Experiment No

Aim: To determine **Regulation and Efficiency** of a single phase transformer using **open circuit (O.C.) and short circuit (S.C.) tests**

Apparatus: -

Single phase transformer
Single phase dimmer stat
Ammeter (AC)
Voltmeter (AC)
Multi-function meter

THEORY:-

The efficiency and regulation of a transformer on any load condition and at any power factor condition can be predetermined by O.C. and S.C. test. In this method, the actual load is not used on transformer. The equivalent circuit parameters of a transformer are determined by conducting these two tests. The parameters calculated from these test results are effective in determining the efficiency and regulation of a transformer on any load condition and at any power factor condition. The advantage of this method is that without much power loss the tests can be performed and results can be obtained.

Open Circuit Test:

The main purpose of this test is to find the iron loss and no load current which are useful in calculating core loss resistance and magnetizing reactance of the transformer.

In O.C. test primary winding is connected to a.c. supply, keeping secondary open. Sometimes a voltmeter may be connected across secondary as voltmeter resistance is very high & voltmeter current is negligibly small so that secondary is treated as open circuit. Usually low voltage side is used as primary and high voltage side as secondary to conduct O.C. test.

When primary voltage is adjusted to its rated value with the help of variac, readings of ammeter and wattmeter are to be recorded.

Ammeter gives no load current. Transformer no load current is always very small, 2 to 5 % of its full load current.

As secondary is open, $I_2 = 0$, hence secondary copper losses are zero. And $I_1 = I_0$ is very low hence copper losses on primary are also very low. Thus the total copper losses in O.C. test are negligibly small, hence neglected. Therefore the wattmeter reading in O.C. test gives iron losses which remain constant for all the loads.

Short Circuit Test:

The main purpose of this test is to find full load copper loss and winding parameters (Ro_1 &Xo_1 or Ro_2 & Xo_2) which are helpful for finding regulation of transformer.
In this test, secondary is short circuited with the help of ammeter. (secondary may be short circuited with thick copper wire or solid link). As secondary is shorted, its resistance is very very small and on rated voltage it may draw very large current. Such large current can cause overheating and burning of the transformer. **To limit this short circuit current, primary is supplied with low/reduced voltage (5 – 15% of the rated voltage) which is just enough to cause rated current to flow through primary which can be observed on an ammeter.** The reduced voltage can be adjusted with the help of variac. The wattmeter reading as well as voltmeter, ammeter readings are recorded.
As the voltage applied is low which is a small fraction of the rated voltage and iron losses are function of applied voltage, hence iron losses are negligibly small. Since the currents flowing through the windings are rated currents hence the total copper loss is full load copper loss. Hence the wattmeter reading is the power loss which is equal to full load copper losses.

Procedure:

A) O.C. test:

1. Connect the circuit as shown in circuit diagram.
2. Switch on the supply after checking connection by concerned teacher.
3. Increase the input voltage to the transformer winding upto rated value (230V) slowly using dimmer stat.
4. Measure the primary voltage, primary current, primary circuit power and secondary voltage of transformer.
5. Reduce the voltage slowly using variac.
6. Switch off the supply and remove connections.

Procedure:

B) S.C. test: (Do not switch on supply yourself.)

1. Connect the circuit as shown in circuit diagram.
2. **Switch on the supply after checking connection by concerned teacher.**
3. Increase the input voltage very **CAREFULLY** and **SLOWLY** so that the current in secondary winding reaches rated value (8.6A) using dimmer stat.
4. Measure the primary voltage, primary current, primary circuit power and secondary current of transformer.
5. Reduce the voltage slowly using dimmer stat.
6. Switch off the supply and remove connections.

Precaution:

1) Do not put on the supply until the circuit is checked by concerned teacher.
2) Do not touch any live part of circuit.
3) Be careful for primary & secondary winding rated current.

Result & Conclusion:

Discussion Questions

1. What is regulation and efficiency of a transformer?
2. Why is core made from silicon steel alloy and not ordinary steel?
3. Why the core is made from thin laminations and not a solid steel core?
4. Why core losses remain almost constant at any load?
5. What are the advantages and disadvantages of direct loading method over open circuit and short circuit test?
6. Justify-open circuit test gives core losses while short circuit test gives copper losses.
7. Discuss the effect of output power on efficiency and regulation.
8. Why reduced voltage is required for s.c. test?
9. Why s.c. test is generally performed with L.V. side short circuited?
10. Why o.c. test is generally performed on L.V. side.

On LHS by Hand with Pencil

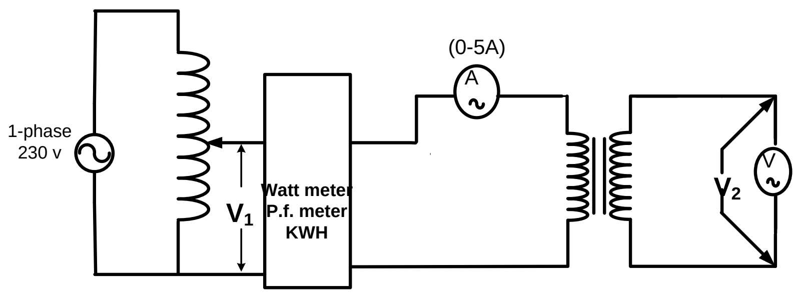
EXPERIMENT NO.

Aim: To determine **Regulation and Efficiency** of a single phase transformer by **open circuit (o.c.) and short circuit (s.c.) tests**

Apparatus:

Sr. No.	Name of Apparatus	Range/Rating	Make
1	Single phase dimmer stat		
2	Ammeter (AC)		
3	Voltmeter (AC)		
4	1-phaseTransformer		
5	Multi-function meter		

Circuit Diagram : open circuit (o.c.) Test

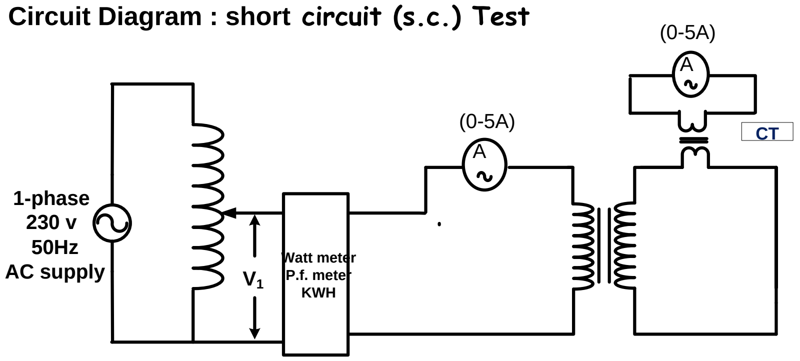


Observation table for open circuit (o.c.) test:-

Sr. No.	Primary rated Voltage V_1 (volts)	No-load current I_0 (Amp)	Wattmeter reading (Iron loss) W_0 (Watts)	Secondary Induced Voltage V_2 (Volts)
1				

On LHS by Hand with Pencil

Circuit Diagram : short circuit (s.c.) Test



Observation table for short circuit (s.c.) test:-

Sr. No.	Primary Voltage V_{sc} (volts)	Primary current I_{1sc} (Amp)	Secondary current I_{2sc} (Amp)	Wattmeter reading W_{sc} (F.L. copper loss) (Watts)
1				

On LHS by Hand with Pencil

Calculations:

From O.C. Test :

$\cos\phi_0 = \dfrac{W_0}{V_1 I_0}$ $\quad I_w = I_o \cos\phi_0$ $\quad I_m = I_o \sin\phi_0$

$R_0 = \dfrac{V_1}{I_0 \cos\phi_o}$ **;** $\quad X_0 = \dfrac{V_1}{I_0 \sin\phi_o}$

From S.C. Test :

$R_{sc} = \dfrac{W_{sc}}{I_1^2 sc}$ $\quad Z_{sc} = \dfrac{V_{sc}}{I_1 sc}$ $\quad X_{sc} = \sqrt{Z_{sc}^{\ 2} - R^2_{sc}}$

$R_{01} = R_{sc}$ $\quad X_{01} = X_{sc}$

$$\%\ Efficiency = \frac{KVA\ \ rating \times 10^3 \times p.f.}{KVA\ \ rating \times 10^3 \times p.f. + Wcu + Wi} \times 100$$ p.f.- load power factor

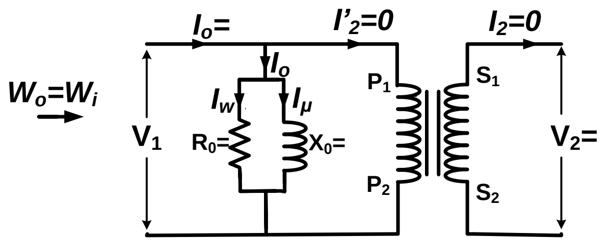
$$\% \operatorname{Re} gulation = \frac{I_1[R_{01}\cos\phi\ \pm X_{01}\sin\phi].}{V_1} \times 100$$

Calculate efficiency & regulation at following load power factor-

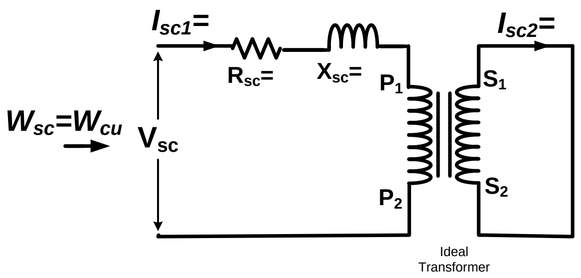
1. At unity p.f.
2. At 0.8 p.f. lagging
3. At 0.8 p.f. leading

On LHS by Hand with Pencil

Equivalent Circuit Diagram from o.c.Test



Equivalent Circuit Diagram from s.c.Test



EXPERIMENT NO.

Aim: To determine **Regulation and Efficiency** of a single phase transformer using **direct loading test.**

Apparatus: -

Single phase dimmer stat, Ammeter (AC), Voltmeter (AC)
Single phase transformer, Wattmeter, Resistive Load Bank

Theory:

This method of calculation of efficiency and regulation of a transformer is entirely different from the determination of efficiency and regulation by o.c. and s.c. test on transformer.

In this method secondary of transformer is connected to load. When secondary is loaded, the secondary current I_2 is set up. The magnitude and phase of I_2 with respect to terminal voltage V_2 depends on the type of load (If load is resistive then I_2 will be in phase with V_2, for inductive load I_2 will lag behind V_2 and for capacitive load it will lead the voltage V_2).

Because of this secondary current I_2, there is a drop in terminal voltage V_2 . Drop in voltage depends on the impedance of load & p.f.

For leading p.f. voltage drop may be negative and for lagging p.f. it is always positive. Since the flux passing through the core is same from no load to full load conditions, core losses remain same and since the copper losses depend on the square of the current, they vary with the current.

Regulation is defined as the ratio of change in terminal voltage from no load to full load to the no load voltage.

$$\text{Regulation} = = \frac{V_2\,(\text{no load}) - V_2\,(\text{full load})}{V_2\,(\text{no load})}$$

Regulation can be found out at any p.f. and at any load current.

Efficiency is defined as the ratio of output power to the input power of the transformer. Efficiency of a transformer varies with power factor at different loads.

$$\eta = \frac{output}{input} = = \frac{V_2 I_2 \cos ø}{V_2 I_2 \cos ø + Wi + Wcu}$$

Cos ø =1 for resistive load**.** W_i = iron loss, W_{cu} =copper loss.

Procedure:-

1) Make the connections as shown in diagram.
2) Keep all the switches of loading rheostat in off position and variac at zero position.
3) Switch on the supply.
4) Apply 230 V to the primary winding.
5) Note down secondary voltage (V_{2NL}) where V_{NL}- No load voltage.
6) Switch on the load and note down all meter readings correctly.
7) Go on increasing the load till the rated secondary current flows up to 8.6 Amp.

Precaution:

1) Do not put on the supply until the circuit is checked by concerned teacher.
2) Do not touch any live part of circuit.
3) Be careful for primary & secondary winding rated current .

Graphs :

1) Output power vs. efficiency
2) Output power vs. regulation.

Result & Conclusion:

Discussion questions:

1) What is regulation and efficiency of a transformer?
2) What are the ranges of efficiency and regulation of a transformer in ideal and practical condition?
3) Why core losses remain almost constant at any load?
4) What is the condition for maximum efficiency? Derive it.
5) Why wattmeter is not used to measure the secondary power or output power in direct loading test?
6) What are the advantages and disadvantages of direct loading method over open circuit (o.c.) and short circuit (s.c.) test?
7) What will happen if the efficiency of a transformer is poor?Explain in terms of losses, loading capacity and cooling requirements.
8) What will happen if the regulation of a transformer is poor? Have you experienced the effect of poor regulation, if yes when and where?

On LHS by Hand with Pencil

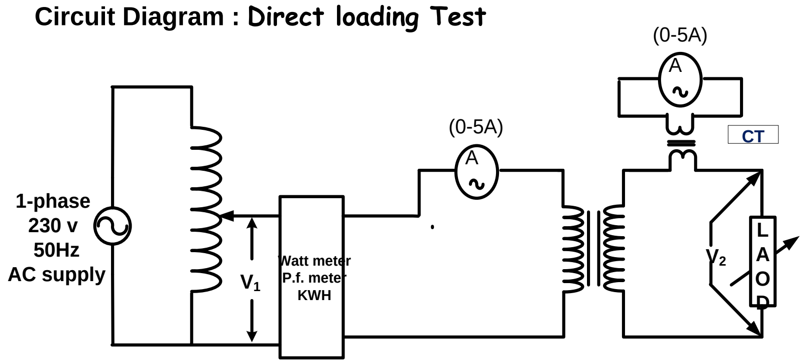
Aim: To determine **Regulation and Efficiency** of a single phase Transformer using **direct loading test.**

Apparatus:

Sr. No.	Name of Apparatus	Range/Rating	Make
1	Single phase dimmer stat		
2	Ammeter (AC)		
3	Voltmeter (AC)		
4	1-phaseTransformer		
5	Multi-function meter		
6	Resistive Load Bank		

Circuit diagram:-

Circuit Diagram : Direct loading Test



Observation table :-

Sr. No.	**Primary voltage V_1**	**Primary current I_1**	**Watt-meter reading W_1**	**Secondary Voltage**	**Secondary current**	**Secondary power**	**% Efficiency**	**% Regulation**
	V_1	I_1	W_1	V_2	I_2	$W_2 = V_2 I_2$	$\%\eta = \frac{W_2}{W_1} \times 100$	$\%\text{Re}gu = \frac{V_{2NL} - V_{2L}}{V_{2NL}} \times 100$
1 2 3 4 5 6 7 8 9	230 volts constant				**0** 8.6			

EXPERIMENT NO.

Aim: To study the balanced three phase system for star & delta connected load.

Apparatus: -

Three phase dimmer stat, Ammeter (AC), Voltmeter (AC)
multi-function meter , rheostats (3-number)

THEORY:-

Any three phase system, either supply system or load can be connected in two ways either star or delta.

(i) **Star Connection→ In** this connection, the starting or termination ends of all winding are connected together & along with their phase ends this common point is also brought out called as neutral point.

(ii) **Delta Connection-** If the terminating end of one winding is connected to starting end of other & If connection are continued for all their windings in this fashion we get closed loop. The three supply lines are taken out from three junctions. This is called as three phase delta connected system.

The load can be connected in similar manner. In this experiment we are concerned with balanced load.

The load is said to be balanced when

i. Voltages across three phases are equal & phases are displaced by 120° electrical.

ii. The impedance of each phase of load is same.

iii. The resulting current in all the three phases are equal & displaced by 120° electrical from each other

iv. Active power & reactive volt amperes of each is equal.

Some term related to 3 ph system

i. **Line Voltage -** The voltage between any two line of 3 ph load is called as line voltage e.g. V_{RY},V_{YB} & V_{BR}.. For balance system all are equal in magnitude.

ii. **Line Current –** The current in each line is called as line current e.g. I_R, I_Y, & I_B. They are equal in magnitude for balance system.

iii. **Phase Voltage –** The voltage across any branch of three phase load is called as phase voltage. $\mathbf{V_{RN}}$**,** $\mathbf{V_{YN}}$**, &** $\mathbf{V_{BN}}$ are phase voltage

iv. Phase **Current –** current passing through any phase of load is called as phase current.

For star connection of load-

Line voltage (V_L) = √3 phase voltage (Vph)

Line current (I_L) = Phase current (Iph)

For delta connection of load-

Line voltage (V_L)= phase voltage (Vph)

Line current (I_L)= √3 phase current(Iph)

Three phase power is given by,

P= power consumed by the load = $\sqrt{3} V_L I_L \cos(\phi)$

Where ϕ is phase angle & it depends on type of load i.e. inductive, capacitive or resistive.

Procedure:

i. Connect circuit as shown in the circuit diagram
ii. Set demmerstat to minimum position.
iii. Switch on the main supply
iv. Note the readings of ammeter, voltmeter & multifunction meter.
v. Note more readings by changing supply voltage.

Commented [s1]:

Result & conclusion:

Discussion questions:-

1. What are the advantages of 3 phase system over single phase system?
2. In case of balanced load, is there any necessity of neutral wire? Why?
3. What should be the consumer load? Star or delta connected? Why?
4. What do you mean by phase sequence of three phase system?
5. If same resistance which were connected in star are connected in delta, what will be the power consumed?
6. Show that for star connection, $V_L = \sqrt{3}$ Vph & for delta connection $I_L = \sqrt{3}$ Iph.
7. With diagram, show how the 3-phase, 4 wire supply from MSEDCL can be distributed to supply power to a 3 story building having one flat on each floor.

On LHS by Hand with Pencil

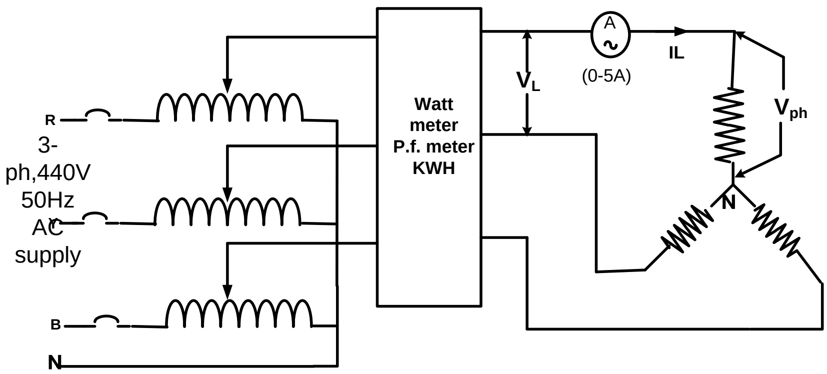
EXPERIMENT NO.

Aim: To study the balanced three phase system for star & delta connected load.

Apparatus: -

Sr. No.	Name of Apparatus	Range/Rating	Make
1	Three phase dimmer stat		
2	Ammeter (AC)		
3	Voltmeter (AC)		
4	Rheostats		
5	Multi-function meter		

Circuit Diagram: A) For star connected load:

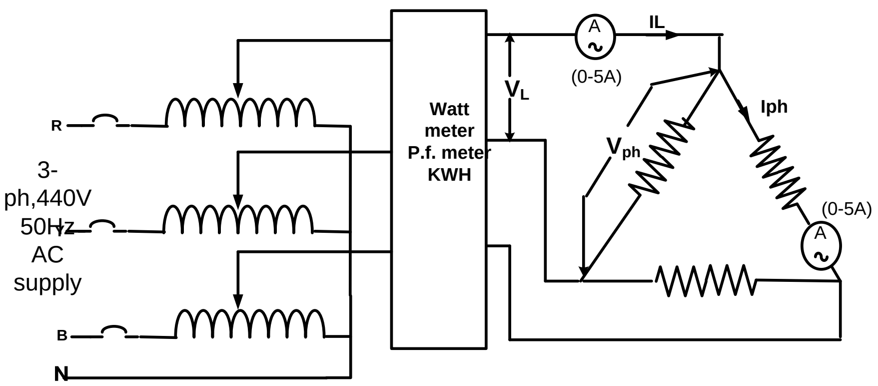


Observation table:- For Star connected load:

Sr No	Line Voltage V_L(volts)	Phase Voltage V_{ph} (volts)	Phase current I_{ph} (Amp)	Ratio of V_L/V_{ph}	Power by calculation $W=\sqrt{3}V_L I_L \cos(\varnothing)$ (watts)
1					
2					
3					

On LHS by Hand with Pencil

Circuit Diagram: B) <u>For Delta connected load:</u>



Observation table:- <u>**For Delta connected load:**</u>

Sr No	**Line Voltage V_L(volts)**	**Line Current I_L (Amp)**	Phase current I_{ph} (Amp)	Ratio of I_L / I_{ph}	Power by calculation W= $\sqrt{3}V_L I_L \cos(\emptyset)$ (watts)
1					
2					
3					

Phasor diagram:

- **Draw phasor diagrams for star and delta balanced connected load.**

EXPERIMENT NO

Aim:-Improvement of the power factor by using static capacitor.

Apparatus:

Single phase dimmerstat
Rheostats
Inductive coil
Capacitor bank
Voltmeters
Ammeters
Multi function meter.

Theory:-

Essentially, power factor is a measurement of how effectively electrical power is being used. The higher the power factor, the more effectively electrical power is being used.

All electrical loads which operate by means of electro-magnetic field effects, such as motors, transformers, fluorescent lighting etc, basically consumes two types of power namely- **active power & re-active power**.

The active power is the power that is used by the load to meet the functional output i.e. the ACTIVE power performs the useful work whereas the REACTIVE power is the power that is used by the load to meet its magnetic field requirements as well as to provide the magnetic losses. Phasor sum of these two power is the power generated by alternators in volt-ampere which is known as **apparent power. Fig1** is known as power triangle.

Three sides of power triangle are-Active power=V*I cos (ϕ)

Re-active power=V*I sin (ϕ)

Apperent power=V*I

With the help of power triangle, **power factor** of an **AC** electrical network/load is defined as the ratio of the active power (real power) flowing to the load to the apparent power in the circuit and is a dimensionless number between **0 and 1**.

Power Factor is a measure of how efficiently electrical power is consumed.

Causes of low power factor: Normally load power factor is of lagging nature due to highly inductive loads. This induction is caused by equipment such as lightly loaded electric motors, transformers, arc lamps, welding equipments and fluorescent lighting ballasts, etc.

Low power factor means over loading the generators, transformers, cables etc. Hence increase in current and copper losses as well as reduction in life of these equipments .Low power factor also causes poor voltage regulation.

Capacitor bank for power-factor improvement-

Loads with low power factor can be improve with a static **capacitors.**

Improving the power factor means reducing the angle of lag between supply voltage and supply current.

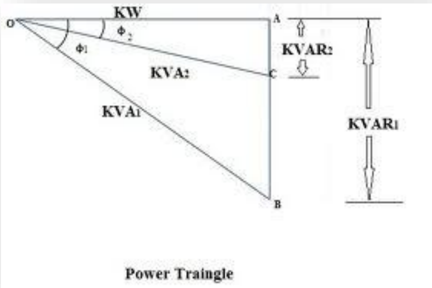


FIG.1

Capacitors are the most cost effective and reliable static devices that can generate and supply re-active power. Capacitors consume virtually negligible active power and are able to produce reactive power, thus known as power factor corrector.

Procedure:-

a) Make the connections as shown in the circuit diagram.
b) Set variac to zero output.
c) Set both rheostats at maximum position.
d) Adjust the variac to give a **150V voltage** to the circuit without capacitor in circuit.
e) Adjust the inductive coil to give 0.6 p.f. lagging in the p.f. meter.
f) Note down the voltage across R, L, C, & Is, $I_{R,}$, I_L& I_c & power factor meter reading without capacitor in circuit.
g) Take different readings for different values of capacitors in circuit & notedown voltages, currents & p.f.meter reading in circuit.

h) Plot the graphs- i) VAr V^s p.f
ii) VAr V^s Source current Is
iii) VAr Vs cable loss (Is^2 Rs)

Precaution: Put ON and OFF capacitor bank switches slowly/carefully.

Result & Conclusion:-

Discussion Questions:-

1. What is power factor?
2. What is active power, re-active power, and apparent power? Write equations of it.
3. What is power triangle?
4. What are the disadvantages of low power factor?
5. Name the apparatus (electrical gadgets) that have poor power factor.
6. Why efficiency of supply system is less with low power factor?
7. What is the range of power factor allowed by power companies (MSEDCL) for industrial loads? Why?
8. What action is taken if power factor is less than or exceeds this range?

On LHS by Hand with Pencil

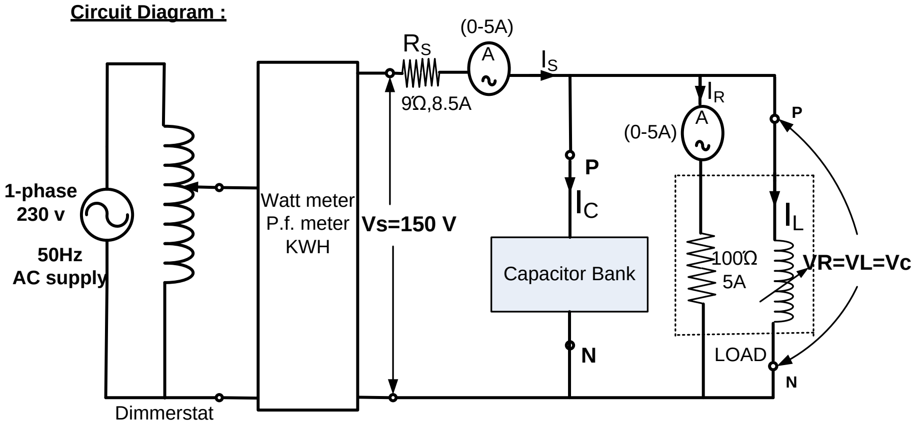
EXPERIMENT NO.

Aim: Improvement of the power factor by using static capacitor.

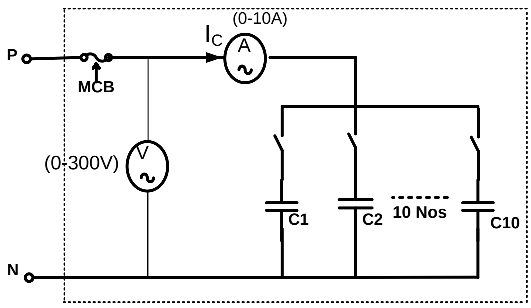
Apparatus:

Sr. No.	Name of Apparatus	Range/Rating	Make
1	Single phase dimmer stat		
2	Ammeter (AC)		
3	Voltmeter (AC)		
4	Rheostats		
5	Inductor		
6	Capacitor bank		
7	Multi-function meter		

Circuit Diagram :



Capacitor Bank



Observation Table

Sr. No.	Vs	Is	IR	IL	Ic	VL=Vc	PF= cos Ø	Nature of p.f. (lag/lead)

Calculation Table:

Sr. No.	**VAr** (CAPACITIVE) **=VcIc**	LOSS IN SUPPLY CABLE=Is^2Rs	APPERENT POWER $=VsIs$	ACTIVE POWER **=VsIs × cos Ø**	REACTIVE POWER **=VsIs × sin Ø**

Graphs- i) VAr V^s^ p.f

ii) VAr V^s^ Source current Is

iii) VAr vs cable loss (Is^2 Rs)