Measurement of Power in R-L-C series circuit

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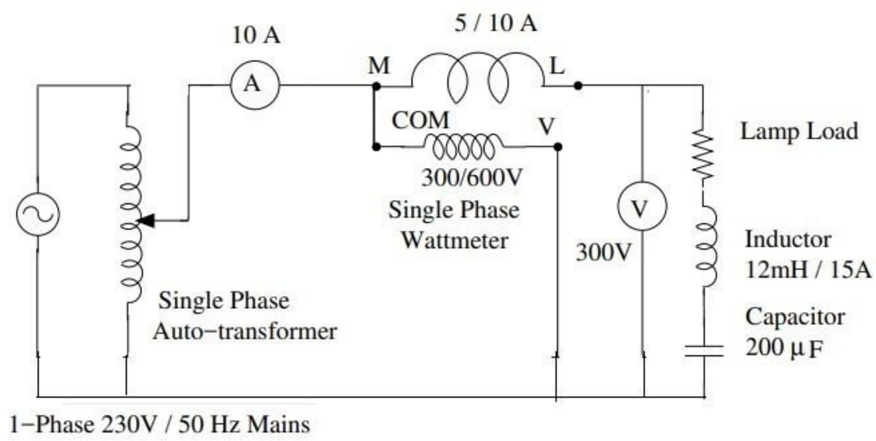
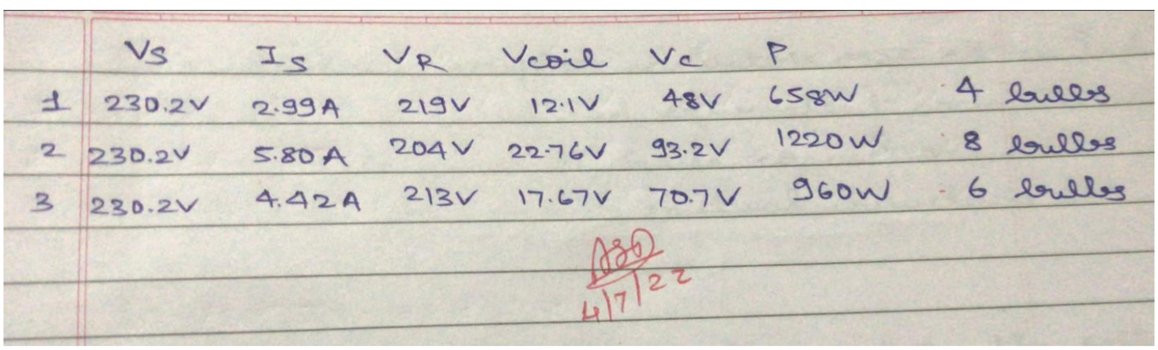
CIRCUIT DIAGRAM:



OBSERVATION TABLE:

Sr. No.	**V_S (V)**	**I_S(A)**	**V_R(V)**	**V_{coil}(V)**	**V_C(V)**	**Active Power (P) (Watts)**	**No. of ON bulbs**
1	230.2	2.99	219	12.1	4.8	658	4
2	230.2	5.80	204	22.76	93.2	1220	8
3	230.2	4.42	213	17.67	70.7	960	6



	Vs	Is	VR	Vcoil	Vc	P	
1	230.2V	2.99A	219V	12.1V	4.8V	658W	4 bulbs
2	230.2V	5.80 A	204V	22.76V	93.2V	1220W	8 bulbs
3	230.2V	4.42A	213V	17.67V	70.7V	960W	6 bulbs

4/7/22

CALCULATIONS:

Useful formulae:

Apparent power $S= V_S*I_S$

Power Factor=P/ S

Total circuit impedance $Z_S=V_S/I_S$

Coil impedance $Z_{coil}=V_{coil}/I_S$

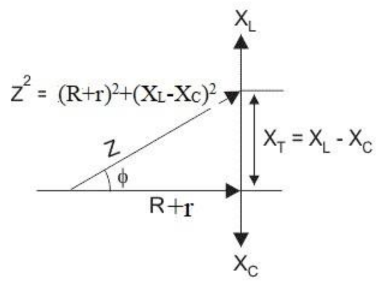
Resistance of Lamp load $R=V_R/I_S$

Capacitive reactance $X_C=V_C/I_S$

The parameters of the circuit can be obtained by solving following two equations:

$Z_{S}^2=(R+r)^2+(X_L-X_C)^2$ and $Z_{coil}^2=r^2+X_L^2$

Impedance Triangle (For $X_L>X_C$)



EXPERIMENT No: 5 **DATE: 04 / 07 / 2022**

Measurement of power in R-L-C series circuit

AIM: 1) To obtain different types of power in R-L-C series circuit.

2) To verify the parameters used in the circuit with the help of the readings taken and vector diagram.

APPARATUS AND COMPONENTS REQIRED:

Single phase auto-transformer (10A), Ammeter (0-10A), Wattmeter (10A/300V), Voltmeter (0-300V), Lamp-load, Inductors (12mH/10A), Capacitors (200µF), connecting wires.

THEORY: Write theory related with following questions:

1) Explain the behavior of series R-L-C circuit when single phase ac supplied is passed through it. Draw vector diagram for the same.
2) What is true, imaginary, and apparent power? Explain its significance.

PROCEDURE:

1) Connect the circuit as shown in the circuit diagram.
2) Adjust V_S=230 V using auto transformer. Note down readings of ammeter (I_S) and wattmeter (P). Also measure V_R, V_L and V_C using multimeter.
3) Calculate apparent power S.
4) Obtain power factor from S and P.
5) Calculate resistance of lamp load R, resistance of coil r, reactance X_L and X_C.
6) Obtain L and C from X_L and X_C respectively.

7) Vary the load (Change the number of on bulbs).
8) Repeat steps 3) to 6).
9) Draw phasor diagram.

Behavior of series R-L-C circuit when single phase ac supplied is passed:

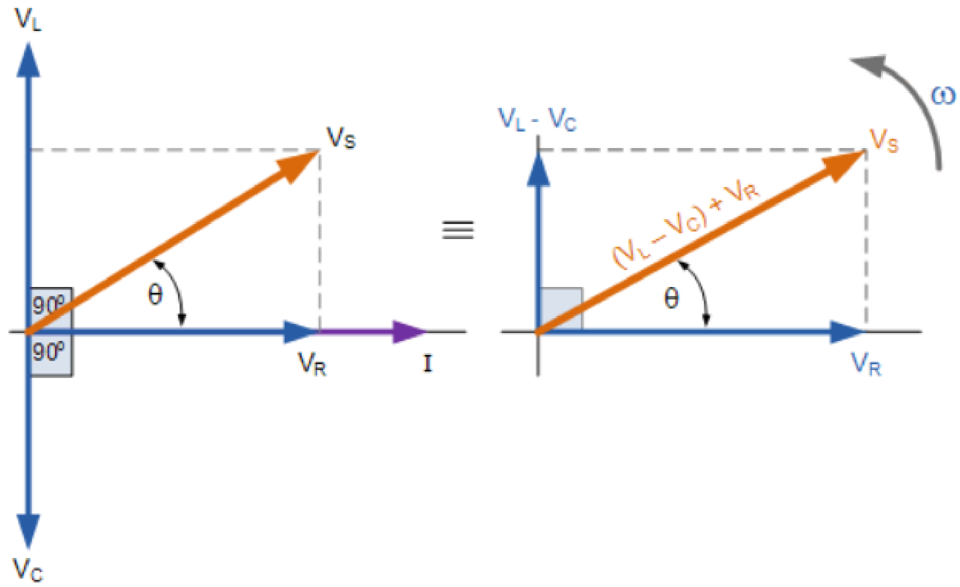
Resistance, *Inductance*, and *Capacitance* have very different phase relationships to each other when connected to a sinusoidal alternating supply.

In a pure ohmic resistor the voltage waveforms are "in-phase" with the current. In a pure inductance the voltage waveform "leads" the current by 90^0, giving us the expression of: ELI. In a pure capacitance the voltage waveform "lags" the current by 90^0, giving us the expression of: ICE.

This Phase Difference, Φ depends upon the reactive value of the components being used and hopefully by now we know that reactance, (X) is zero if the circuit element is resistive, positive if the circuit element is inductive and negative if it is capacitive thus giving their resulting impedances as:

Circuit Element	Resistance, (R)	Reactance, (X)	Impedance, (Z)
Resistor	R	0	$Z_R = R$ $= R\angle 0^0$
Inductor	0	ωL	$Z_L = j\omega L$ $= \omega L \angle +90^0$
Capacitor	0	$\frac{1}{\omega C}$	$Z_C = \frac{1}{j\omega C}$ $= \frac{1}{\omega C}\angle -90^0$

Impedances of R, L and C components



Phasor Diagram

True Power: In an AC circuit, true power is the actual power consumed by the equipment to do useful work. It is distinguished from apparent power by eliminating the reactive power component that may be present.

The true power is measured in watts and signifies the power drawn by the circuit's resistance to do useful work. In a single phase system, the true power;

$$P = VI \cos \Phi$$

Other names that refer to True Power are, real power, actual power Useful power, or Watt-full power.

Imaginary Power: We know that reactive loads such as inductors and capacitors dissipate zero power, yet the fact that they drop voltage and draw current gives the deceptive impression that they actually do dissipate power.
This "phantom power" is called reactive power, and it is measured in a unit called Volt-Amps-Reactive (VAR), rather than watts.
The mathematical symbol for reactive power is the capital letter Q.

Apparent Power: The combination of reactive power and true power is called apparent power, and it is the product of a circuit's voltage and current, without reference to phase angle.

Apparent power is measured in the unit of Volt-Amps (VA) and is symbolized by the capital letter S.

CALCULATIONS:

1) $V_s = 230.2\ V$ (4 bulbs ON)

$I_s = 2.99\ A$

$V_R = 219\ V$

$V_{coil} = 12.1\ V$

$V_c = 48\ V$

Active power $(P) = 658\ W$

$$S = V_s \times I_s = 230.2 \times 2.99$$
$$= 688.298\ VA$$

$$p.f. = \frac{P}{S} = \frac{658}{688.298} = 0.956$$

$$Z_s = V_s / I_s = 230.2 / 2.99 = 76.99\ \Omega$$

$$Z_{coil} = \frac{V_{coil}}{I_s} = \frac{12.1}{2.99} = 4.05\ \Omega$$

$$R = \frac{V_R}{I_s} = \frac{219}{2.99} = 73.24\ \Omega$$

$$X_c = \frac{V_c}{I_s} = \frac{48}{2.99} = 16.05\ \Omega$$

$$Z_{coil}^2 = r^2 + X_L^2$$
$$(4.05)^2 = r^2 + X_L^2$$
$$16.4 = r^2 + X_L^2$$
$$r = \sqrt{16.4 - X_L^2} \quad \text{——} \quad (1)$$

$$Z_s^2 = (R + r)^2 + (X_L - X_c)^2$$
$$5927.46 = \left(73.24 + \sqrt{16.4 - X_L^2}\right)^2 + (X_L - 16.05)^2$$

— from (1)

$$5927.46 = 5364.1 + 16.4 - \cancel{X_L^2} + 146.48\sqrt{16.4 - x_L^2} + \cancel{X_L^2} - 32.1X_L + 257.6$$

$$(289.36 + 32.1X_L)^2 = \left(146.48\sqrt{16.4 - X_L^2}\right)^2$$

$$83729.21 + 18576.91X_L + 1030.41X_L^2 = 21450.53(16.4 - X_L^2)$$

$$-268059.48 + 18576.91X_L + 22480.94X_L^2 = 0$$

$$X_L = 3.06\ \Omega \quad \text{———} \quad (2)$$

from (1) & (2)

$$r = \sqrt{16.4 - (3.06)^2}$$

$$r = 2.65\ \Omega$$

$$Q = S\sin\phi = 688.298\sqrt{1 - (0.956)^2}$$
$$= 201.924\ \text{VAR}$$

$$X_L = \omega L$$

$$L = \frac{X_L}{\omega} = \frac{X_L}{2\pi\nu} = \frac{3.06}{2\pi(50)} = 9.74\times10^{-3}\ \text{H}$$

$$X_c = \frac{1}{\omega C}$$

$$C = \frac{1}{X_c\omega} = \frac{1}{X_c 2\pi\nu} = \frac{1}{16.05\times2\pi\times50}$$

$$C = 1.98\times10^{-4}\ \text{F}$$

2) $V_s = 230.2\,V$ (8 bulbs ON)

$I_s = 5.80\,A$

$V_R = 204\,V$

$V_{coil} = 22.76\,V$

$V_c = 93.2\,V$

Active power $(P) = 1220\ W$

$$S = V_s \times I_s = 230.2 \times 5.80 = 1335.16\ VA$$

$$p.f = \frac{P}{S} = \frac{1220}{1335.16} = 0.9137$$

$$Z_s = V_s / I_s = 230.2/5.80 = 39.6896\,\Omega$$

$$Z_{coil} = \frac{V_{coil}}{I_s} = \frac{22.76}{5.80} = 3.924\,\Omega$$

$$R = \frac{V_R}{I_s} = \frac{204}{5.80} = 35.1724\,\Omega$$

$$X_c = \frac{V_c}{I_s} = \frac{93.2}{5.80} = 16.0689\,\Omega$$

$$Z_{coil}^2 = r^2 + X_L^2$$

$$(3.924)^2 = r^2 + X_L^2$$

$$X_L = \sqrt{15.397 - r^2} \quad \text{—— (1)}$$

$$Z_s^2 = (R+r)^2 + (X_L - X_c)^2$$

$$(39.6896)^2 = (35.1724 + r)^2 + (X_L - 16.0689)^2$$

$$1575.264 = 1237.097 + 70.3448\,r + r^2$$

$$+ 15.397 - r^2 - 32.1378\sqrt{15.397 - r^2} + 258.209$$

—— from (1)

$$64.561 = 70.3448\, r - 32.1378\sqrt{15.397 - r^2}$$

$$32.1378\sqrt{15.397 - r^2} = 70.3448\, r - 64.561$$

$$15902.609 - 1032.838\, r^2 = 4948.390\, r^2 - 9083.061\, r + 4168.1227$$

$$5981.228\, r^2 - 9083.061\, r - 11734.4863 = 0$$

$$r = 2.35 \quad \text{—— (2)}$$

from (1) & (2)

$$X_L = \sqrt{15.397 - (2.35)^2}$$

$$X_L = 3.14\ \Omega$$

$$Q = S\sin\phi = 1335.16\sqrt{1 - (0.937)^2}$$

$$Q = 542.595\ \text{VAR}$$

$$X_L = \omega L$$

$$L = \frac{X_L}{\omega} = \frac{X_L}{2\pi\nu} = \frac{3.14}{2\times\pi\times 50}$$

$$L = 9.99\times 10^{-3}\ \text{H}$$

$$X_c = \frac{1}{\omega C}$$

$$C = \frac{1}{X_c\,\omega} = \frac{1}{X_c\, 2\pi\nu}$$

$$= \frac{1}{16.0689\times 2\pi\times 50}$$

$$C = 1.98\times 10^{-4}\ \text{F}$$

3) $V_s = 230.2\,V$

$I_s = 4.42\,A$

$V_R = 213\,V$

$V_{coil} = 17.67\,V$

$V_c = 70.7\,V$

Active power $(P) = 960\,W$

$$S = V_s \times I_s = 230.2 \times 4.42 = 1017.484\ VA$$

$$p.f = \frac{P}{S} = \frac{960}{1017.484} = 0.9435$$

$$Z_s = V_s/I_s = 230.2/4.42 = 52.08\ \Omega$$

$$Z_{coil} = \frac{V_{coil}}{I_s} = \frac{17.67}{4.42} = 3.997\ \Omega$$

$$R = \frac{V_R}{I_s} = \frac{213}{4.42} = 48.19\ \Omega$$

$$X_c = \frac{V_c}{I_s} = \frac{70.7}{4.42} = 15.995\ \Omega$$

$$Z_{coil}^2 = r^2 + X_L^2$$

$$(3.997)^2 = r^2 + X_L^2$$

$$r = \sqrt{15.976 - X_L^2} \quad \text{—— (1)}$$

$$Z_s^2 = (R+r)^2 + (X_L - X_c)^2$$

$$(52.08)^2 = (48.19 + r)^2 + (X_L - 15.995)^2$$

$$2712.3264 = 2322.2761 + 96.38\sqrt{15.976 - x_L^2}$$
$$+ 15.976 - \cancel{x_L^2} + \cancel{x_L^2} - 31.99x_L + 255.84$$

$$118.2343 = 96.38\sqrt{15.976 - x_L^2} - 31.99x_L$$
$$118.2343 + 31.99x_L = 96.38\sqrt{15.976 - x_L^2}$$
$$13979.3497 + 7564.63x_L + 1023.36x_L^2$$
$$= 148402.7319 - 9289.1044x_L^2$$
$$-134423.3822 + 7564.63x_L + 10312.4644x_L^2$$
$$\therefore x_L = 3.26\ \Omega \quad \text{--- (2)}$$

from (1) & (2)
$$r = \sqrt{15.976 - (3.26)^2}$$
$$r = 2.31\ \Omega$$

$$Q = S\sin\phi = 1017.484\sqrt{1 - (0.9435)^2}$$
$$= 337.166\ \text{VAR}$$

$$x_L = \omega L$$
$$L = \frac{x_L}{\omega} = \frac{3.26}{2\pi(50)} = 10.37 \times 10^{-3}\ \text{H}$$

$$x_c = \frac{1}{\omega C}$$

$$C = \frac{1}{x_c\omega} = \frac{1}{15.995 \times 2\pi \times (50)}$$
$$= 1.99 \times 10^{-4}\ \text{F}$$

RESULT:

Parameter	R	r	L	C	P	Q	S	Power Factor
Is=2.99A	73.24	2.65	$9.74*10^{-3}$	$1.98*10^{-4}$	658	201.924	688.298	0.956
Is=5.80A	35.1724	2.35	$9.99*10^{-3}$	$1.98*10^{-4}$	1220	542.595	1335.16	0.9137
Is=4.42A	48.19	2.31	$10.37*10^{-3}$	$1.99*10^{-4}$	960	337.166	1017.484	0.94

CONCLUSION:

In this experiment we learnt about the various components of R-l-C circuit mainly resistance, inductance & capacitance. We studied their behaviour & impact when single phase AC is supplied. We learnt that power factor depends on impedance & from that we studied true, imaginary & apparent power. We also simulated the circuit.