Course Name:	**Elements of Electrical and Electronics Engineering Laboratory**	**Semester:**	**I**
Date of Performance:	**12/11/2024**	**Batch No:**	**C5-3**
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Faculty Sign & Date:		**Grade/Marks:**	**/ 20**

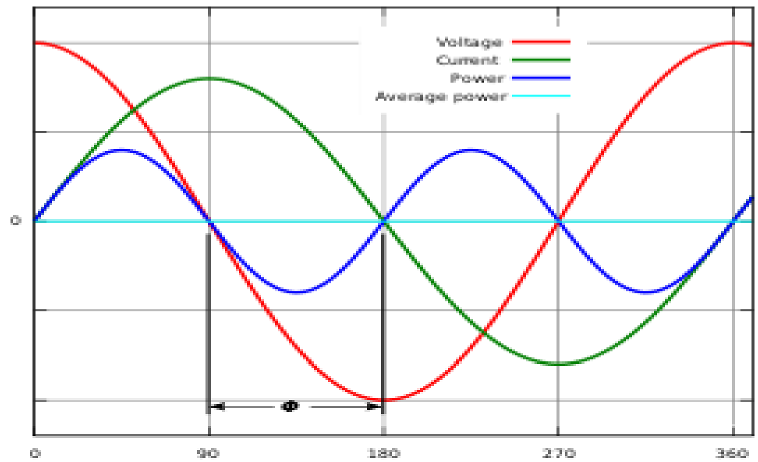
Experiment No: 5
Title: Power factor improvement (series)

Aim and Objective of the Experiment:
To improve power factor of a single phase inductive AC circuit using capacitor in series with it.

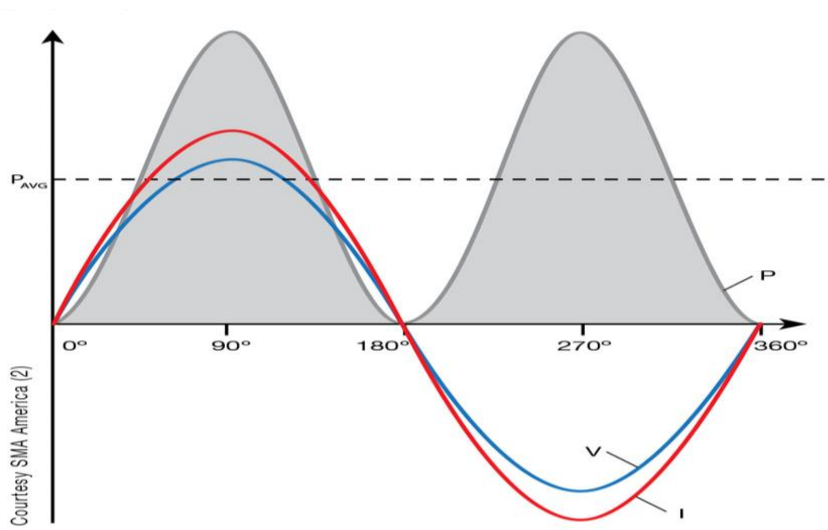
Requirements:
Inductor box, 1 KΩ-3W Resistor, Capacitor box, AC Ammeter and AC Voltmeter.

COs to be achieved:
CO2: Demonstrate and analyze steady state response of single phase and three phase circuits

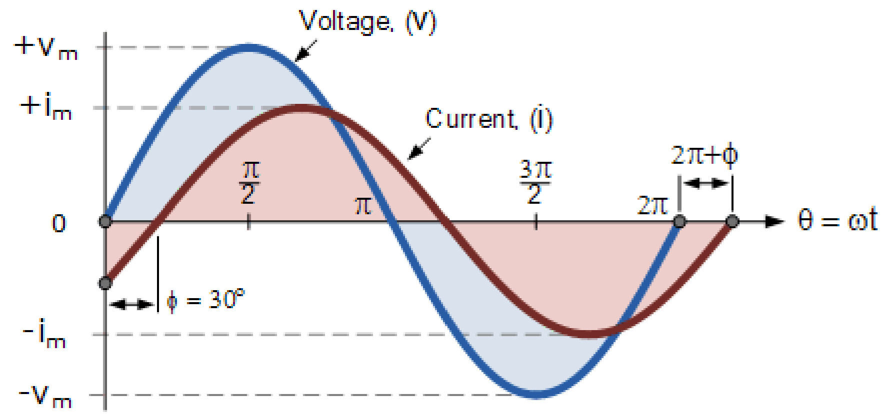
Theory:
When we need to convert electrical energy to mechanical energy, electric motors are used for it. These AC motors converts electric energy in two forms namely mechanical energy in the form of rotary motion and other is magnetic field. Magnetizing currents are lagging to the supply voltage. This magnetic energy is not a mechanical energy so it is kind of wastage, but without which motor will not run and convert electric energy into mechanical energy. Such form of energy is called as reactive power. Reactive power must be as less as possible so that the load will utilize maximum power and current requirement will be less for the same amount power. As the current requirement is less, so wire thickness will be small in diameter. Installation cost and energy cost will be also reduced. To reduce reactive power of the circuit, different power factor improvement methods are used. One of the most familiar methods is the use of capacitor bank. We can use capacitor in series with the load or across the load. Following diagrams are illustrating effect of PF on active power.



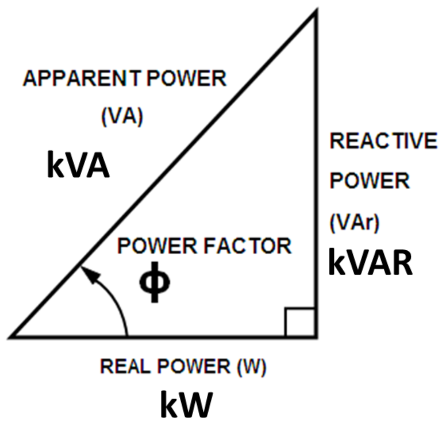
In the above figure instantaneous and average power calculated from AC voltage and current with a zero power factor. The blue line shows all the power is stored temporarily in the load during the first quarter cycle and returned to the grid during the second quarter cycle, so no real power is consumed by the load which is shown by sky-blue colour line.



In the above figure instantaneous and average power calculated from AC voltage and current with a unity power factor. The gray part shows all the power is absorbed in the load during the first half cycle as well as the second half cycle, so real power is fully consumed.



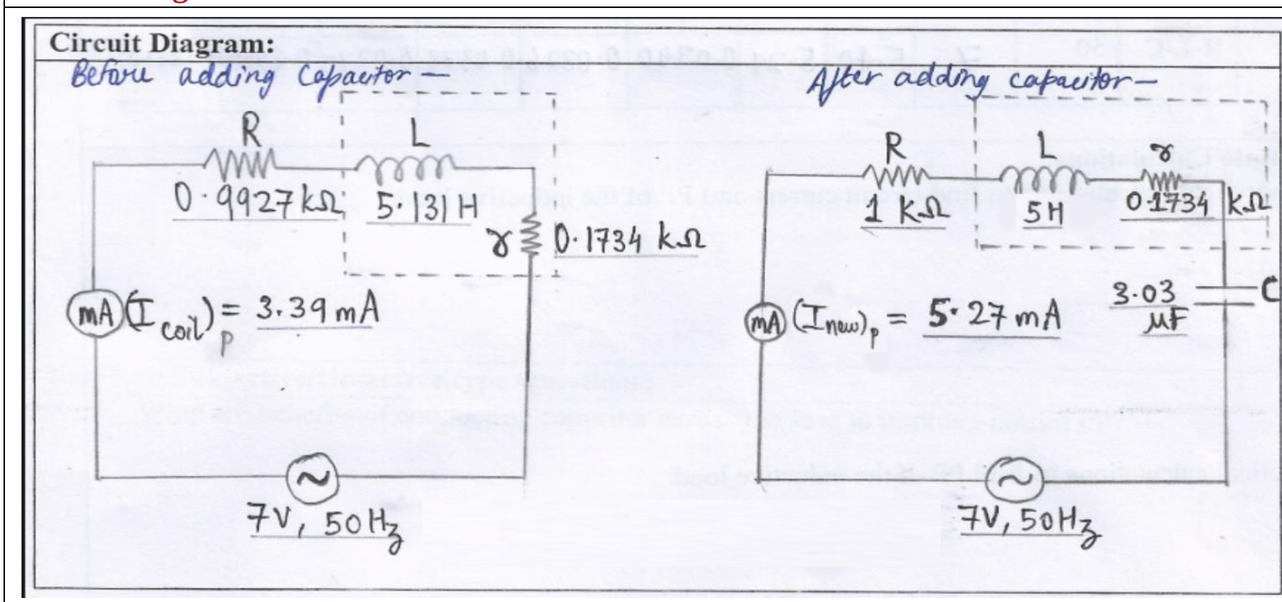
When power factor is between zero and unity, then real power consumed by the load depends upon PF of the circuit. Greater the power factor is always better to consume power.



$$\text{Power Factor} = \frac{\text{True Power}}{\text{Apparent Power}}$$

$$\text{Power Factor} = \cos \Phi = \frac{\text{kW}}{\text{kVA}}$$

Circuit Diagram:



Stepwise-Procedure:

1. Connect series R and L circuit across 230V, 1ø, 50 Hz AC supply and note down circuit voltage and current.
2. Calculate practical value of circuit power factor by taking ratio of active power (P) and apparent power (S).
3. Connect required value of capacitor in series with R-L load and switch on power supply to note circuit current.
4. Calculate practical value of circuit power factor by taking ratio of active power (P) and apparent power (S).
5. Compare theoretical and practical values of PF before connecting the capacitor and after connecting capacitor.

Observation Table:

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Sr No	Type of load	Voltage (V)		Current (mA)		P (W)		S (VA)		Power factor	
		Th	Pr	Th	Pr	Th	Pr	Th	Pr	Th	Pr
	R-L	7	7	3.51	3.39	0.01436	0.13340	0.02457	0.02373	0.5846	0.5621
	R-L-C	7	7	5.40	5.29	0.0340	0.0326	0.0378	0.0370	0.8990	0.8810

Sample Calculations:

$R = 0.9927\ k\Omega$
$L = 5.131\ H$
$r = 0.173\ k\Omega$
$I_{coil} = 3.39\ mA$ (Practical)

(I) Theoritical calculations to find circuit current & power factor of inductive load:

(1) I_{coil}: $Z = (R + r) + j(2\pi f L)$
$= (0.9927 + 0.173) + j(2\pi \times 50 \times 5.131)$
$= 1.1657\ k\Omega + j(1612)$
$Z = 1166 + j(1612)$
$\therefore Z = 1989 \angle 54.12$

$\therefore I_{coil} = \frac{V}{Z} = \frac{7}{1989} = 3.51\ mA$ (Theoretical)

(2) Power factor $= \cos(54.12)$
$\therefore p.f. = 0.5860$

(II) Practical calculations to find power factor of inductive load

(1) Power factor: (Practical)
$S = VI$
$= 7 \times 3.39 \times 10^{-3}\ VA$
$S = 0.02373\ VA$ (Practical)

$P = I^2 (R + r)$
$= (3.39 \times 10^{-3})^2 \times 1166$
$P = 0.01334\ W$ (Practical)

Thus, power factor $= \frac{P}{S} = \frac{0.01334}{0.02373} = 0.5621$

power factor ($\cos\phi$) $= 0.5621$ (Practical)

(2) Powerfactor (Theoritical) :

$$S = VI$$
$$= 7 \times 3.51 \times 10^{-3}\ VA$$
$$\Rightarrow S = 0.02457\ VA \quad \text{(Theoritical)}$$

$$P = I^2(R+r)$$
$$= (3.51 \times 10^{-3})^2 \times 1166$$
$$\Rightarrow P = 0.01436\ W \quad \text{(Theoritical)}$$

$$\cos\phi = \frac{P}{S} = \boxed{0.5846} \quad \text{(Theoritical)}$$

(III) Calculations to find value of capacitor to be connected with load

$$Z_n = \frac{(R+r)}{\cos\phi_n} = \frac{1166}{0.9} = 1295.5$$

$$\because \frac{X_L - X_C}{\sin\phi_n} = Z_n$$

$$\therefore X_L = 2\pi f L$$
$$= 2\pi \times 50 \times 5.131$$
$$X_L = 1612\,\Omega$$

$$\therefore \frac{1612 - X_C}{\sin(25.84)} = 1295.5$$

$$\therefore X_C = -[1295.5 \times \sin(25.84)] + 1612$$
$$X_C = 1048\,\Omega$$

$$\therefore C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi \times 50 \times 1048} = 3.03\,\mu F$$

IV) Calculations:

→ $I_N = \frac{V}{Z_n} = \frac{7}{1295} = 5.40$ mA (Theoritical)

→ $I_N = 5.29$ mA (Practical)

a) $S = V \cdot I$

$= 7 \times 5.40 \times 10^{-3}$ VA

⇒ $S = 0.0378$ VA (Theoritical)

b) $S = V \cdot I$

$= 7 \times 5.29 \times 10^{-3}$ VA

⇒ $S = 0.0370$ VA (Practical)

a) $P = I^2 (R + r)$

$= (5.29 \times 10^{-3})^2 \times 1166$

$P = 0.0326$ W (Theoritical)

b) $P = I^2 (R + r)$

$= (5.40 \times 10^{-3})^2 \times 1166$

$P = 0.0340$ W (Practical)

a) Power factor $= \frac{P}{S} = \frac{0.0340}{0.0378} = 0.899$ (Theoritical)

b) Powerfactor $= \frac{P}{S} = \frac{\cancel{0.036}\ 0.0326}{0.0370} = 0.881$ (Practical)

Post Lab Subjective/Objective type Questions:

1. **What are benefits of connecting capacitor across the load to improve circuit PF?**

Ans:

a) Reduced Power Losses: By improving the power factor, the reactive power in the circuit is reduced, which minimizes energy losses in the transmission lines.
b) Lower Apparent Power: With the help of improved power factor, the apparent power drawn by the load, which allows for efficient utilization of the electrical supply system.
c) Improved Voltage Regulation: Adding a capacitor reduces the voltage drop across the supply lines, this maintains stable voltage levels for the load.
d) Increased System Capacity: With reduced reactive power, we can utilize the capacity of the existing system more effectively so that we can power additional loads.
e) Reduced Electricity Costs: Utilities often charge penalties for poor power factors. Improving PF leads to significant cost savings with reduced energy consumption.
f) Enhanced Equipment Lifespan: Reducing stress on generators, transformers, and other components decrease the likelihood of the equipment's overheating; this extends equipment life.

Conclusion:

The above experiment successfully demonstrates the significance of power factor improvement in an electrical circuit. Initially, the circuit exhibited a low power factor, this resulted in higher apparent power, increased current, and inefficient energy utilization. By using a capacitor in series to the load, the reactive power was significantly reduced, leading to a significant improvement in the power factor. This enhancement in power factor directly contributed to reduced apparent power, lower current flow, and minimized power losses in the circuit. Also, the addition of the capacitor stabilized the voltage levels, which helped in reducing the burden on the power supply and optimizing the overall efficiency of the system. Practically, this experiment emphasizes the importance of capacitors in industrial and household applications, ensuring energy savings, cost efficiency, and extended equipment lifespan. It displays the critical role of power factor correction in efficient energy management for household and industrial applications.

Signature of faculty in-charge with Date: