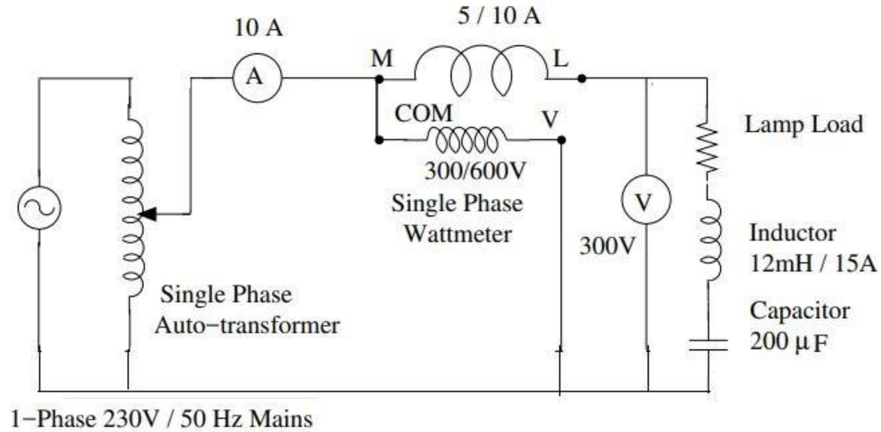
# Measurement of Power in R-L-C series circuit

**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) |
|---|---|---|---|---|---|---|
| 1 | 230.1V | 1.54A | 229.7V | 6.23V | 24.86V | 353.4W |
| 2 | 230.1V | 3.05A | 224.7V | 12.7V | 48.8V | 693.3W |
| 3 | 230.1V | 3.81A | 223.2 | 15.69V | 60.8V | 858.3W |

**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 $Z_{coil}=V_{coil}/I_S$

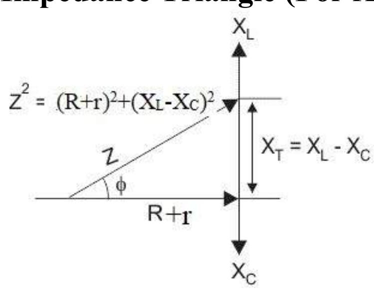
Resistance of Lamp load $R=V_R/I_S$

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 $X_L>X_C$)**



| | Sr No. | $V_S$ (V) | $I_S$(A) | $V_R$(V) | $V_{coil}$(V) | $V_C$(V) | Active Power (P) watt |
|---|---|---|---|---|---|---|---|
| (2 bulbs) | 1 | 230.1 | 1.54 | 229.7 | 6.23 | 24.86 | 359.4 |
| 4 bulbs | 2 | 230.1 | 3.05 | 224.7 | 12.7 | 48.8 | 693.3 |
| 5 | 3 | 230.1 | 3.81 | 223.2 | 15.67 | 60.8 | 858.3 |

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Calculations :-

- For (2 bulbs) $V_S = 230.1V$ ; $I_S = 1.54A$

1) Apparent power $S = V_S \times I_S = 354.354$ VA
2) Power factor $P/S =$ ~~0.014~~ $0.997$
3) Total circuit Impedence $Z_S = V_S/I_S = 149.415\ \Omega$
4) Coil Impedence $Z_{coil} = \frac{V_{coil}}{I_S} = 4.045\ \Omega$
5) Resistance of lamp load $= R = V_R/I_S = 149.155\ \Omega$
6) Capacitive Reactance $X_C = V_C/I_S = 16.14\ \Omega$

$C = \frac{1}{\omega X_C} = 197.2\ \mu F$

$X_L = ?$ $r = ?$

$Z_S^2 = (R+r)^2 + (X_L - X_C)^2$ —(i) $Z_{coil}^2 = r^2 + X_L^2$ —(ii)

solving (i) & (ii) simultaneously,

$Z_S^2 = (R + \sqrt{Z_{coil}^2 - X_L^2})^2 + (X_L - X_C)^2$

$Z_S^2 = R^2 + 2R(\sqrt{Z_{coil}^2 - X_L^2}) + Z_{coil}^2 \cancel{- X_L^2} \cancel{+ X_L^2} - 2X_LX_C + X_C^2$

$Z_S^2 = R^2 + 2R(\sqrt{Z_{coil}^2 - X_L^2}) + Z_{coil}^2 - 2X_LX_C + X_C^2$

$22324.84 = 22247.214 + 16.36 - 32.28X_L + 260.50 + 298.31(\sqrt{16.36 - X_L^2})$

$-199.233 = -32.28X_L + 298.31(\sqrt{16.36 - X_L^2})$

$32.28X_L - 199.233 = 298.31(\sqrt{16.36 - X_L^2})$

$1041.99X_L^2 - 12862.48X_L + 39693.79 = 88988.86(16.36 - X_L^2)$

$1041.99X_L^2 - 12862.48X_L + 39693.79 = 1455857.75 - 88988.86X_L^2$

~~$90030.85 X_L^2$~~

$90030.85X_L^2 - 12862.48X_L - 1416163.96 = 0$

$X_L = 4.038\ \Omega$ $X_L = -3.895\ \Omega$

but since $X_L$ cannot be negative

$\therefore X_L = 4.038\ \Omega$

$\boxed{L = 0.0128\ H}$

$r = \sqrt{Z_{coil}^2 - X_L^2}$

$= \sqrt{(4.045)^2 - (4.038)^2}$

$\boxed{r = 0.238\ \Omega}$

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Case II :- for (4 bulbs) - { $V_s = 230.1V$ ; $I_s = 3.05A$ }

1) Apparent Power = $V_s \times I_s$ = $230.1 \times 3.05$ = 701.805 VA

2) Power factor ($\phi$) = $P/S$ = 0.98

3) Total circuit Impedance ($Z_s$) = $V_s/I_s$ = $75.44\,\Omega$

4) Total Coil Impedance ($Z_{coil}$) = $V_{coil}/I_s$ = $4.164\,\Omega$

5) Resistance of lamp load ($R$) = $V_R/I_s$ = $73.67\,\Omega$

6) Capacitive Reactance ($X_c$) = $V_c/I_s$ = $16\,\Omega$

$X_L = ?$ $r = ?$

$Z_s^2 = (R+r)^2 + (X_L - X_c)^2$ —(i) ; $Z_{coil}^2 = r^2 + X_L^2$ —(ii)

solving (i) & (ii) simultaneously.

$Z_s^2 = (R + \sqrt{Z_{coil}^2 - X_L^2})^2 + (X_L - X_c)^2$

$Z_s^2 = R^2 + 2R(\sqrt{Z_{coil}^2 - X_L^2}) + Z_{coil}^2 - \cancel{X_L^2} + \cancel{X_L^2} - 2X_LX_c + X_c^2$

$Z_s^2 = R^2 + 2R(\sqrt{Z_{coil}^2 - X_L^2}) + Z_{coil}^2 - 2X_LX_c + X_c^2$

$5691.19 = 5427.27 + 147.34(\sqrt{17.34 - X_L^2}) + 17.34 - 32X_L + 256$

$32X_L - 9.42 = 147.34(\sqrt{17.34 - X_L^2})$

$1024X_L^2 - 602.88X_L + 88.74 = 21709.08(17.34 - X_L^2)$

$\therefore 1024X_L^2 - 602.88X_L + 88.74 = 376435.45 - 21709.08X_L^2$

$\therefore 22733.08X_L^2 - 602.88X_L - 376346.71 = 0$

$\boxed{X_L = 4.082\,\Omega}$ $\boxed{r = 0.822\,\Omega}$

$\boxed{L = 0.0129\,H}$ $\boxed{C = 198.9\,\mu F}$

Case III :- for (5 bulbs) - { $V_s = 230.1V$ ; $I_s = 3.81A$ }

1) Apparent Power = $V_s \times I_s$ = $230.1 \times 3.81$ = 876.681 VA

2) Power factor ($\phi$) = $P/S$ = 0.979

3) Total circuit Impedence ($Z_s$) = $V_s/I_s$ = $60.393\,\Omega$

4) Total coil Impedence ($Z_{coil}$) = $V_{coil}/I_s$ = $4.118\,\Omega$

5) Resistance of lamp load ($R$) = $V_R/I_s$ = $58.582\,\Omega$

6) Capacitive Reactance ($X_c$) = $V_c/I_s$ = $15.958\,\Omega$

$X_L = ?$ $r = ?$

$Z_s^2 = (R+r)^2 + (X_L - X_c)^2$ —(i) ; $Z_{coil}^2 = r^2 + X_L^2$ —(ii)

solving (i) & (ii) simultaneously.

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$$Z_s^2 = \left(R + \sqrt{Z_{coil}^2 - X_L^2}\right)^2 + (X_L - X_C)^2$$

$$Z_s^2 = R^2 + 2R\left(\sqrt{Z_{coil}^2 - X_L^2}\right) + Z_{coil}^2 - \cancel{X_L^2} + \cancel{X_L^2} - 2X_LX_C + X_C^2$$

$$Z_s^2 = R^2 + 2R\left(\sqrt{Z_{coil}^2 - X_L^2}\right) + Z_{coil}^2 - 2X_LX_C + X_C^2$$

$$3647.314 = 3431.85 + 117.164\left(\sqrt{16.958 - X_L^2}\right) + 16.958 - 31.916X_L + 254.658$$

$$31.916X_L - 56.152 = 117.164\left(\sqrt{16.958 - X_L^2}\right)$$

$$(31.916X_L - 56.152)^2 = 13727.4(16.958 - X_L^2)$$

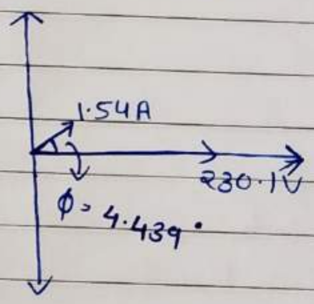
$$1018.631X_L^2 - 3584.294X_L + 3153.047 = 232789.249 - 13727.4X_L^2$$

$$14746.031X_L^2 - 3584.294X_L - 229636.202 = 0$$

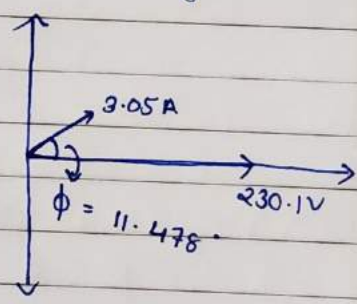
$\boxed{X_L = 4.069\ \Omega}$ $\boxed{r = 0.233\ \Omega}$

$\boxed{L = 0.0129\ H}$ $\boxed{C = 199.46\ \mu F}$

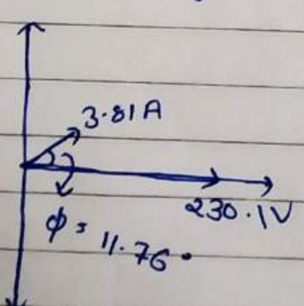
Phasor diagram ①




Phasor diagram (case II)




Phasor diagram (case-III)



**NAME: Pranay Singhvi EXPERIMENT No: 5 DATE: 5/7/ 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.

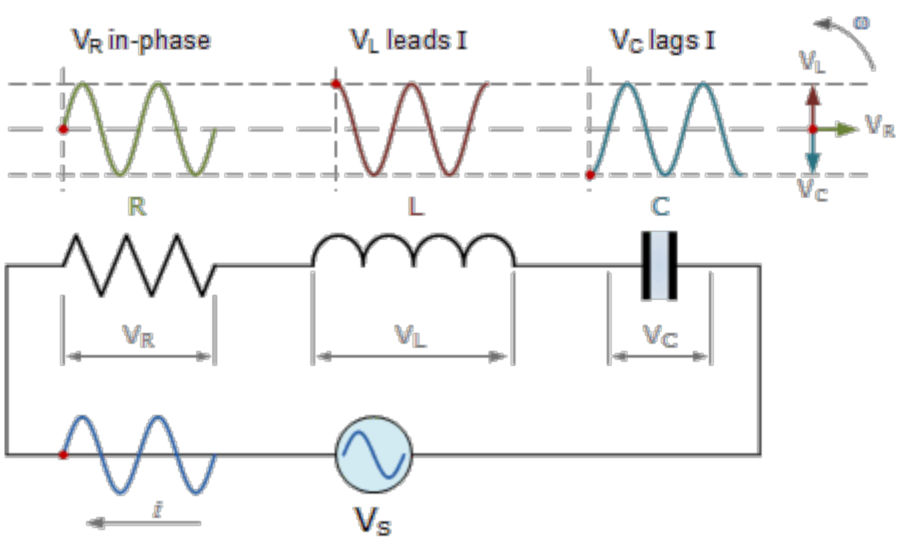
**THEORY: Write theory related with following questions:**

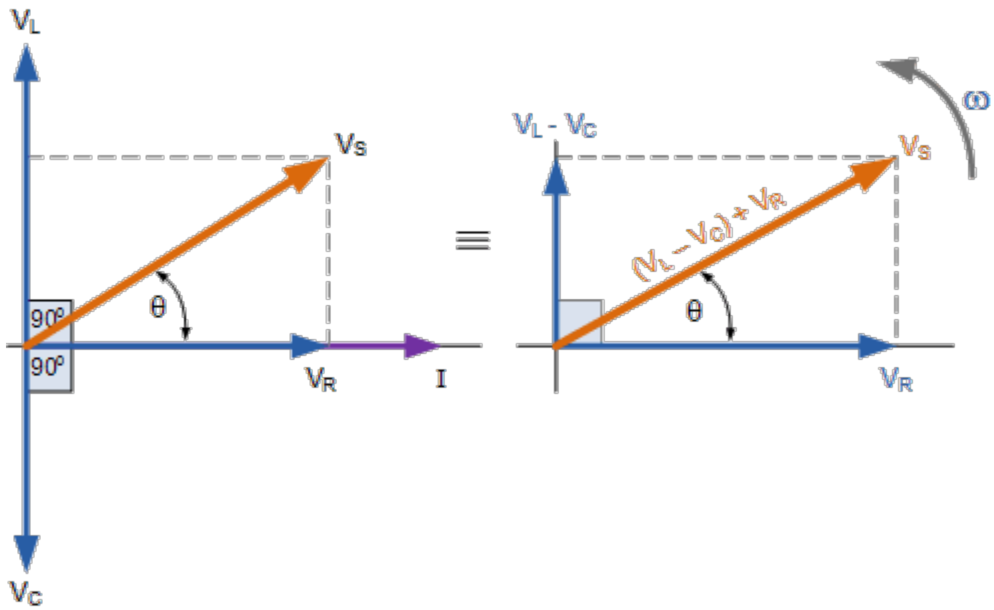
1) Explain the behavior of series R-L-C circuit when single phase ac supplied is passed through it. Draw vector diagram for the same.

ANS: The series RLC circuit above has a single loop with the instantaneous current flowing through the loop being the same for each circuit element. Since the inductive and capacitive reactance's $X_L$ and $X_C$ are a function of the supply frequency, the sinusoidal response of a series RLC circuit will therefore vary with frequency, ƒ. Then the individual voltage drops across each circuit element of R, L and C element will be "out-of-phase" with each other as defined by:

- $i_{(t)} = I_{max} \sin(\omega t)$
- The instantaneous voltage across a pure resistor, $V_R$ is "in-phase" with current
- The instantaneous voltage across a pure inductor, $V_L$ "leads" the current by $90^o$
- The instantaneous voltage across a pure capacitor, $V_C$ "lags" the current by $90^o$
- Therefore, $V_L$ and $V_C$ are $180^o$ "out-of-phase" and in opposition to each other.

For the series RLC circuit above, this can be shown as:






2) What is true, imaginary, and apparent power? Explain its significance.
ANS: 1. TRUE POWER: The actual amount of power being used, or dissipated, in a circuit is called *true power*, and it is measured in watts (symbolized by the capital letter P, as always).
2. IMAGINARY POWER: It is the part of complex power that corresponds to storage and retrieval of
energy rather than consumption. Imaginary power provides the important function of regulating voltage.
3. APPARENT POWER: Apparent power is a measure of alternating current (AC) power that is computed by multiplying the root-mean-square (rms) current by the root-mean-square voltage. It is the apparent power seen to be consumed by the circuit.

**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.

**RESULT:**

| **Parameter** | **R** | **r** | **L** | **C** | **P** | **Q** | **S** | **Power Factor** |
|---|---|---|---|---|---|---|---|---|
| **Is=1.54A** | 149.155ohm | 0.238 ohm | 12.8 millihenry | 197.2 microfarad | 353.4 W | 25.984 VAR | 354.354 VA | 0.997 |
| **Is= 3.05A** | 73.67 ohm | 0.322 ohm | 12.9 millihenry | 198.9 microfarad | 673.3 W | 197.983 VAR | 701.805 VA | 0.98 |
| **Is= 3.81A** | 58.582 ohm | 0.233 ohm | 12.9 millihenry | 199.46 microfarad | 858.3 W | 178.579 VAR | 876.681 VA | 0.979 |

**CONCLUSION:**

From this experiment we learnt about series RLC circuit and what are the behaviour of the circuit connection to an AC source. We learnt about Real and complex power and also the lagging and leading property of current in inductive and capacitive circuit respectively.