UNIVERSITY OF NORTH CAROLINA AT CHARLOTTE
Department of Electrical and Computer Engineering

EXPERIMENT 7 – AC OPERATION OF RLC NETWORKS

OBJECTIVES

The purpose of this experiment is to obtain the voltages, currents and powers for circuits excited by a sinusoidal source and compare the results with theoretical calculations in phasor notation.

MATERIALS/EQUIPMENT NEEDED

AC Variable Source (capable of 40V)
(2) Power Analyzer
Resistors: (1) 1 kΩ, (1) 1.5 kΩ
Capacitor: 1 µF
Inductor: 2.65 H

INTRODUCTION

Linear circuits with a sinusoidal excitation will have currents and voltages that are also sinusoidal and of the same frequency. Phasor methods instead of differential equations can be used to solve this particular variety of time- varying circuits. When written in phasor notation, the circuit equations become complex equations that can be solved algebraically. A circuit including inductors and/or capacitors, excited by a sinusoid, will produce phase related sinusoidal voltages and currents, where the current through a capacitor will lead the applied voltage by 90 deg., while the current through an inductor will lag the applied voltage by 90 deg.

Impedance

Circuit elements in a linear circuit with a sinusoidal excitation will exhibit a quantity known as complex impedance. The magnitude of impedance for capacitors and inductors will be a function of the element value and the frequency. The impedance phase for capacitors will be -90 deg. (or a –j in the complex plane) and for inductors will be +90 deg. (or a +j in the complex plane). Impedances for resistance, capacitance, and inductance are given as follows:

$$\mathbf{Z}_R = R$$
$$\mathbf{Z}_L = j\omega L$$
$$\mathbf{Z}_C = 1/(j\omega C)$$

where,
$\omega = 2\pi f$ (frequency in radians/second)
f (frequency in Hertz)

Admittance

When dealing with parallel circuits it may be more convenient to work with admittance instead of impedance. The reason is that admittances in parallel add like impedances in series. Admittances for resistance, capacitance, and inductance are given as follows:

$$\mathbf{Y}_R = 1/R$$
$$\mathbf{Y}_L = 1/(j\omega L)$$
$$\mathbf{Y}_C = j\omega C$$

Complex Power

The complex power (**S**) in an AC circuit consists of real and imaginary components and is the product of the voltage phasor and conjugate of the current phasors, given by:

$$\mathbf{S} = \mathbf{V}\,\mathbf{I}^* = P + j\,Q$$

P is the real power in Watts and represents the real power used by the circuit. Q is the imaginary power in VARS (Volt Amps Reactive) and represents the power traded back and forth between the circuit and the source. A short method for finding these quantities is to first determine the phase angle by which current leads voltage (ϕ) and the apparent power (magnitude of the complex power phasor, $|\mathbf{S}|$) given by the product of the RMS current and the RMS voltage.

Theerefore, the real power (P) and the imaginary power (Q) can be calculated as

$$P = |S| \cos \phi = V_{RMS} I_{RMS} \cos \phi$$
$$Q = |S| \sin \phi = V_{RMS} I_{RMS} \sin \phi$$

The term $\cos \phi$ is referred to as the power factor, while the term $\sin \phi$ is referred to as the reactive factor. Since ϕ is restricted to the range -90 to +90 deg., the power factor and P will always be positive. On the other hand, if ϕ is between -90 and 0 deg., as it is for an inductive load, the reactive factor and Q will be negative. The power factor is designated as leading when ϕ is positive and lagging when it is negative. Thus, a lagging power factor indicates an inductive load with a negative apparent power.

PRELAB

1. For the circuit in Figure 7-1, derive an expression for the impedance, Z, between A and B in terms of R_s, L and ω.
2. Calculate |I|, power factor angle, V_{Rs}, V_L, S, P and Q. Assume: $R_s = 1k\Omega$, $L = 2.65$ H, $f = 60Hz$ and $V = 40V$.
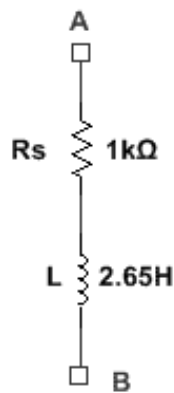3. Sketch a phasor diagram of all the voltages and currents in the circuit of Figure 7-1.
4. For the circuit in Figure 7-2, derive and expression for the admittance, Y, between A and B in terms of R_p, C and ω.
5. Calculate |I|, power factor angle, I_C, I_R, S, P, and Q. Assume: $R_p = 1.5k\Omega$, $C = 1.77\mu F$, $f = 60Hz$ and $V = 40V$
6. Sketch a phasor diagram of all the voltages and currents in the circuit of Figure 7-2.
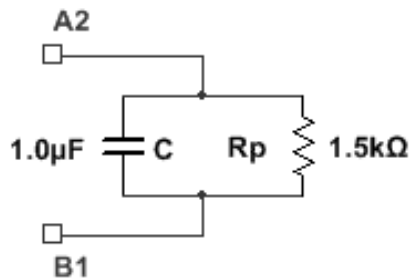

Figure 7-1 Series RL circuit

Figure 7-2 Parallel RC circuit

PROCEDURE
CAUTION: DO NOT CONNECT OR MAKE CHANGES IN THE FOLLOWING CIRCUITS UNLESS THE AC SUPPLY IS TURNED OFF!!

1. Connect the circuit of Figure 7-1 to the source as shown in Figure 7-3. You will need to measure R_L (inductor resistance) and make a note of this value.
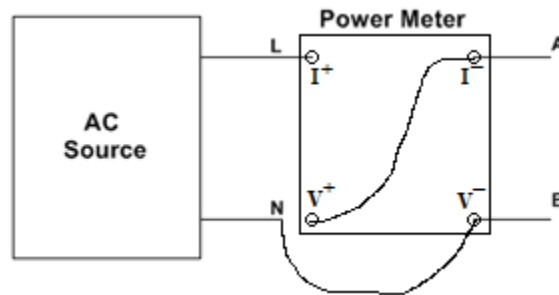

Figure 7-3 Power meter 1 and AC source connection

2. Adjust the ac supply until the power-meter is reading 40V. Record the input voltage, current, and real power from the power-meter.
3. Re-arrange the circuit elements and power-meter as shown in Figure 7-4 and 7-5 to obtain the individual element voltages, currents, and real powers. DO NOT CHANGE THE AC SUPPLY SETTING FROM THAT OF STEP 2!
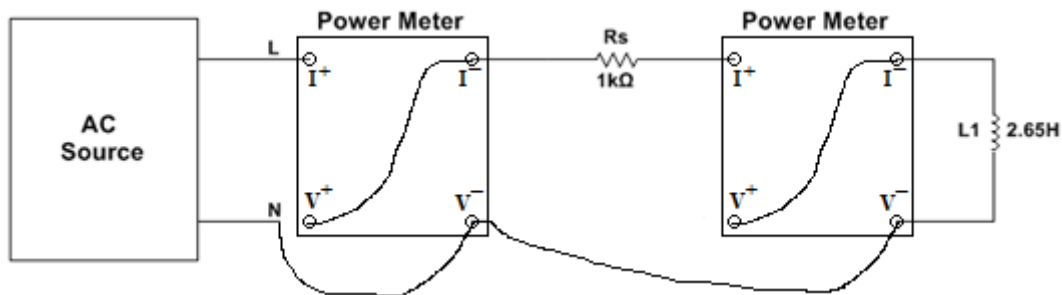

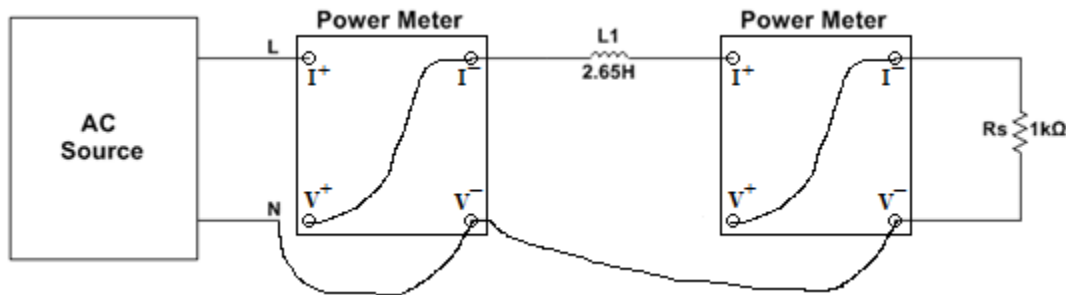**Figure 7-4 Circuit to measure the power of the inductor.**

Figure 7-5 Circuit to measure the power of the series resistor.

4. Connect the circuit of Figure 7-2 to the source shown in Figure 7-3.
5. Adjust the ac supply until the power-meter is reading 40V. Record the input voltage, current, and real power from the power-meter.
6. Re-arrange the circuit elements and power-meter as shown in Figures 7-6 and 7-7 to obtain the individual element voltages, currents, and real powers. DO NOT CHANGE THE AC SUPPLY SETTING FROM THAT OF STEP 5!
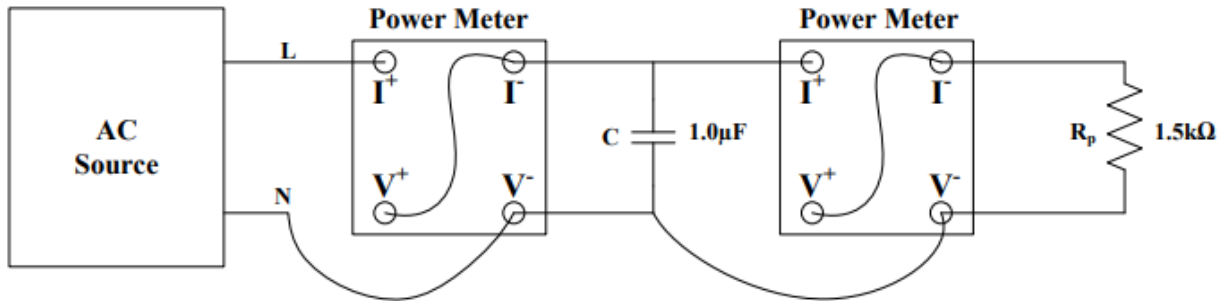

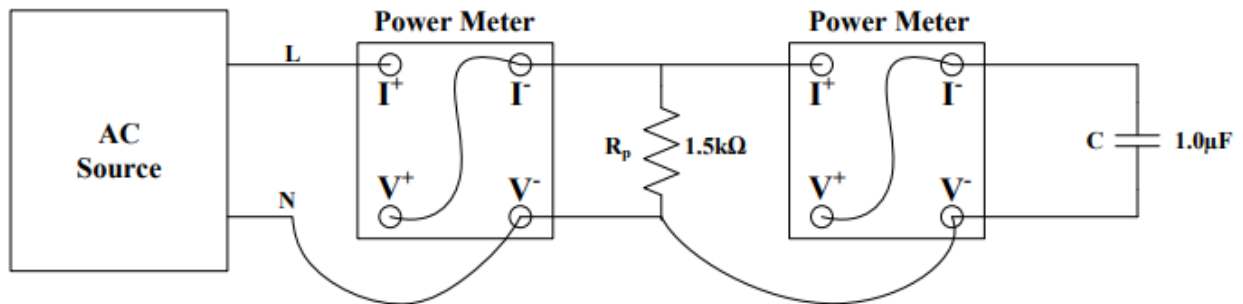**Figure 7-6 Circuit to measure the power of the parallel resistor.**

Figure 7-7 Circuit to measure the power of the parallel capacitor.

DATA/OBSERVATIONS

Table 7-1 Voltage, current, and real power measurements

Procedure	Figures	Voltage	Current	Real Power
1	7-1&7-3			
3	7-4			
3	7-5			
4	7-2&7-3			
6	7-6			
6	7-7			

INSTRUCTOR'S INITIALS: DATE:

POST-LAB

Post-Lab questions must be answered in each experiment's laboratory report.

1. Using measured values from the circuit of Figure 7-1, determine S, Q and power factor angle. Compare with the values of part 1 of the PreLab.
2. Add the measured real power of each element for the circuit in Figure 7-1 and compare with the total real power obtained in part 2 of the PreLab.
3. Using measured values from the circuit of Figure 7-2, determine S, Q and the power factor angle. Compare with values from part 5 of the PreLab.
4. Add the measured real power of each element for the circuit in Figure 7-2 and compare with the total real power obtained in part 5 of the PreLab.
5. Explain any differences between the experimental results and the calculated results.

Be sure to include all items from the post-lab exercise above in your written lab report.