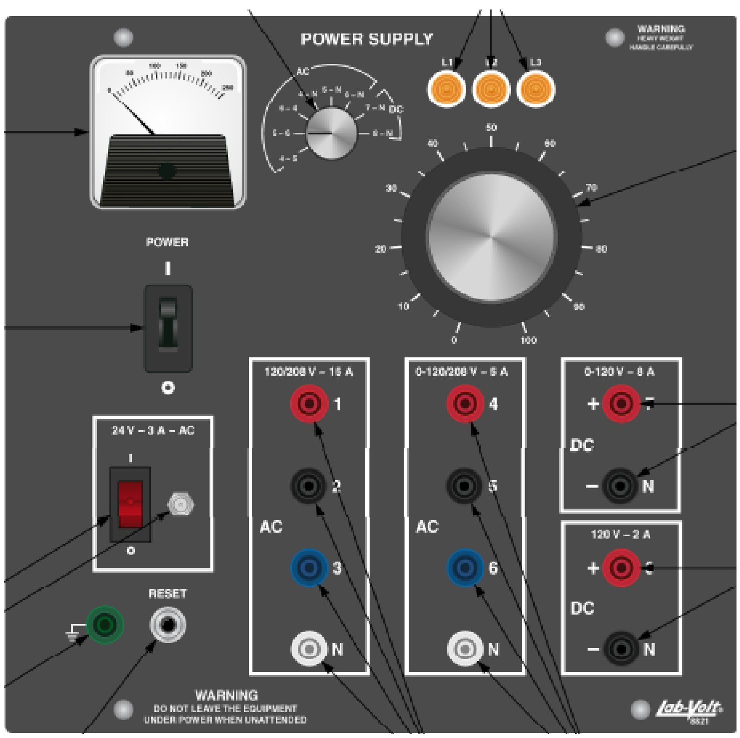
**Date:**____________________

**Name:** __________________

**ID:** __________________

# LABORATORY EXPERIMENT NO. 2

## Single-Phase System with RLC Load



**OBJECTIVE**

1. To understand and discuss alternating current (ac) circuits that contain resistance, inductance, and capacitance.
2. To connect an RLC series circuit.
3. To compute values of impedance, inductance, capacitance, power, vars, voltage drop across individual components, power factor, and phase angle from measurement taken.

**MATERIALS AND EQUIPMENT**

Power Supply Module
Variable-Resistance Module
Variable-Capacitance Module
Variable-Inductance Module
AC Ammeter
Watt/Var meter
AC Voltmeter

**DISCUSSION**

When an ac circuit contains elements of resistance, inductance, and capacitance, the voltage dropped across each element will be out of phase wit that across each of the other elements. The voltage dropped across the resistor will be in phase with the current. The voltage dropped across the inductor will be 90 degrees leading the current, and the voltage dropped across the capacitor will be 90 degrees lagging the current. The ratio of resistance, inductance, and capacitance will determine how much the applied voltage will lead or lag the current.

For the circuit shown in Fig.1, the total complex impedance of the circuit **Z** = R + j($X_L$ - $X_C$), where inductive reactance $X_L$ =$\omega$L and the capacitive reactance $X_C$ = 1/$\omega$C, with $\omega$ the angular frequency $\omega = 2\pi f$, and f as frequency of the ac voltage source. The amount of inductance in the circuit can be computed L = $X_L/(2\pi f)$= 24/377=0.0637 H. The amount of capacitance of the circuit is computed by C = $1/(2\pi f*X_C)$=1/3015.929 = 0.0003316 F = 331.6 $\mu$F.

The magnitude of the impedance |Z| = sqrt(R^2 + ($X_L$-$X_C$)^2) = sqrt(12^2 + (24-8)^2) = 20 Ω.

Then the magnitude of the total current is computed by |I| = |E|/|Z| = 240 /20 = 12 A.

The voltage drop across the resistor is computed as |$E_R$ | = |I| * R = 12 * 12 = 144 V. The power of the circuit is consumed by the resistor only, it can be computed as:

P = $E_R$*I= 144 * 12 = 1728 W.

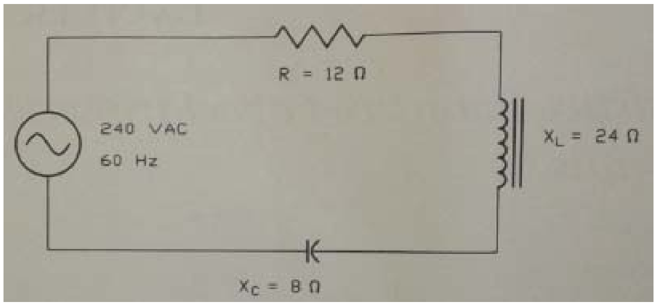



Fig.1. RLC series circuit

The amount of voltage drop across the inductor is computed as:

|$E_L$|=|I|*$X_L$ = 12 * 24 = 288 V.

The amount of reactive power of the inductor is computed as:

$Q_L$= |$E_L$|*|I| = 288*12 = 3456 Var.

The amount of voltage drop across the capacitor can be computed as:

|$E_C$|=|I|*($X_C$ )= 12 * 8 = 96 V.

The amount of reactive power of the capacitor is computed as:

$Q_C$= |$E_C$|*|I| = 96*12 = 1152 Var.

The net amount of reactive power of the circuit is obtained by the difference between $Q_L$ and $Q_C$:

Q=$Q_L$-$Q_C$=3456 - 1152 = 2304 Var

The volt-amps (apparent power) can be computed by multiplying the applied voltage and the circuit current:

VA = |$E_T$|*|I| = 240 * 12 = 2880.

The volt-amperes are obtained also as:

VA= sqrt(P^2 + Q^2)= 2880.

The power factor can be computed by diving the real power of the circuit by the apparent power:

Pf = (P/VA)= 1728/2880 = 0.6.

The phase angle of the current or the phase angle difference between the voltage and the current is obtained by

$\theta$= atan(Q/P) = atan(2304/1728) = 0.9273 rad = 53.13 deg.

The power factor is also defined as the cosine of the phase angle:

Pf = cos($\theta$) = 0.6.

Now consider an RLC parallel circuit as depicted in Fig. 2. The first unknown value to be found will be the current flow through the resistor:
$|I_R| = |E|/R = 240/12 = 20$ A.

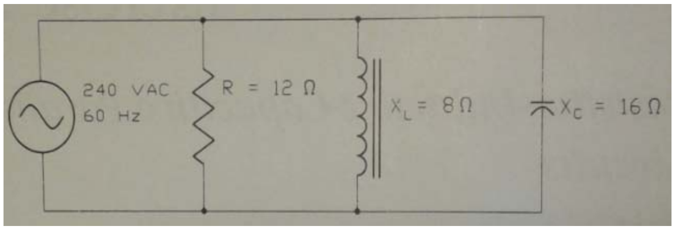



Fig.2. RLC parallel circuit.

The real power, or watts, for the resistor (or the entire circuit) can be computed as:
$P = E_R * |I| = 240 * 20 = 4800$ W.

The magnitude of the current flow through the inductor can be computed as:
$|I_L| = |E|/X_L = 240/8 = 30$ A.

The amount of the reactive power produced by the inductor can be computed as:
$Q_L = |E| * |I_L| = 240 * 30 = 7200$ Var.

The amount of inductance in the circuit can be computed as:
$L = X_L/(2\pi f) = 8/377 = 0.0212$ H

The magnitude of the current flow through the capacitor can be computed as:
$|I_C| = |E|/X_C = 240/16 = 15$ A.

The amount of the capacitive reactive power produced by the capacitor can be computed as:
$Q_c = |E| * |I_C| = 240 * 15 = 3600$ Var.

The amount of capacitance in the circuit can be computed as:
$C = 1/X_C*(2\pi f) = 0.0001658$ F = 165.8 μF.

The net amount of reactive power of the circuit is obtained by the difference between $Q_L$ and $Q_C$:
$Q = Q_L - Q_C = 7200 - 3600 = 3600$ Var

The total current is not the algebraic sum of the currents in the 3 branches - resistor, inductor, and capacitor. Instead, the magnitude of the total current is obtained by:
$|I_T| = \mathrm{sqrt}(|I_R|^2 + (|I_L| - |I_C|)^2)$.

The reason is that $I_R$ is in-phase with the source voltage, but $I_L$ and $I_C$ are 90 degrees lagging and leading, respectively, the voltage.

More specifically, the total impedance (complex impedance, no the magnitude) is:
$1/\mathbf{Z} = 1/R + 1/jX_L - 1/jX_C$
$= 1/12 - j\,1/8 + j\,1/16 = (1/48)(4 - j3)$

Therefore, the equivalent complex impedance is
$\mathbf{Z} = 7.68 + j\,5.76$

Then the total current is obtained by:
$\mathbf{I}_T = \mathbf{E}/\mathbf{Z} = 240/(7.68 + j5.76) = 20 - j15$
$= 25\angle -36.87°$

So the magnitude of the total current is 25 A, and the phase angle of the current is -36.87 deg.

The volt-amps (apparent power) can be computed by multiplying the applied voltage and the circuit current:
$VA = |E| * |I_T| = 240 * 25 = 6000$.

The volt-amperes are obtained also as:
$VA = \mathrm{sqrt}(P^2 + Q^2) = 6000$.

The power factor can be computed by diving the real power of the circuit by the apparent power:
$Pf = (P/VA) = 4800/6000 = 0.8$.

The phase angle of the current or the phase angle difference between the voltage and the current is obtained by
$\theta = \mathrm{atan}(Q/P) = \mathrm{atan}(3600/4800) = 0.6435$ rad = 36.87 deg.

The power factor is also defined as the cosine of the phase angle:
$Pf = \cos(\theta) = 0.8$.

**EXPERIMENT**

1. Connect the circuit shown in Fig. 3. Do not turn on power yet.
2. Set the variable-resistor module for a resistance of 60 Ω, the variable-inductance module for an inductive reactance of 100 Ω, and the variable-capacitance module for a capacitive reactance of 80 Ω.
3. Calculate the complex impedance of the circuit **Z** and the magnitude |Z| using $\mathbf{Z} = R + j(X_L - X_C)$
   **Z**= _______________
   |Z| = _________Ω

4. Turn on the power supply and set the output voltage for a value of 75 V.
5. Measure the amount of current flow in the circuit with the ac ammeter. Compare with the theoretical value of |I| = E/|Z|:

Measure current: ________ A
Theoretical current |I|:_____ A

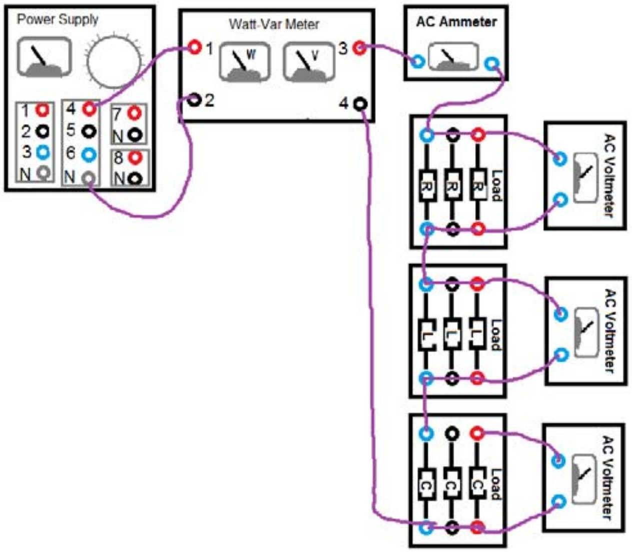



Fig.3. Connecting the RLC series circuit.

6. Measure the voltage drop across each of the elements and compare it with theoretical value:

Measured voltage drop across R: ____ V
Theoretical value $|E_R|=|I|*R$: _____ V

Measured voltage drop across L: ____ V
Theoretical value $|E_L|=|I|*X_L$: _____ V

Measured voltage drop across C: ____ V
Theoretical value $|E_C|=|I|*X_C$: _____ V

7. Measure the real power (W) and the reactive power (Var) and compare with theoretical values by following the processes below:

Measure real power: ________ W
Theoretical value $P=|I|^2 * R$: ______ W

Measure reactive power: _______ Var
Theoretical value $Q=Q_L - Q_C$ where $Q_L=|I|^2*X_L$ and $Q_C=|I|^2*X_C$: _______ Var

8. Turn off the power.

9. Connect the circuit shown in Fig. 4. Do not turn on power yet.

10. Set the variable-resistor module for a resistance of 60 Ω, the variable-inductance module for an inductive reactance of 75 Ω, and the variable-capacitance module for a capacitive reactance of 100 Ω.

11. Calculate the complex impedance of the circuit **Z** and the magnitude |Z| using $1/\mathbf{Z} = 1/R + 1/jX_L - 1/jX_C$ (Correction made)

**Z**= ________________ Z=R+j(XL-XC)
|Z| = __________Ω

12. Turn on the power supply and set the output voltage for a value of 120 V.

13. Measure the amount of current flow through the resistor, inductor, and capacitor in the ac ammeter. Compare with the theoretical values:

Measured current through R: ________ A
Theoretical current $|I_R| = E/R$:_____ A

Measured current through L: ________ A
Theoretical current $|I_L| = E/X_L$:_______ A

Measured current through C: ________ A
Theoretical current $|I_c| = E/X_C$:_____ A

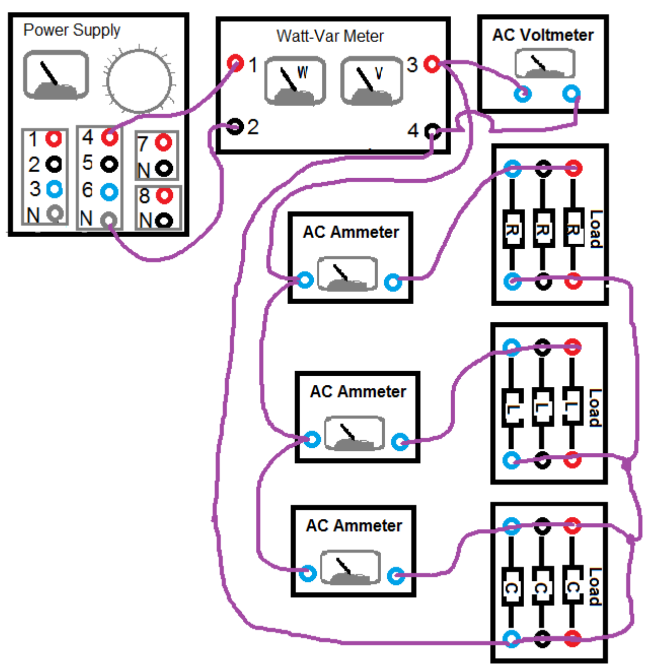



Fig. 4. Connecting the RLC parallel circuit.

14. Turn off the power supply.

15. Reconnect the circuit as shown in Fig 5. Leave the resistance, inductance, and capacitance modules set at the present values.

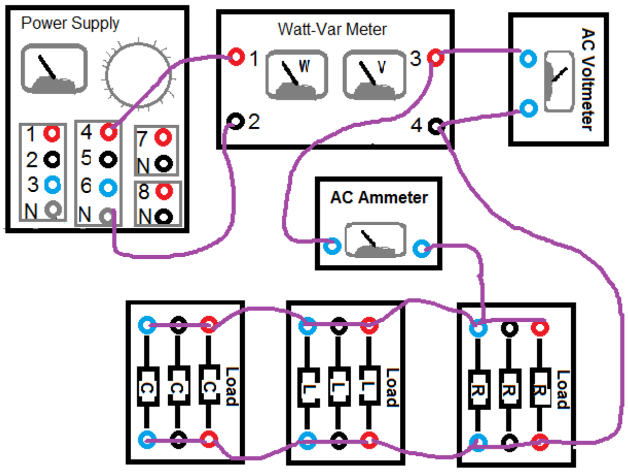



Fig.5. Measuring the total current flow.

16. Turn on the power supply and adjust the voltage for 120 V.

17. Measure the total current in the ac ammeter and compare with the theoretical value:
Measure total current:______ A
Theoretical total current ($|I_T|$=sqrt($|I_R|$^2 + ($|I_L|$-$|I_C|$^2)):________ A

18. Turn off the power supply.

19. We can calculate the total current (not just the magnitude) with the complex impedance of the parallel RLC module. Calculate the equivalent complex impedance Z of the parallel RLC block:

From 1/**Z** = 1/R + 1/j$X_L$ - 1/j$X_C$
**Z**= ________________

From $\mathbf{I}_T$ = E/**Z**, calculate the current:
$\mathbf{I}_T$: ______________
$|I_T|$: ______________A

Compare and discuss the result with those of 17 above.

Discussion: ________________________________
________________________________________

## QUESTIONS AND PROBLEMS

1. An ac circuit has a frequency of 400 Hz. A 16-Ω resistor, a 0.0119-H inductor, and a 16.6-µF capacitor are connected in series. 440V ac voltage is connected to the circuit.

(a) What is the inductive reactance $X_L$?

(b) What is the capacitive reactance $X_C$?

(c) What is the total complex impedance **Z** of the circuit?

(d) What is the total magnitude of the impedance |Z| of the circuit?

(e) How much current will flow in the circuit (complex current **I** = E/**Z**)?

(f) How much voltage (complex voltage) would be dropped across the resistor, inductor, and capacitor?

$\mathbf{E}_R$ =**I***R =

$\mathbf{E}_L$= **I***j$X_L$=

$\mathbf{E}_C$=**I** *(-j$X_C$)=

(g) What is the real power of the circuit (P)?

(h) What is the net reactive power of the circuit (Q)?

(i) What is the apparent power of the circuit (VA)?

(j) What is the power factor of the circuit (pf)?

(k) What is the phase angle of the current (θ)?

2. An ac circuit contains a 24-Ω resistor, a 15.9-mH inductor, and a 13.3-µF capacitor connected in parallel. The circuit is connected to a 240-V, 400-Hz power supply.

(a) What is the inductive reactance $X_L$?

(b) What is the capacitive reactance $X_C$?
(c) Find the current flow through the resistor $\mathbf{I}_R$ = E/R ?

(d) Find the current flow through the inductor $\mathbf{I}_L$ = $E/jX_L$ ? (complex current, not the magnitude)

(e) Find the current flow through the inductor $\mathbf{I}_C$ = $E/-jX_C$ ? (complex current, not the magnitude)

(f) Find the equivalent complex impedance of the circuit **Z**.

(g) Find the total current (complex) $\mathbf{I}_T = E/\mathbf{Z}$.

(h) What is the real power of the circuit (P)?

(i) What is the net reactive power of the circuit (Q)?

(j) What is the apparent power of the circuit (VA)?

(k) What is the power factor of the circuit (pf)?

(l) What is the phase angle of the total current ($\theta$)?