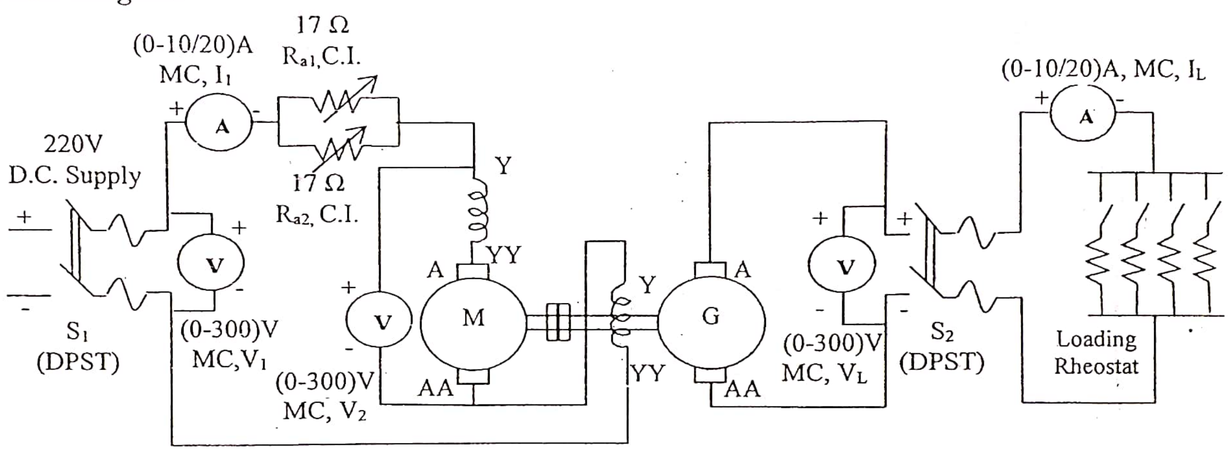
Experiment no.: 6
Field's test

Aim: To conduct the field test on two identical DC series machines to determine their efficiencies.

Apparatus Required:

D.C. Motor- D.C. Generator set		- 01
Ammeter	(0 – 10/20)A, MC	- 02
Voltmeter	(0 - 300)V, MC	- 03
Rheostat	(17 Ω)	- 02
Loading Rheostat		- 01
Tachometer		- 01
Patch cords		- 06
Connecting wires		

Circuit Diagram:



Name plate details	
D.C. Motor	D.C. Generator
P =	P =
V =	V =
I_L =	I_L =
I_f =	I_f =
N =	N =

Procedure:

1. Connections are made as shown in circuit diagram.
2. Keeping the rheostats in cut-in position and with load switch S_2 closed apply 50% load on the generator, then supply switch S_1 is closed.
3. The motor is brought to rated speed (1500 rpm) by cutting out the rheostats simultaneously and by varying the load.
4. The readings of all meters are noted down.
5. The load on the generator is increased in steps and at each step the readings of all the meters are noted down.
6. Finally, the load on generator is decreased to about 50%, the rheostats are brought to original positions and supply switch S_1 & load switch S_2 are opened.
7. Armature resistances of motor (R_{am}) and generator (R_{ag}) are measured across the terminals A-AA using multimeter. Also the series field resistance of the motor (R_{sm}) and that of generator (R_{sg}) are measured across the terminals Y-YY.

…uit diagram.

Tabular Column:

Sl.No.	V_1 Volts	V_2 Volts	I_1 Amps	V_L Volts	I_L Amps	% η_m	% η_g

R_{am} = ________ Ω, R_{ag} = ________ Ω, R_{sm} = ________ Ω, R_{sg} = ________ Ω

Calculations:

P_{in} = Power input to the set $= V_1 \times I_1$ = ________ Watts

P_{out} = Power output $= V_L \times I_L$ = ________ Watts

W_t = Total losses in the set $= P_{in} - P_{out}$ = ________ Watts

W_{cu} = Armature & field copper losses of motor & generator $= (R_{am} + R_{sm} + R_{sg}) \times I_1^2 + (R_{ag} \times I_L^2)$
= ________ Watts

Stray losses per machine $= W_s = \frac{W_t - W_{cu}}{2}$ = ________ Watts

Motor efficiency:

Motor input $= V_2 \times I_1$ = ________ Watts
Motor losses (W_{ml}) $= (R_{am} + R_{sm}) \times I_1^2 + W_s$ = ________ Watts

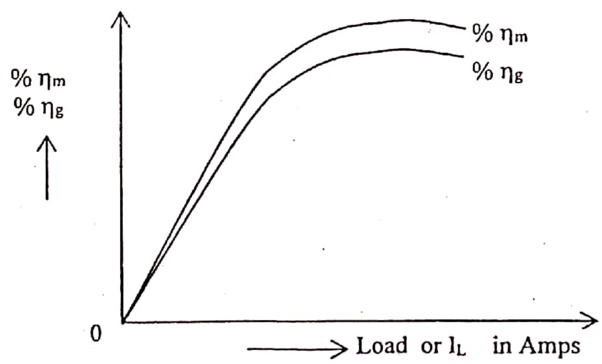
Percentage efficiency of the motor = % η_m $= \frac{(V_2 \times I_1) - W_{ml}}{(V_2 \times I_1)} \times 100$ = ________ %

Generator efficiency:

Generator output $= V_L \times I_L$ = ________ Watts
Generator losses (W_{gl}) $= (R_{sg} \times I_1^2) + (R_{ag} \times I_L^2) + W_s$ = ________ Watts

Percentage efficiency of the generator = % η_g $= \frac{(V_L \times I_L)}{(V_L \times I_L) + W_{gl}} \times 100$ = ________ %

Graph:



Experiment no.: 07

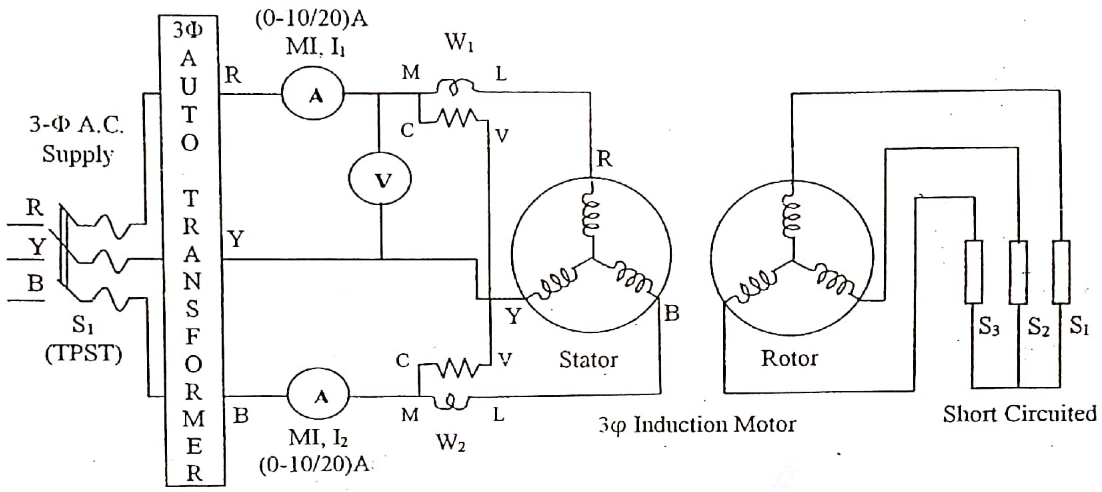
No-Load and Blocked Rotor Test on Three Phase Induction Motor

Aim: To conduct No load and Blocked rotor test on the given three phase induction motor to draw equivalent circuit and circle diagram and hence determine the performance parameters.

Apparatus Required:

3φ Induction Motor		- 01
Ammeter (0 – 10/20)A, MI		- 02
Voltmeter (0 – 150/300/600)V,	MI	- 01
Wattmeter (0 – 10/20)A, 500V, LPF		- 02
Wattmeter (0 – 10/20)A, 250V, UPF		- 02
Patch cords		- 06
Connecting wires		

Circuit Diagram:



For No-Load Test: Wattmeters → W_1 & W_2 : (0 – 10/20)A, 500V, LPF
Voltmeter→ V : (0 – 600)V, MI
For Blocked Rotor Test: Wattmeters → W_1 & W_2 : (0 – 10/20)A, 250V, UPF
Voltmeter→ V: (0 – 150)V, MI

Name plate details		
3 φ Induction Motor		
Power =	f =	N =
V_L =	P = Poles =	
Stator Current (I_s) =	Rotor Current (I_r) =	

Procedure:

No-Load test:

1. Connections are made as shown in the circuit diagram.
2. Keeping the 3-φ autotransformer in zero output position, the supply switch S_1 is closed.
3. With the help of 3-φ autotransformer, the input voltage to the stator is gradually increased up to rated value (415V) and readings of all the meters are noted. If any of the wattmeters 'kick back', then its potential coil terminals common (C) & voltage (V) are interchanged & its reading is noted as negative.
4. The input voltage is gradually reduced to zero using 3-φ autotransformer & then the supply switch S_1 is opened.

Blocked Rotor test:

1. The connections are made as shown in the circuit diagram.
2. Keeping the 3-φ autotransformer in zero output position, the supply switch S_1 is closed.
3. The rotor is held firmly and is not allowed to rotate and then, using the 3-φ autotransformer, a low voltage is applied so that rated current flows through the induction motor. The readings of all meters are noted. If any of the wattmeters 'kick back',
   then its potential coil terminals common (C) & voltage (V) are interchanged & its reading is noted as negative.
4. The input voltage is gradually reduced to zero using 3-φ autotransformer & then the supply switch S_1 is opened.
5. The resistance per phase of stator & rotor are measured using multimeter.
   (Multiplied by 1.6 because of taking into account the skin effect and temperature)

   R_1 = Stator resistance/phase = $\frac{R_{YB}}{2}$ X1.6 = ______ Ω

   R_2 = Rotor resistance /phase = $\frac{R_{S1S2}}{2}$ X1.6 = ______ Ω

Tabular Column:

No-Load test:

Sl. No.	V_0 Volts	I_1 Amps	I_2 Amps	$I_0 = \frac{I_1 + I_2}{2}$ Amps	$W_1 = W_{R1} \times K_1$ Watts	$W_2 = W_{R2} \times K_2$ Watts	$W_0 = W_1 + W_2$	$\cos\varphi_0 = \frac{W_0}{\sqrt{3}\, V_0 I_0}$	φ_0
1									

Blocked Rotor test:

Sl. No.	V_{sc} Volts	I_1 Amps	I_2 Amps	$I_{sc} = \frac{I_1 + I_2}{2}$ Amps	$W_1 = W_{R1} \times K_1$ Watts	$W_2 = W_{R2} \times K_2$ Watts	$W_{sc} = W_1 + W_2$	$\cos\varphi_{sc} = \frac{W_{sc}}{\sqrt{3}\, V_{sc} I_{sc}}$	Φ_{sc}
1									

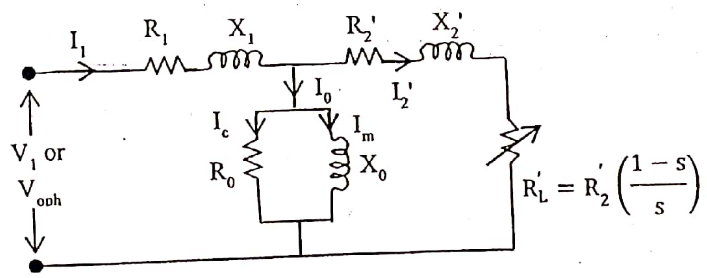
W_{R1} & W_{R2} = Wattmeter Readings,

K_1 & K_2 = Wattmeter constants = $\left[\frac{(\text{Voltage range}) \times (\text{Current range}) \times (\text{p.f. of wattmeter})}{\text{Full scale divisions of wattmeter}}\right]$

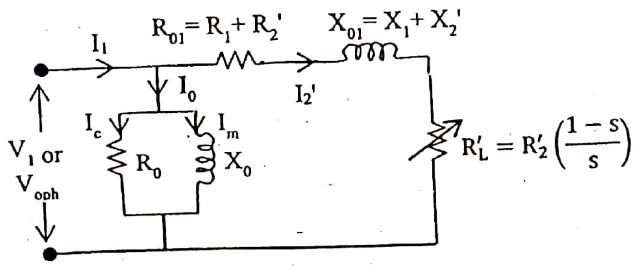
Calculations:

Equivalent Circuits: (All are per phase quantities)

Complete Equivalent Circuit



Approximate Equivalent Circuit .



$V_{oph} = \frac{V_o}{\sqrt{3}} =$ ________ Volts, $I_{oph} = I_o =$ ________ Amps, $W_{oph} = \frac{W_o}{3} =$ ________ Watts

$V_{scph} = \frac{V_{sc}}{\sqrt{3}} =$ ________ Volts, $I_{scph} = I_{sc} =$ ________ Amps, $W_{scph} = \frac{W_{sc}}{3} =$ ________ Watts

R_o = Shunt resistance of the magnetizing circuit = $\frac{V_{oph}^2}{W_{oph}} =$ ______ Ω

X_o = Shunt reactance of the magnetizing circuit = $\frac{V_{oph}}{I_{oph}\ \sin\varphi_o} =$ ______ Ω

R_{01} = Total equivalent resistance per phase referred to stator = $\frac{W_{scph}}{I_{scph}^2} =$ ______ Ω

R_2' = Rotor resistance per phase referred to stator = $R_{01} - R_1 =$ ______ Ω

Z_{01} = Total equivalent impedance per phase referred to stator = $\frac{V_{scph}}{I_{scph}} =$ ______ Ω

X_{01} = Total equivalent reactance per phase referred to stator = $\sqrt{Z_{01}^2 - R_{01}^2} =$ ______ Ω

Also, $X_{01} = X_1 + X_2' =$ ______ Ω, Assuming that, $X_1 = X_2'$,

∴ Stator reactance per phase, $X_1 = \frac{X_{01}}{2} =$ ______ Ω

Rotor reactance per phase referred to stator, $X_2' = X_1 =$ ______ Ω

Let us assume slip of the induction motor, **s = 0.04**

N_s = Synchronous speed of induction motor = $\frac{120 \times f}{P} =$ ______ rpm

N = Induction motor speed = $N_s (1 - s) =$ ________ rpm

R_L' = Equivalent load resistance referred to stator = $R_2' \left(\frac{1-S}{S}\right) =$ ________ Ω

I_2' = Rotor current referred to stator = $\frac{V_{oph}}{(R_{01} + R_L') + jX_{01}} =$ ________ $= |I_2'|\angle\varphi_2$ Amps

I_0 = Exciting current = $|I_0|\angle\varphi_0 =$ ______ Amps

I_c = Core loss current = $|I_0|\ \cos\varphi_0 =$ ____ Amps, I_m = Magnetizing current = $|I_0|\ \sin\varphi_0 =$ ____ Amps

I_1 = Stator current = ~~$I_0 + I_2'$~~ = $|I_0|\angle\varphi_0 + |I_2'|\angle\varphi_2 =$ ________ $= |I_1|\angle\varphi_1$ Amps

$\cos\varphi_1$ = Input power factor = ________

P_{in} = Power input to the induction motor = $3\ V_{oph}|I_1|\ \cos\varphi_1 =$ ________ Watts

P_{m_loss} = Mechanical losses = 4% of power rating of machine = 0.04 × Power = ________ Watts

P_{m_out} = Gross mechanical output = $3\ |I_2'|^2\ R_L' =$ ________ Watts

P_{out} = Power output from the induction motor = $P_{m\_out} - P_{m\_loss} =$ ________ Watts

Percentage efficiency of the induction motor = $\%\eta = \frac{P_{out}}{P_{in}} \times 100 =$ ________ %

$B.H.P = \frac{P_{out}}{735.5} =$ ________ H.P. Torque $(T) = \frac{P_{out} \times 60}{2\pi \times N} =$ ________ N − m

Circle Diagram:

I_{SN} = Short circuit current at normal voltage (V_L) = $\frac{V_L}{V_{sc}} \times I_{sc}$ = ________Amps

P_{SN} = Short circuit input power at normal voltage (V_L) = $\left(\frac{I_{SN}}{I_{SC}}\right)^2 \times W_{sc}$ = ________Watts

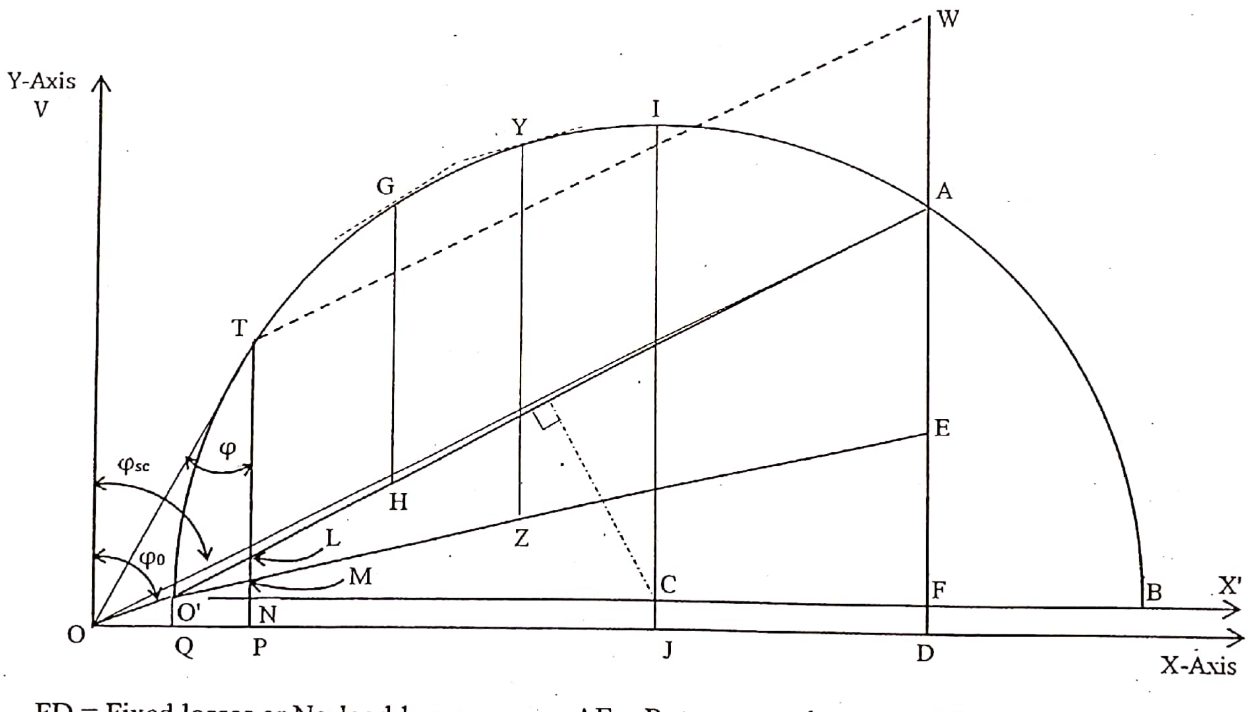
Construction of Circle diagram:

Step 1: Stator Voltage V is taken as reference phasor along the Y-axis.
Step 2: Select a suitable current scale such that diameter of circle is about 20 cm (say, 1cm = 3A).
Step 3: Draw the line OO' = I_o , lagging behind V by an angle φ_o.
Step 4: Draw horizontal line O'X' through O' , parallel to X-axis.
Step 5: Draw the line O'A= I_{SN} , lagging behind V by an angle φ_{sc}.
Step 6: Join O' and A. This line is called as output line.
Step 7: Draw the perpendicular bisector of O'A and extended it to meet the line O'X' at point C.
Step 8: Draw a semicircle with point C as centre and O'C as radius. This meets the line O'X' at point B.
Step 9: Draw a perpendicular AD from point A to X-axis meeting O'B at point F. Also, draw perpendicular O'Q on X-axis.
Step 10: Point E is marked on the line AD such that,

$$\frac{AE}{EF} = \frac{\text{Rotor copper loss}}{\text{Stator copper loss}} = \frac{I_1^2 R_2'}{I_1^2 R_1} = \frac{R_2'}{R_1} = X \qquad \text{i.e,} \quad \frac{AF - EF}{EF} = X, \qquad \therefore EF = \frac{AF}{1+X}$$

Then join O' and E which represents the torque line.

Circle Diagram:



FD = Fixed losses or No-load losses, AE = Rotor copper losses, EF = Stator copper losses
AD = Power input at I_{SN} = W_{SN}, O'A = Output line, O'E = Torque line

Calculations from Circle diagram:

AD = ______ cm, $\therefore$ Power scale = $\frac{W_{SN}}{AD}$ = ________ W/cm

8 29

Full-load quantities:

Length corresponding to full-load output or H.P rating of induction motor is,

$$AW = \frac{H.P \times 735.5}{\text{Power scale}} = \_\_\_\_\_\_\_\_ cm$$

Line AD is extended up to W which corresponding to full-load output length AW. Draw a line WT parallel to O'A, which cuts the semicircle at point T. Join T and O. Draw line TP perpendicular to X-axis, which intersects output line at L, torque line at M, O'X' at N and X-axis at P.

P_{in} = Power input to the induction motor = TP x Power scale = ________ Watts

P_0 = Fixed loss = NP x Power scale = ________ Watts

Stator copper loss = MN x Power scale = ________ Watts

Rotor copper loss = LM x Power scale = ________ Watts

Total losses = LP x Power scale = ________ Watts

P_{out} = Power output from the rotor = TL x Power scale = ________ Watts

Power input to the rotor = TM x Power scale = ________ Watts

$$s = \text{Slip} = \frac{\text{Rotor copper loss}}{\text{Power input to the rotor}} = \frac{LM}{TM} = \_\_\_\_\_\_ \text{ or } \_\_\_\_\_\_ \%$$

N = Induction motor speed = N_s (1 – s) = ________ rpm

$$T = \text{Torque} = \frac{TM \times 60 \times \text{Power scale}}{2\pi \times N} = \_\_\_\_\_\_\_\_ N-m$$

$$\text{Power factor} = \cos\varphi = \frac{TP}{TO} = \_\_\_\_\_\_$$

Line current = TO x Current scale = ________ Amps

Percentage efficiency of the induction motor = $\% \eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{TL}{TP} \times 100 = \_\_\_\_\_\_\_\_ \%$

Maximum quantities:

The point G is obtained by drawing tangent to the semicircle, parallel to the output line O'A and draw line GH parallel to Y-axis.

Maximum output power = GH x Power scale = ________ Watts

The point Y is obtained by drawing tangent to the semicircle, parallel to the output line O'E and draw line YZ parallel to Y-axis.

$$\text{Slip at maximum torque} = \frac{SZ}{YZ} = \_\_\_\_\_\_ \text{ or } \_\_\_\_\_\_ \%$$

Speed at maximum torque = N_s (1 – slip at maximum torque) = ________ rpm

$$\text{Maximum torque} = \frac{YZ \times 60 \times \text{Power scale}}{2\pi \times \text{speed at maximum torque}} = \_\_\_\_\_\_\_\_ N-m$$

Draw line IJ perpendicular to X-axis and passing through the point C.

Maximum input power = IJ x Power scale = ________ Watts

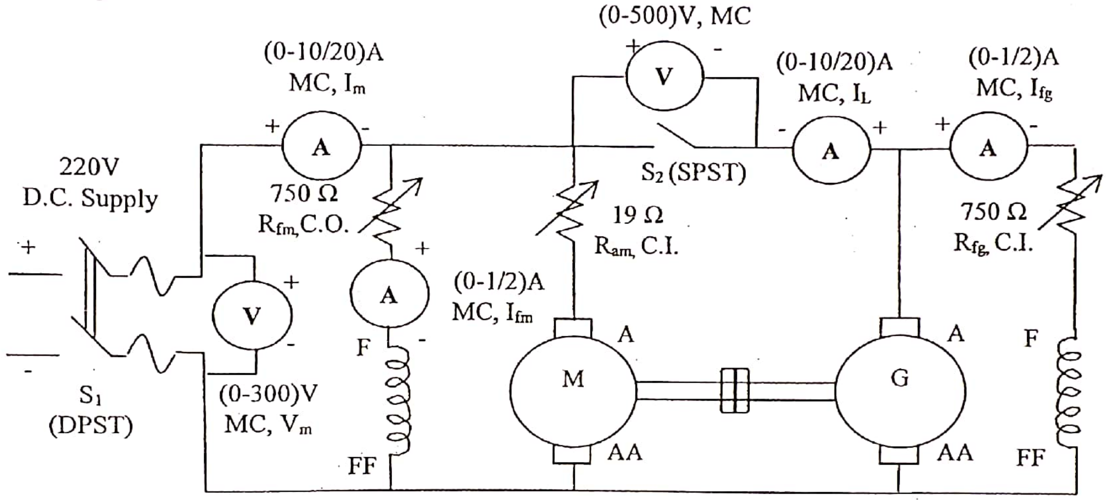
Experiment no.: 08
Regenerative Test

Aim: To conduct regenerative test or back to back test or Hopkinson's test on two identical D.C Shunt machines to determine their efficiencies.

Apparatus Required:

D.C. Motor- D.C. Generator set	- 01
Ammeter (0 – 10/20)A, MC	- 02
Ammeter (0 – 1/2)A, MC	- 02
Voltmeter (0 - 300)V, MC	- 01
Voltmeter (0 - 500)V, MC	- 01
Rheostat (19Ω)	- 01
Rheostats (750 Ω)	- 02
Tachometer	- 01
Patch cords	- 04
Connecting wires	

Circuit Diagram:



Name plate details	
D.C. Motor	D.C. Generator
P =	P =
V =	V =
I_L =	I_L =
I_f =	I_f =
N =	N =

Procedure:

1. Connections are made as shown in circuit diagram.
2. Keeping R_{am} in cut-in, R_{fm} in cut-out, R_{fg} in cut-in and Switch S_1 is closed.
3. The motor is brought to its rated speed (1500 rpm) by first cutting-out R_{am} completely and then slowly cutting-in the R_{fm} , if necessary.
4. Now, the voltmeter connected across switch S_2 indicates supply voltage. The generator is excited by gradually cutting out R_{fg} until the voltmeter indicates zero and close the switch S_2. The no-load readings of all the meters are noted.
   (**Note:** If the polarities are incorrect then the voltmeter connected across switch S_2 indicates double the supply voltage. In this case the connections to A - AA of generator are interchanged).
5. Both the motor and generator can be loaded by either over exciting the generator or under exciting the motor. The generator is over excited by operating R_{fg} cut-out further till ammeter reading I_L is equal to 25% full load current of generator. At the same time speed of the motor decreases and it can be adjusted to rated value by under-exciting the motor i.e., by operating R_{fm} cut-in further.
6. The readings of all the meters at this load are noted down.

7. The steps 5 & 6 are repeated for 50% full load, 75% full load & full load current of the generator.
8. The generator is under excited by operating R_{fg} cut-in gradually till ammeter reading I_L is equal to zero. At the same time speed of the motor is maintain its rated value by operating R_{fm} cutting out gradually. Then, the switch S_2 is opened.
9. Now, brought R_{fg} to cut-in position, and then R_{fm} and R_{am} to cut-out and cut-in positions respectively. Finally, open the supply switch S_1.
10. Armature resistances of motor (R_{am}) and generator (R_{ag}) are measured across the terminals A-AA using multimeter.

Tabular Column:

Sl.No.	Load	V_m Volts	I_m Amps	I_{fm} Amps	I_L Amps	I_{fg} Amps	% η_m	% η_g
1	No load						-------	-------
2	25% full load							
3	50% full load							
4	75% full load							
5	Full load							

R_{am} = ________ Ω R_{ag} = ________ Ω

Calculations: **From the no-load readings:**

P_i = Power drawn from the supply = $V_m \times I_m$ = ________ Watts

P_{fm} = Field copper loss of motor = $V_m \times I_{fm}$ = ________ Watts

P_{am} = Armature copper loss of motor = $(I_m - I_{fm} + I_L)^2 \times R_{am}$ = ________ Watts

P_{fg} = Field copper loss of generator = $V_m \times I_{fg}$ = ________ Watts

P_{ag} = Armature copper loss of generator = $(I_L + I_{fg})^2 \times R_{ag}$ = ________ Watts

Stray losses of motor-generator set = $P_{mg} = P_i - (P_{fm} + P_{am} + P_{fg} + P_{ag})$ = ________ Watts

Stray losses per machine = $W_s = \frac{P_{mg}}{2}$ = ________ Watts

From the load readings, calculate the efficiency of motor:

P_{im} = Power input to the motor = $V_m \times (I_m + I_L)$ = ________ Watts

$P_{fm} = V_m \times I_{fm}$ = ________ Watts

$P_{am} = (I_m - I_{fm} + I_L)^2 \times R_{am}$ = ________ Watts

∴ Total losses = $W_s + P_{fm} + P_{am}$ = ________ Watts

P_{om} = Power output of the motor = P_{im} – (Total losses) = ________ Watts

Percentage efficiency of the motor = % $\eta_m = \frac{P_{om}}{P_{im}} \times 100$ = ________%

From the load readings, calculate the efficiency of generator:

P_{og} = Power output of the generator = $V_m \times I_L$ = ________ Watts

$P_{fg} = V_m \times I_{fg}$ = ________ Watts

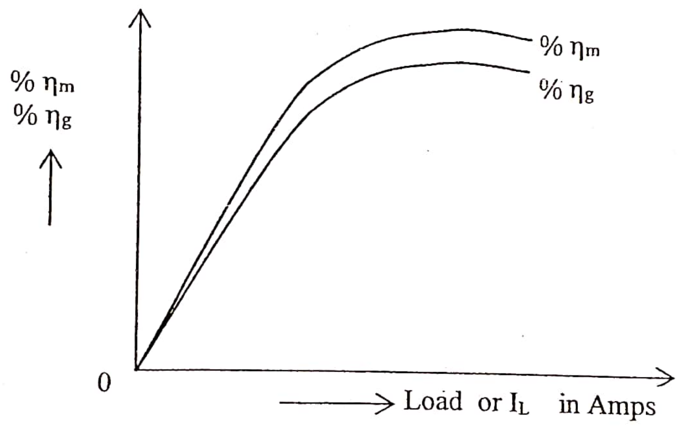
$P_{ag} = (I_L + I_{fg})^2 \times R_{ag}$ = ________ Watts

∴ Total losses = $W_s + P_{fg} + P_{ag}$ = ________ Watts

P_{ig} = Power input of the generator = P_{og} + (Total losses) = ________ Watts

Percentage efficiency of the generator = $\% \eta_g = \frac{P_{og}}{P_{ig}} \times 100$ = ________ %

Graph:



Experiment no.: 09

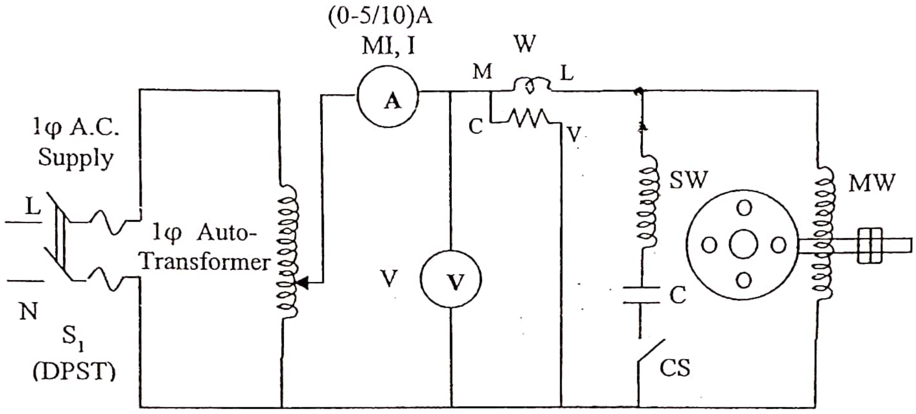
No-Load and Blocked Rotor Test on Single Phase Induction Motor

Aim: To conduct No load and Blocked rotor test on the given single phase induction motor to draw equivalent circuit and hence, determine the performance parameters.

Apparatus Required:

1φ Induction Motor		- 01
Ammeter	(0 – 5/10)A, MI	- 01
Voltmeter	(0 – 75/150/300)V, MI	- 01
Wattmeter	(0 – 5/10)A, 250V, LPF	- 01
Wattmeter	(0 – 5/10)A, 150V, UPF	- 01
Patch cords		- 04
Connecting wires		

Circuit Diagram:



SW → Starting Winding
MW → Main Winding
C → Capacitor
CS → Centrifugal Switch

For No-Load test: Wattmeter → W: (0 – 5/10)A, 250V, LPF
Voltmeter → V: (0 – 300)V, MI

For Blocked Rotor test: Wattmeter → W: (0 – 5/10)A, 150V, UPF
Voltmeter → V: (0 – 75/150/300)V, MI

Name plate details	
1 φ Induction Motor	
Power =	f =
V =	
I =	
N =	
P = Poles =	

Procedure:

No-Load test:

1. Connections are made as shown in the circuit diagram.
2. Keeping the 1-φ autotransformer in zero output position, the supply switch S_1 is closed.
3. With the help of 1-φ autotransformer, the input voltage to the stator is gradually increased up to rated value (230V) and readings of all the meters are noted.
4. The input voltage is gradually reduced to zero using 1-φ autotransformer & then the supply switch S_1 is opened.

Blocked Rotor test:

1. The connections are made with Starting Winding (SW) open circuited, in the circuit diagram.
2. Keeping the 1-φ autotransformer in zero output position, the supply switch S_1 is closed.
3. Using the 1-φ autotransformer, a low voltage is applied so that rated current flows through the induction motor. The readings of all the meters are noted.
4. The input voltage is gradually reduced to zero using 1-φ autotransformer & then the supply switch S_1 is opened.
5. The resistance of stator main winding is measured using multimeter.
   (Multiplied by 1.6 because of taking into account the skin effect and temperature)
   R_1 = Stator resistance = Measured resistance X1.6 = ______ Ω

Tabular Column:

No-Load test:

Sl. No.	V_0 Volts	I Amps	$W_0 = W_R \times K$ Watts	$\cos\varphi_0 = \frac{W_0}{V_0 I_0}$	φ_0
1					

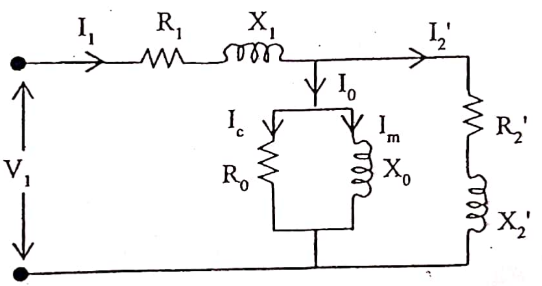
Blocked Rotor test:

Sl. No.	V_{sc} Volts	I Amps	$W_{sc} = W_R \times K$ Watts	$\cos\varphi_{sc} = \frac{W_{sc}}{V_{sc} I_{sc}}$	φ_{sc}
1					

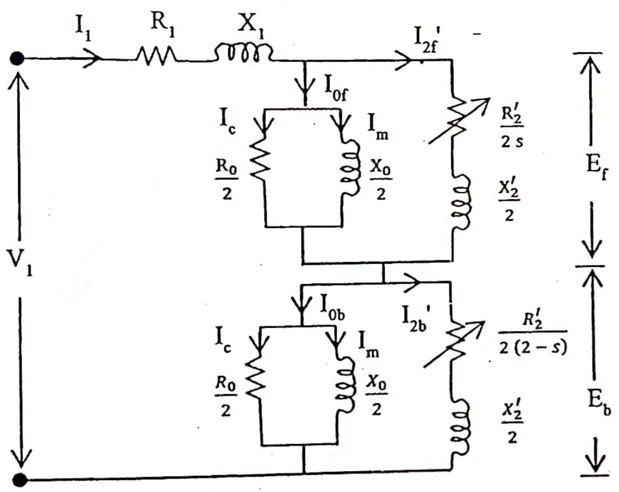
W_R = Wattmeter Reading,

$$K = \text{Wattmeter constant} = \left[\frac{(\text{Voltage range}) \times (\text{Current range}) \times (\text{p.f. of wattmeter})}{\text{Full scale divisions of wattmeter}}\right]$$

Calculations:
Equivalent Circuit:



Equivalent Circuit at Standstill



Equivalent Circuit at slip s (Running Condition)

R_1 = Stator resistance = Measured resistance × 1.6 = ______ Ω

R_{01} = Total equivalent resistance referred to stator = $\frac{W_{sc}}{I_{sc}^2}$ = ______ Ω

R_2' = Rotor resistance referred to stator = $R_{01} - R_1$ = ______ Ω

Z_{01} = Total equivalent impedance referred to stator = $\frac{V_{sc}}{I_{sc}}$ = ______ Ω

X_{01} = Total equivalent reactance referred to stator = $\sqrt{Z_{01}^2 - R_{01}^2}$ = ______ Ω

Also, $X_{01} = X_1 + X_2'$ = ______ Ω, Assuming that, $X_1 = X_2'$,

∴ Stator reactance, $X_1 = \frac{X_{01}}{2}$ = ______ Ω

Rotor reactance referred to stator, $X_2' = X_1$ = ______ Ω

R_o = Shunt resistance of the magnetizing circuit = $\frac{V_o^2}{W_o}$ = ______ Ω

Z_o = Total equivalent impedance referred to stator = $\frac{V_o}{I_o}$ = ______ Ω

X_o = Shunt reactance of the magnetizing circuit = $2\left[\sqrt{Z_o^2 - \left(R_1 + \frac{R_2'}{4}\right)^2} - \left(X_1 + \frac{X_2'}{2}\right)\right]$ = ______ Ω

Core, friction and windage losses = $W_o - I_o^2\left(R_1 + \frac{R_2'}{4}\right)$ = ______ Watts

Let us assume slip of the induction motor, s = **0.04** and $V_1 = V_0 = V$ = ______ Volts

N_s = Synchronous speed of induction motor = $\frac{120 \times f}{P}$ = ______ rpm

N = Induction motor speed = $N_s(1 - s)$ = ______ rpm

$Z_1 = R_1 + jX_1$ = ______ Ω, $Z_{f0} = Z_{b0} = \frac{\left(\frac{R_0}{2} \times j\frac{X_0}{2}\right)}{\left(\frac{R_0}{2} + j\frac{X_0}{2}\right)}$ = ______ Ω,

$Z_{f2} = \left(\frac{R_2'}{2s} + j\frac{X_2'}{2}\right)$ = ______ Ω

Z_f = Rotor impedance offered to the forward field = $\left(\frac{Z_{f0} \times Z_{f2}}{Z_{f0} + Z_{f2}}\right)$ = ______ Ω

$Z_{b2} = \left(\frac{R_2'}{2(2-s)} + j\frac{X_2'}{2}\right)$ = ______ Ω

Z_b = Rotor impedance offered to the backward field = $\left(\frac{Z_{f0} \times Z_{b2}}{Z_{f0} + Z_{b2}}\right)$ = ______ Ω

Z_{eq} = Equivalent impedance = $Z_1 + Z_f + Z_b$ = ______ $= |Z_{eq}|\angle\varphi_1$ Ω

$|I_1|$ = Stator current = $\frac{V_1}{|Z_{eq}|}$ = ______ Amps

$\cos\varphi_1$ = Input power factor = ______

P_{in} = Power input to the induction motor = $V_1 \, |I_1| \cos\varphi_1$ = ________ Watts

$E_f = |I_1| \times |Z_f|$ = ________ Volts, $E_b = |I_1| \times |Z_b|$ = ________ Volts

$I_{2f}' = \dfrac{E_f}{|Z_{f2}|}$ = ________ Amps, $I_{2b}' = \dfrac{E_b}{|Z_{b2}|}$ = ________ Amps,

P_{gf} = Air-gap power of forward field = $(I_{2f}')^2 \left(\dfrac{R_2'}{2\,s}\right)$ = ______ Watts

P_{bf} = Air-gap power of backward field = $(I_{2b}')^2 \left(\dfrac{R_2'}{2\,(2-s)}\right)$ = ______ Watts

P_{m_out} = Gross mechanical output = $(1 - s) \times (P_{gf} - P_{gf})$ = ________ Watts

P_{m_loss} = Mechanical losses = 4% of power rating of machine = 0.04 × Power = ________ Watts

P_{out} = Power output from the induction motor = $P_{m\_out} - P_{m\_loss}$ = ________ Watts

Percentage efficiency of the induction motor = $\%\eta = \dfrac{P_{out}}{P_{in}} \times 100$ = ________ %

$B.H.P = \dfrac{P_{out}}{735.5}$ = ________ H.P.

$\text{Torque}\ (T) = \dfrac{P_{out} \times 60}{2\pi \times N}$ = ________ N – m

Experiment no.: 10

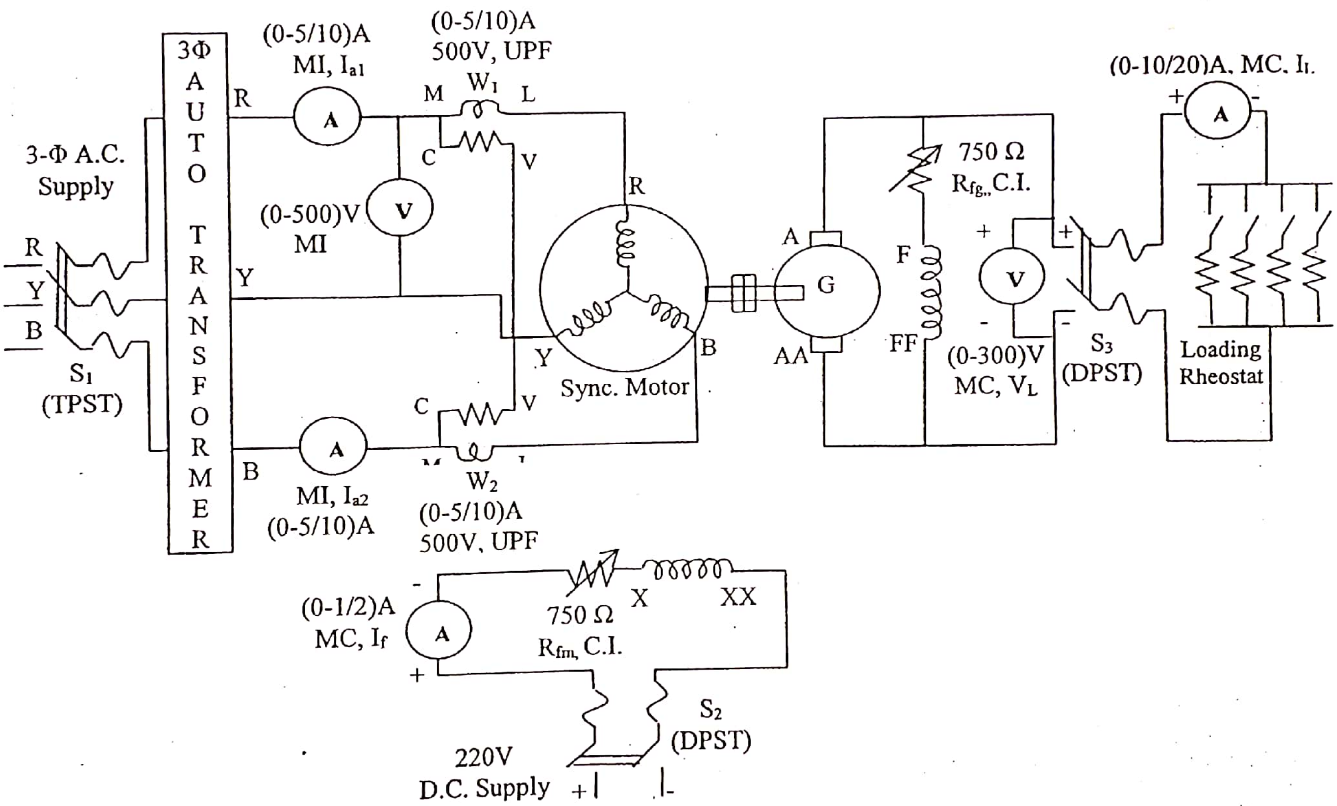
V and Inverted V curves of a synchronous motor

Aim: To obtain the V and inverted V curves of the synchronous motor at no-load and on load.

Apparatus Required:

3φ Synchronous Motor-D.C. Generator set		- 01
3φ Auto-transformer		- 01
Ammeter	(0 – 5/10)A, MI	- 01
Ammeter	(0 – 1/2)A, MC	- 01
Ammeter	(0 – 10/20)A, MC	- 01
Voltmeter	(0 – 500)V, MI	- 01
Voltmeter	(0 – 300)V, MC	- 01
Wattmeter (0 – 5/10)A, 500V, UPF		- 02
Loading rheostat		- 01
Rheostat (750 Ω)		- 02
Patch cords		- 06
Connecting wires		

Circuit Diagram:



Name plate details	
3 φ Sync. Motor	D.C. Generator
S =	P =
V_L =	V =
I_L =	I_L =
I_f =	I_f =
N =	N =

Procedure:

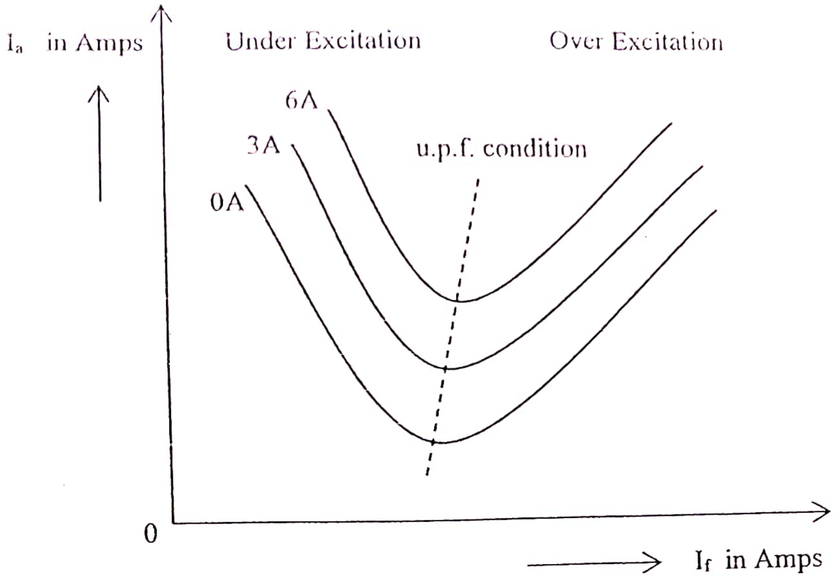
1. Connections are made as shown in the circuit diagram.
2. Keeping the three phase auto-transformer in zero output position, switches S_2 and S_3 open and R_{fm} & R_{fg} in cut-in positions, the supply switch S_1 is closed.
3. Using the auto-transformer, the rated voltage is applied to the stator of the synchronous motor.
4. The field winding of synchronous motor is excited by closing the switch S_2. The motor starts running at its synchronous speed.
5. The d.c. generator voltage is build upto its rated value by cutting out of R_{fg}.
6. With the load switch S_3 still open ($I_L = 0$), the field current of the motor is varied gradually in steps using R_{fm} till the motor draws rated current and at each step, the readings of all the meters are noted down. The R_{fm} rheostat is brought to cut-in position.
7. Now, the load switch S_3 closed and using loading rheostat, the load current I_L is set to 3A (say).
8. For this constant output, the field excitation of the motor is varied in steps and at each step, the readings of all the meters are noted down. The R_{fm} rheostat is brought to cut-in position.
9. Repeat the steps 7 and 8 for another load current $I_L = 6A$ (say).
10. Decrease the load current to zero and open the load switch S_3. Brought, R_{fm} & R_{fg} to cut-in positions, open the switch S_2 and the three phase auto-transformer to zero output position, open the supply switch S_1.

Tabular Column:

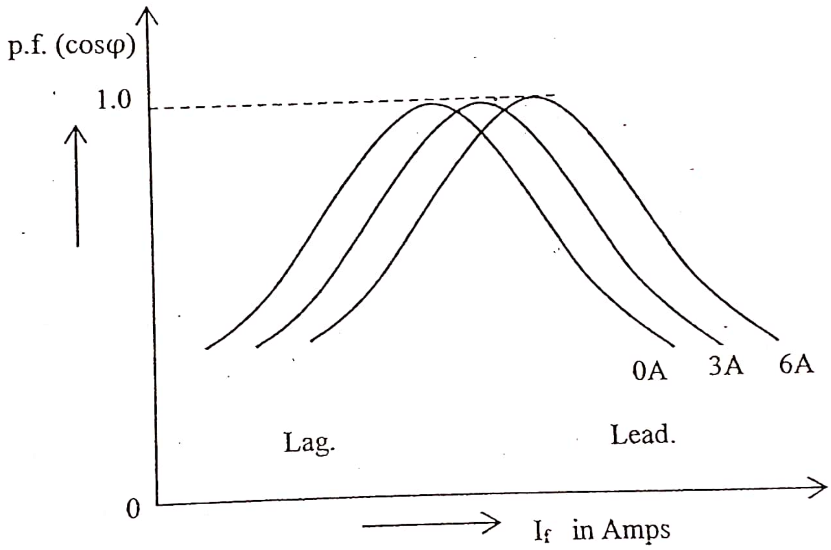
			$I_L = 0A$		
Sl.No.	I_f Amps	$I_a = \frac{I_{a1} + I_{a2}}{2}$ Amps	$W_1 = W_{R1} \times K_1$ Watts	$W_2 = W_{R2} \times K_2$ Watts	$\text{p.f.} = \cos\left\{\tan^{-1}\left[\frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}\right]\right\}$
1					
2					
3					
4					
5					
			$I_L = 3A$		
1					
2					
3					
4					
5					
			$I_L = 6A$		
1					
2					
3					
4					
5					

Where, W_{R1} & W_{R2} = Wattmeter readings, K_1 & K_2 = Wattmeter constants or Multiplying factors.

Graphs:



V- curves



Inverted V -curves