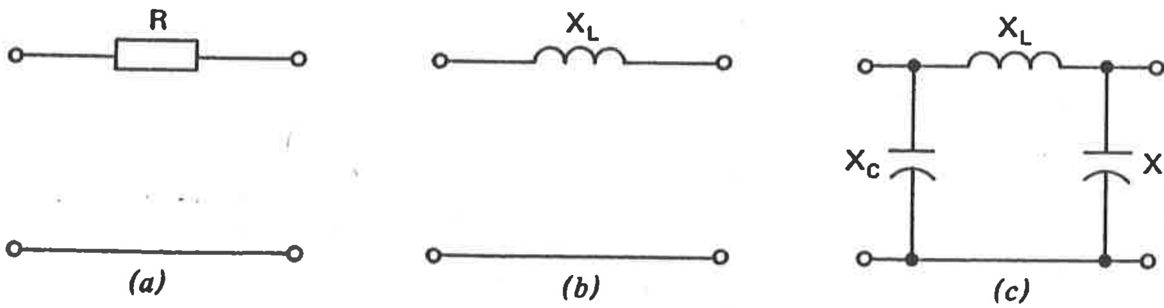

Fig. 4-4

inductance of *Fig. 4-4(b)*. It is this circuit which will be used in this experiment.

As a matter of interest, typical *60Hz* lines have a series reactance of about *0.8 ohm* per mile per phase. The shunt capacitive reactance is about *200,000 ohms* per mile.*

INSTRUMENTS AND COMPONENTS

Power Supply Module (*120/208V 3ϕ, 0-120/208V 3ϕ*)	*EMS 8821*
Resistance Module	*EMS 8311*
Inductance Module	*EMS 8321*
Three-Phase Transmission Line Module	*EMS 8329*
Capacitance Module	*EMS 8331*
AC Metering Module (*250V/250V*)	*EMS 8426*
Three-Phase Watt-Varmeter Module (2) (*300W/300var*)	*EMS 8446*
Connection Leads	*EMS 9128*

EXPERIMENTS

Caution: High voltages are present in this Laboratory Experiment! Do not make any connections with the power on!

* From "Regulation and Losses of Transmission Lines" Electrical Transmission and Distribution Reference Book, pp 279-280, Westinghouse Electric Corporation, East Pittsburgh, Pennsylvania.

☐ 4-1) Connect two watt-varmeters in series to the variable three-phase *208 V* power supply and apply a three-phase inductive load of *300 ohms*, wye connected, as shown in Fig. 4-5. Adjust the power supply output to 208 V. Particular care should be taken in connecting so that the proper phase sequence is applied to the watt-varmeters.

If the meters are connected as shown, both varmeters should read positive when the polarity reversing switch is in the (+) position. If the reading is negative, the phase sequence is incorrect and any two leads a, b or c should be interchanged.

Note: Although both meters should give the same readings, the one on the left may show a slightly higher reading owing to the load which the right-hand meter imposes.

W_1 = ... W_2 = ...

var_1 = ... var_2 = ...

☐ 4-2) Using the variable-voltage AC source, connect the circuit as shown in *Fig. 4-6*, and set the impedance of the transmission line to *120 ohms*. Connect an inductive load of *300 ohms* in wye and apply power. All meters should read positive if their polarity switches are in the (+) position. If the readings are not positive, check your wiring for phase sequence. We are now ready to proceed with the experiment, using the circuit of *Fig. 4-6*.

☐ 4-3) With the line on open circuit, adjust the voltage of the source so that the line-to-line voltage

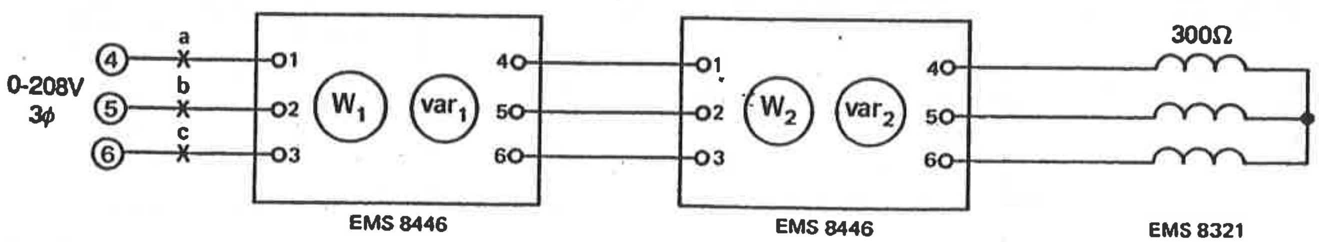

Fig. 4-5

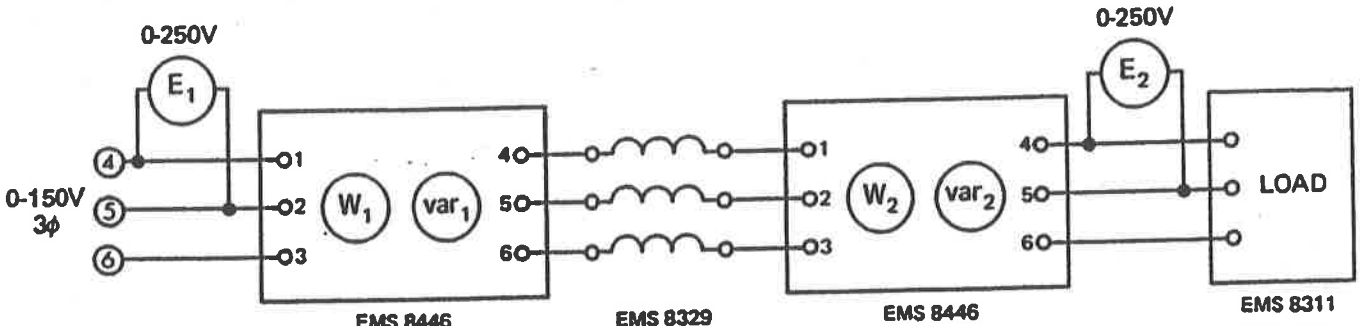

Fig. 4-6

E_1 is *150 volts.* (Keep this voltage constant for the remainder of the experiment). Measure E_1, W_1, var_1 and E_2, W_2, var_2, and record in *Table 4-1.*

☐ 4-4) Connect a three-phase inductive load of *300 ohms* per phase, take readings and record in *Table 4-1.*

☐ 4-5) Apply a three-phase resistive load of *300 ohms* per phase, take readings and record in *Table 4-1.*

☐ 4-6) Apply a three-phase capacitive load of *300 ohms* per phase, take readings and record in *Table 4-1.*

☐ 4-9) Calculate the real and reactive power which is absorbed by the transmission line in Experiments 4-4, 4-5, 4-6 and record in *Table 4-1.*

☐ 4-10) Calculate the voltage regulation of the transmission line from the formula:

$$\%\ regulation = \frac{(E_O - E_L) \times 100}{E_O}$$

in which E_O is the open-circuit voltage and E_L is the voltage under load, both at the load (or receiver) end. Record your results in *Table 4-1.*

EXPERIMENT NO.	LOAD	E_1 (V)	W_1 (W)	var_1 (vars)	E_2 (V)	W_2 (W)	var_2 (vars)	LINE WATTS	LINE vars	REGULATION (%)
4-3	OPEN CIRCUIT	150								
4-4	INDUCTIVE	150								
4-5	RESISTIVE	150								
4-6	CAPACITIVE	150								

Table 4-1

QUESTIONS AND PROBLEMS

1. A three-phase transmission line having a reactance of *120 ohms* per phase is connected to a wye-connected load whose resistance is *160 ohms* per phase. If the supply voltage is *70kV* line-to-line, calculate

a) The line-to-neutral voltage per phase.

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b) The line current per phase.

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c) The real and reactive power supplied to the load.

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d) The real and reactive power absorbed by the line.

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e) The line-to-line voltage at the load.

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f) The voltage drop per phase in the line.

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g) The total apparent power supplied by the source.

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h) The total real and reactive power supplied by the source.
