List of Experiments
(Cycle-2)

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Experiment No:1

HOPKINSON'S TEST

AIM

1. To conduct Hopkinson's test or Regenerative Test or Back to back test on a pair of DC shunt machine and hence predetermine the efficiency of the machine working as a motor and generator under various load conditions.
2. Draw Output Vs Efficiency graph (as a motor and as a generator).

APPARATUS REQUIRED

Sl. No:	Apparatus	Specification*	Quantity
1	Voltmeter	0-300 V, MC 0-600V , MC	1 1
2	Ammeter	0-30A, MC 0-10A.MC 0-2A, MC	2 1 2
3	Rheostat	1000 Ω, 1 A 272 Ω, 1.7 A	1 1
4	Tachometer		1

PRINCIPLE

This is a regenerative test and is also known as back to back test which can be carried out on two identical DC shunt machine. The two machines are mechanically coupled and so adjusted electrically that one of them act as motor and the other as generator. The motor supplies mechanical power to drive the generator while the generator supplies electrical power to the motor. The power drawn from supply mains is only to meet losses of the two machines.

Calculation of efficiency

Let field currents of the machines be are so adjusted that the second machine is acting as generator and the first machine is acting as motor. Also let us assume the current drawn from the supply be I_1. Total power drawn from supply is VI_1 which goes to supply all the losses (i.e. Cu losses in armature & field and rotational losses) of both the machines,

Now:

Input from supply = $V(I_1+I_3+I_4)$

Armature Cu losses in motor= $(I_1 + I_2)^2 * R_{am}$

Armature Cu losses in generator= $I_2^2 R_{ag}$

Field copper loss in motor = VI_3

Field copper loss in generator = VI_4

∴ Rotational losses of both the machines, Ws = Input – Total copper loss

$= V(I_1+I_3+I_4) - (I_1 + I_2)^2 * R_{am} - I_2^2 R_{ag} - VI_3 - VI_4$

Hence stray loss per machine, $W_0 = Ws/2$

Since speed of both the machines are same, it is reasonable to assume the rotational losses of both the machines are equal; which is strictly not correct as the field current of the generator will be a bit more than the field current of the motor.

Efficiency of the motor

As pointed out earlier, for efficiency calculation of motor, first calculate the input power and then subtract the losses to get the output mechanical power as shown below,

Motor input $=VI_5$

Armature Cu losses in motor= $(I_1 + I_2)^2 * R_{am}$

Field copper loss in motor = VI_3

Total losses in motor= $W_0 + (I_1+I_2)^2 * R_{am} + VI_3$

Motor output = Motor input - Total losses in motor

$= V I_5 - W_0 - (I_1+I_2)^2 * R_{am} - VI_3$

Motor efficiency = Output / Input

Efficiency of the generator

For generator start with output power of the generator and then add the losses to get the input mechanical power and hence efficiency as shown below,

Generator Output = VI_2

Armature Cu losses in generator= $I_2^2 R_{ag}$

Field copper loss in generator = VI_4

Generator total losses = $W_0 + I_2^2 R_{ag} + VI_4$

Generator input = Generator Output+ Generator total losses

$= VI_2 + W_0 + I_2^2 R_{ag} + VI_4$

Generator efficiency = Output / Input

The following are the advantages and disadvantages of Hopkinson's test.

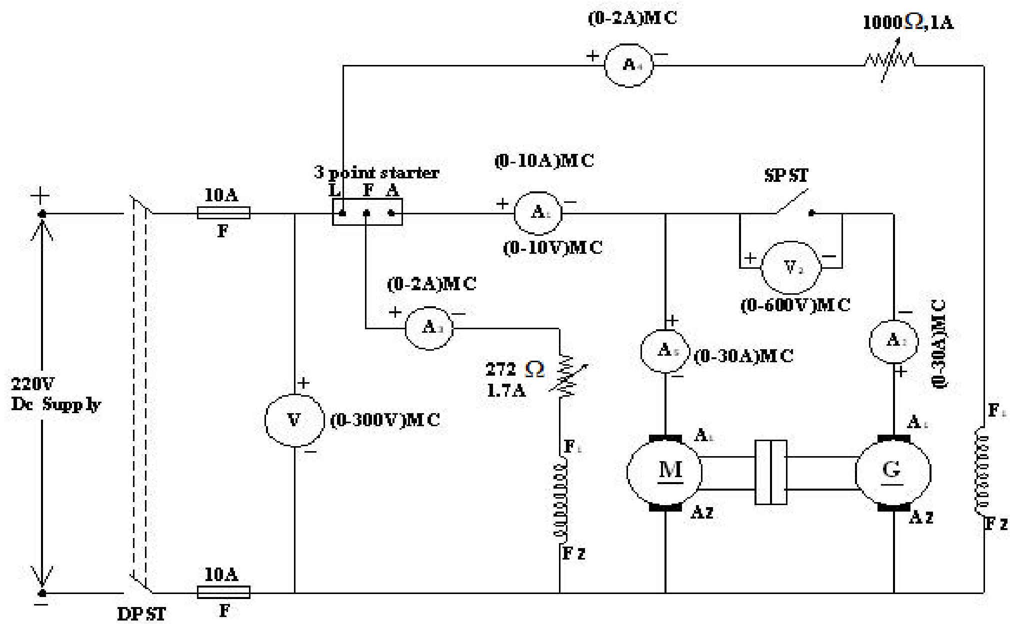
Advantages:

1. The power required for conducting the test is small compared to full load powers of the two machines.
2. Since the machines are operated at full load condition, change in iron loss due to distortion in flux at full load will be included in the calculations.
3. As the machines are tested under full load conditions, the temperature rise and quality of commutation of the two machines can be observed.
4. The test is economical as the power required for the test is very small which is just sufficient to meet the losses.
5. There is no need for arranging any actual load. Similarly by changing the field currents of two machines, the load can be easily changed and a load test over complete range of load can be taken.

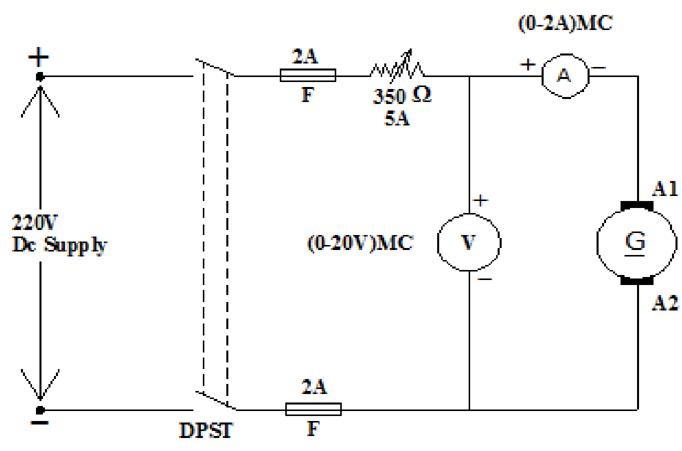
Disadvantages:

1. There is difficulty in availability of two identical machines.
2. The iron losses in the two machines cannot be separated. The iron losses are different in both the machines because of different excitations.
3. The machines are not loaded equally in case of small machines which may lead to difficulty in analysis.

CIRCUIT DIAGRAM



MEASUREMENT OF ARMATURE RESISTANCE



PROCEDURE

1. Connect the circuit as shown in the circuit diagram.
2. Keep the field rheostat of the motor at minimum and that of generator at maximum position.

3. Keep the SPST switch in open condition.
4. Close DPST switch.
5. Start the DC shunt motor using 3 point starter.
6. Apply rated voltage to the motor.
7. Check the speed of the machine by using Tachometer.
8. If it is not rated speed, adjust the speed of the motor to rated speed by using field rheostat.
9. Keep the machine in rated speed condition.
10. Then check the polarities using voltmeter reading V_2.
11. If the voltmeter reads the difference of supply and generator voltage, then the polarity is correct.
12. Otherwise the polarity is corrected by interchanging the armature terminals.
13. Make the voltmeter reading zero by adjusting generator field rheostat.
14. Close SPST switch when V_2=0
15. Record the first set readings of A_1, A_2, A_3, A_4, A_5 and V_1.
16. The field current is increased by adjusting generator field rheostat.
17. Check for any decrease in speed has take place. If yes, bring back the speed of Motor-Generator set to the earlier value (rated).
18. Record the readings of meters.
19. Repeat the steps 16, 17, 18 till the ammeter becomes 1.25 times rated current.
20. Disconnect the supply after keeping the rheostats in initial position.
21. Measure the armature resistance of both motor and generator by voltmeter-ammeter method.
22. Draw the required graphs

PRECAUTIONS

1. There should not be any loose connection in the circuit.
2. Parallel operation must be done with so care that voltmeter V_2 must be zero.
3. Speed of the system must be kept at rated value.

TABULAR COLUMN

Sl. No	V (V)	I_1 (A)	I_2 (A)	I_3 (A)	I_4 (A)	I_5 (A)	Motor Cu loss		Generator Cu loss		Input from supply (W)	Stray Loss, W_s (W)	W_0= $W_o/2$ (W)
							Armature (W)	Field (W)	Armature (W)	Field (W)			

1													
2													
3													
4													
5													
6													

MEASUREMENT OF ARMATURE RESISTANCE

SL NO	Voltage (v)	Current(A)	Resistance R=V/I (Ω)

SAMPLE CALCULATION

Input from supply = $V(I_1+I_3+I_4)$ =…………..W

Armature Cu losses in motor = $(I_1 + I_2)^2 * R_{am}$=……………W

Armature Cu losses in generator= $I_2^2R_{ag}$=…………………W

Field copper loss in motor = VI_3 =………………..W

Field copper loss in generator = VI_4 =………………..W

Total Stray losses, Ws = Input – Total copper loss

= $V(I_1+I_3+I_4) - (I_1 + I_2)^2 * R_{am} - I_2^2R_{ag} - VI_3 - VI_4$=…………..W

Stray losses/machine, W_0 = Ws/2 = ………………..W

Machine as Motor:

Motor input = $V I_5$= …………….W

Armature Cu losses in motor = $(I_1 + I_2)^2 * R_{am}$=……………W

Field copper loss in motor = VI_3 =………………..W

Total losses in motor = $W_0 + (I_1+I_2)^2 * R_{am} + VI_3$ = …………W

Motor output = Motor input - Total losses in motor

= $VI_5 - W_0 - (I_1+I_2)^2 * R_{am} - VI_3$ = …………W

Motor efficiency = Output / Input = …………..%

Efficiencies when the Machine working as Motor:

Sl No	V (V)	I_1 (A)	I_2 (A)	I_3 (A)	I_4 (A)	I_5 (A)	Motor Input (W)	Armature Cu loss in Motor (W)	Field Cu loss in motor (W)	Total loss in motor (W)	Motor Output (W)	Efficiency of Motor (%)
1												
2												
3												
4												
5												
6												

Machine as Generator:

Generator Output = VI_2 = …………….W

Armature Cu losses in generator= $I_2^2R_{ag}$=…………………W

Field copper loss in generator = VI_4 =………………..W

Generator total losses = $W_0 + I_2^2R_{ag} + VI_4$ = …………… W

Generator input = Generator Output+ Generator total losses

= $VI_2 + W_0 + I_2^2R_{ag} + VI_4$ =…………………W

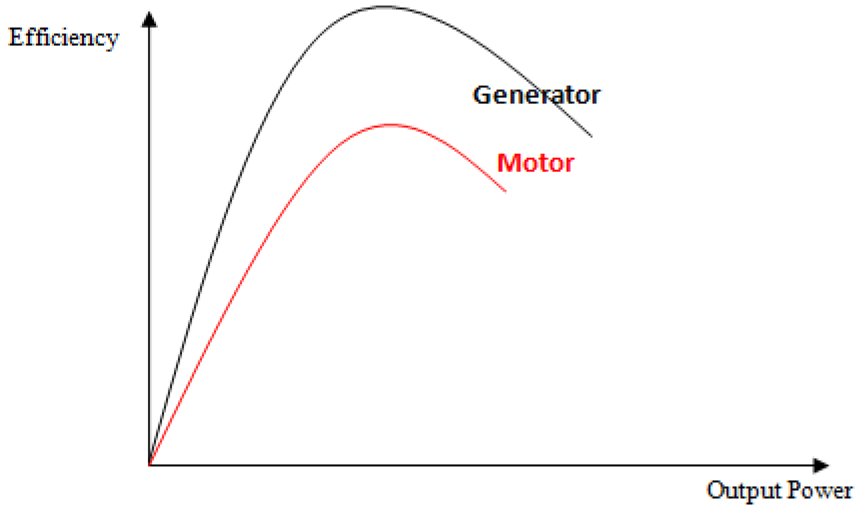
Generator efficiency = Output / Input = ………….. %

Efficiencies when the Machine working as Generator:

Sl No	V (V)	I_1 (A)	I_2 (A)	I_3 (A)	I_4 (A)	I_5 (A)	Generator Output (W)	Armature Cu loss in Generator (W)	Field Cu loss in Generator (W)	Total loss in Generator (W)	Generator Output (W)	Efficiency of Generator (%)
1												
2												
3												

4												
5												
6												

SAMPLE GRAPH



RESULT

Hopkinson's test was conducted on the given pair of DC shunt machine. The efficiencies were determined for various loads when it works as a motor and as a generator.

Experiment No:2

RETARDATION TEST

AIM

1. To separate the losses in a DC shunt machine by conducting retardation test.
2. Calculate the moment inertia of the rotating system.

APPARATUS REQUIRED

Sl. No:	Apparatus	Specification*	Quantity
1	Voltmeter	0-300 V, MC	1
2	Ammeter	0-5A, MC	1
3	Rheostat	20Ω, 5A 1000Ω,1A 120Ω, 2.8A	1 1 1
4	Wattmeter	300V,5A,LPF	1
5	Tachometer	Digital	1
6	Stopwatch		1
7	Change over switch	DPDT	1

PRINCIPLE

This method is generally employed for shunt generators and shunt motors. From this method we can find out stray losses. Thus if armature and shunt field copper losses at any given load current are known, then he efficiency of a machine of a machine can be easily estimated.

The machine under test is run at a speed which is run at a speed which is slightly above its normal speed. Then the supply to the motor is cut off from the armature while the field is kept excited. Consequently the armature slow down and its kinetic energy is used for supplying the rotational or stray losses which includes friction, windage and iron losses .If the armature slow down with no excitation, then the energy of the armature is used to overcome the mechanical loss only.

Consider the following cases of a DC Motor.

1. If the supply to the armature as well as field excitation is cut off, the motor slows down and finally stops. Now the kinetic energy of the armature is used up to overcome only the friction and windage losses. This is expected because in the absence of flux, there will be no iron losses. The combination of friction and windage loss is known as mechanical loss.
2. If the supply to the armature is cut off but field remains normally excited, the motor again slows down gradually and finally stops. The kinetic energy of the armature is used up to overcome friction, windage and iron losses. The combination is known as stray loss.
3. If supply to the armature is cut off and it is connected to a load, the motor slow down and finally stops. Now the kinetic energy of the armature is used to overcome the load losses.

Hence by carrying out the first test, we can find out the friction and windage losses and hence the efficiency of the machine. However, if we perform the second test also, we can find out the iron loss. And from the third case, we will get total load losses.

K.E. of armature = $\frac{1}{2} I \omega^2$

∴ Losses, W = Rate of loss of K.E. of armature

$W = \frac{d}{dt}\left(\frac{1}{2} I \omega^2\right) = I\omega \left(\frac{d\omega}{dt}\right)$

Where I is the moment of inertia of the rotating system

Since ω= normal angular velocity in rad/s = 2πN/60

$$\therefore W = \left(\frac{2\pi}{60}\right)^2 IN\frac{dN}{dt}$$

Where N = normal speed in r.p.m

Case (i)

Run the motor beyond normal speed. Then cut off the supply to the armature as well as field, the motor slows down and finally stops. The time taken for the speed to decrease from one speed to another say 1800 rpm to 1200rpm is noted. .Now the kinetic energy of the armature is used up to overcome only the friction and windage losses. From this mechanical loss is found out by the relation

$$Pm = \left(\frac{2\pi}{60}\right)^2 IN\frac{dN}{dt1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(1)$$

Where I = Moment of Inertia of rotating system.

Case (ii)

Machine under test is run beyond normal speed say 1800 rpm. Now supply to the armature is cut off but field remains normally excited. The time for the speed to decrease from 1800 to

120rpm is noted. In this e case losses include iron loss in addition to mechanical loss, which is called stray losses.

$$Ps = \left(\frac{2\pi}{60}\right)^2 IN\frac{dN}{dt2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Case (iii)

Once again the machine is speeded up to 1800rpm. The cut off the supply to the armature and is connected to load circuit while the field remains excited. The time taken to decrease the speed from 1800 rpm to 1200rpm is noted. The wattmeter reading indicates the total losses.

$$Ps + PL = \left(\frac{2\pi}{60}\right)^2 IN\frac{dN}{dt3} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where

$$\mathrm{PL} = \frac{\mathrm{W1} + \mathrm{W2}}{2}$$

W_1 = initial reading

W_2 = Final reading

Equation No: (3) / (2)

$$\frac{\mathrm{Ps} + \mathrm{PL}}{Ps} = \frac{\mathrm{t2}}{t3}$$

$$\frac{\mathrm{Ps} + \mathrm{PL}}{Ps} = 1 + \frac{\mathrm{PL}}{Ps} = \frac{\mathrm{t2}}{t3}$$

$$\frac{\mathrm{PL}}{Ps} = \frac{\mathrm{t2}}{t3} - 1$$

$$\frac{\mathrm{Ps}}{PL} = \frac{\mathrm{t3}}{t2 - t3}$$

$$Ps = PL\ \frac{\mathrm{t3}}{t2 - t3}$$

Equation No: (1) / (2)

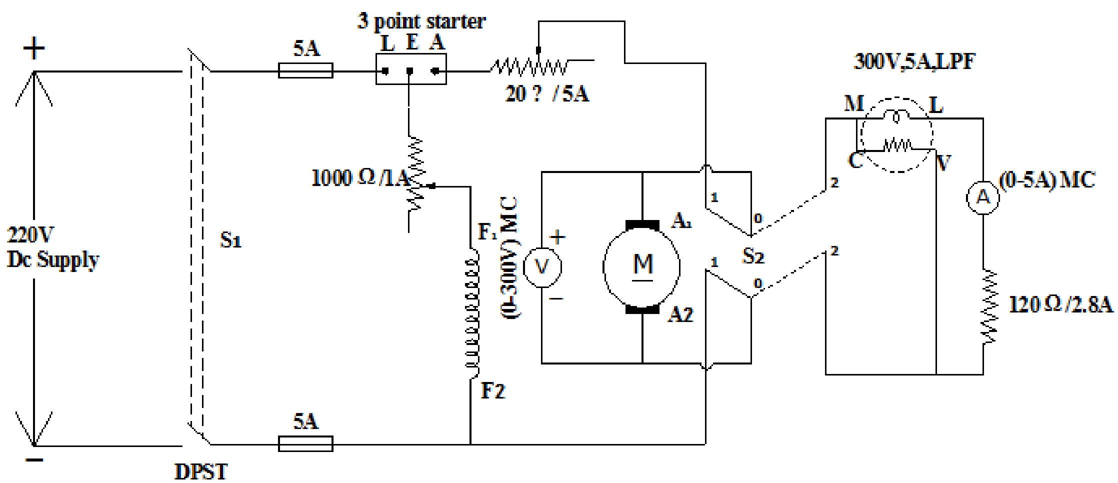
$$\frac{\mathrm{Pm}}{Ps} = \frac{\mathrm{t2}}{t1}$$

$$Pm = Ps\ \frac{\mathrm{t2}}{t1}$$

$$Pm = PL\ \frac{\mathrm{t3}}{t2 - t3}\ \frac{\mathrm{t2}}{t1}$$

$$I = \left(\frac{60}{2\pi}\right)^2 \frac{Pm}{N} \frac{dt1}{dN}$$

CIRCUIT DIAGRAM



PROCEDURE

1. Connections are made as per the circuit diagram.
2. Keep the field rheostat at minimum position, armature rheostat at maximum position, load at maximum position, and switch S_1 at open position and S_2 at position 1.
3. Switch on the power supply by closing the switch S_1 and start the motor using three point starter.
4. Adjust the armature and field rheostat to obtain a speed of 1800 rpm.
5. Now cut the power supply by opening the switch S_1.
6. Note down the time taken to reach 1200 rpm from 1800 rpm.
7. Repeat the step 1 to 4.
8. Now open the switch S_2 from position 1.
9. Note down the time taken to reach 1200 rpm from 1800 rpm.
10. Repeat the step 1 to 4.
11. Now move the switch S_2 from position 1 to position 2.
12. Note down the time taken to reach 1200 rpm from 1800 rpm.
13. Also note the wattmeter reading corresponding to 1200 rpm and 1800 rpm.

14. Calculate different losses and moment of inertia of DC machine by using relevant formula.

PRECAUTIONS

1. There should not be any loose connection in the circuit.
2. Care must be taken during switching operation since there is a chance for sparking.
3. Tachometer and stopwatch used must have enough accuracy.

TABULAR COLUMN

SL. NO:	Switch positions		Speed (rpm)		Time taken (s)	Wattmeter reading (W)
	S1	S2	From	To		
1	Open	Position 1	1800	1200		NIL
2	Closed	Open from Position 1	1800	1200		NIL
3	Closed	Move from position 1 to position 2	1800	1200		1800rpm → W_1= 1200rpm → W_2=

SAMPLE CALCULATION

W_1 =……… (W)
W_2 =………. (W)
t_1 =………… (s)
t_2=………… (s)
t_3 =………… (s)

Load loss, $PL = \frac{W1+W2}{2}$ =……………… (W)

Stray loss, $Ps = PL \frac{t3}{t2-t3}$ = ……………… (W)

Mechanical loss, $Pm = Ps \frac{t2}{t1}$ =…………….. (W)

Iron loss = Ps – Pm = …………….... (W)

Moment of Inertia, $I = \left(\frac{60}{2\pi}\right)^2 \frac{Pm}{N} \frac{dt1}{dN}$

RESULT

Separated the losses in a DC machine by retardation test and hence calculated the moment of inertia of rotating system.

Moment of inertia =……………Kg m^2

Experiment No:3

SEPARATION OF LOSSES IN A SINGLE PHASE TRANSFORMER

AIM

To separate the hysteresis and eddy current losses from iron loss in a single phase Transformer at normal voltage and frequency.

APPARATUS REQUIRED

Sl. No:	Apparatus	Specification*	Quantity
1	Voltmeter	0-150 V, MI	1
2	Ammeter	0-1A MC 0-1A, MI	1 1
3	Wattmeter	150V, 5A, LPF	1
4	Rheostat	272 Ω, 1.7A	1
5	Rheostat	100 Ω,5A, 1000 Ω,1A	1
6	Transformer	1Φ,120/240V, 1KVA	1

PRINCIPLE

The components of iron loss consist of hysteresis loss and eddy current loss. Both are functions of frequency and maximum flux density in the core can be separated by finding iron losses at various frequencies and plotting the graphs P_c/N V_s N. Variable supply frequency can be obtained from an alternator.

There are mainly two types of losses occurs in a transformer. They and iron loss or core loss and copper loss or winding loss. As the name indicates, the loss occurs in core is known as core loss and loss in winding is known as winding loss. The iron loss includes hysteresis losses and eddy current losses, both are functions of frequency and maximum flux density in the core.

Hysteresis loss, $W_H \alpha (B_m)^{1.6}f$

Eddy current loss, $W_E \alpha (B_m)^2f^2$

Where Bm is the maximum flux density in the core and f is the supply frequency.

The values of these losses are independent of load current. Hence it is assumed as constant from no load to full load and named as constant loss.

Hence constant loss in a transformer is given by,
Constant loss (core loss / iron loss) = hysteresis loss + eddy current loss.

$Pc = W_H + W_E$

$W_H = K_H (B_m)^{1.6} f$

$W_E = K_E (B_m)^2 f^2$

Where K_H and K_E are proportionality constants.

Therefore $Pc = K_H (B_m)^{1.6} f + K_E (B_m)^2 f^2$

The hysteresis loss is varying linearly with the frequency while the eddy current loss varies as the square of supply frequency.
The core loss per cycle is given by,

$Pc/f = K_H (B_m)^{1.6} + K_E (B_m)^2 f$

This shows that hysteresis loss per cycle is independent of frequency and eddy current per cycle is proportional to the frequency. For the open circuit test V and f are varied together so that V/f is a constant. Since B_m α V/f for a particular value of V/f, the equation for core loss per cycle can be written as, $Pc/f = K_1 + K_2 f$

Where $K_1 = K_H (B_m)^{1.6}$ and $K_2 = K_E (B_m)^2 f$.

Thus the plot of Pc/f versus f results a straight line. From the graph, value of K_1 and K_2 can be determined. Slope of the straight line gives K_2 and intercept gives K_1. Thus core loss can be separated as,

Hysteresis loss, $W_H = K_1 f$

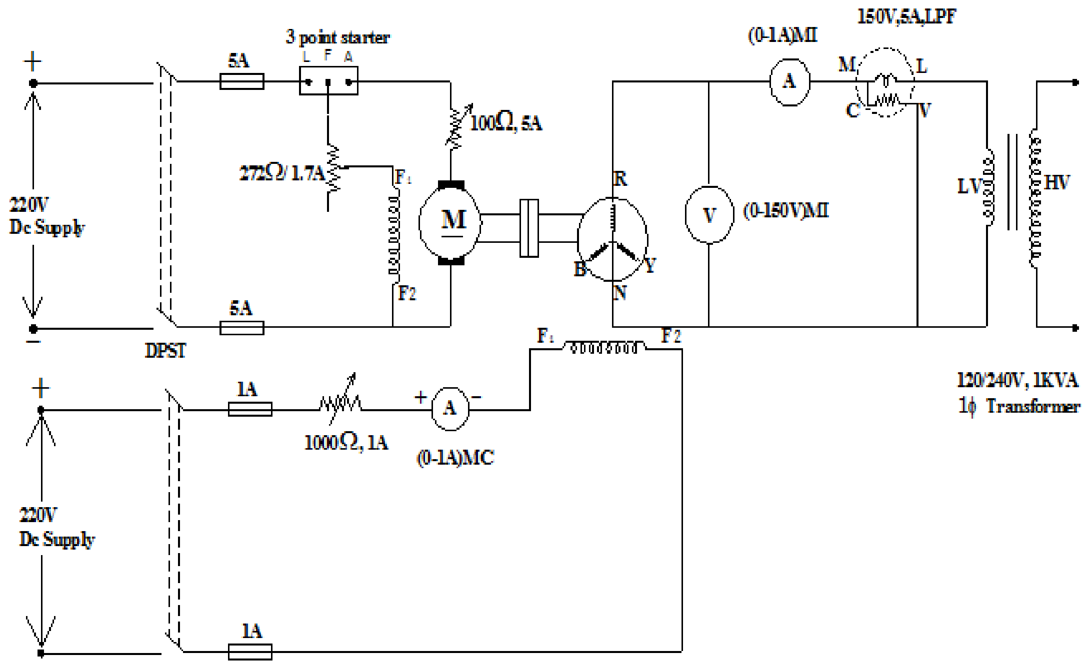
Eddy current loss, $W_E = K_2 f^2$

An alternator is a three phase a.c. generator whose speed and frequency are related as N=120f/P.

Where N- Speed
f- Frequency
P- Number of poles of alternator.

Thus by reusing the alternator at different speeds any of the different frequencies can be obtained. Also the magnitude of emf can be adjusted to the desired value by adjusting the field current of the alternator.

CIRCUIT DIAGRAM



PROCEDURE

1. Connect the circuit as shown in figure.
2. Keep the field rheostat of alternator in maximum position and field rheostat of motor in minimum position. Also keep the armature rheostat of motor in maximum position.
3. Switch ON the power supply.
4. Start the motor using three point starter.
5. Cut off the starting rheostat gradually.
6. Adjust the field rheostat of motor to drive the alternator at its rated speed to get normal supply frequency (50Hz).
7. Adjust the field rheostat of alternator to supply rated voltage to the transformer.
8. Note the wattmeter reading.
9. Now the frequency is varied to different convenient values by adjusting the speed of the prime mover (motor) and in each case voltage is also adjusted to keep V/f ratio constant.
10. Tabulate the readings.
11. Switch OFF the power supply after bringing all the rheostats to initial positions.

PRECAUTIONS

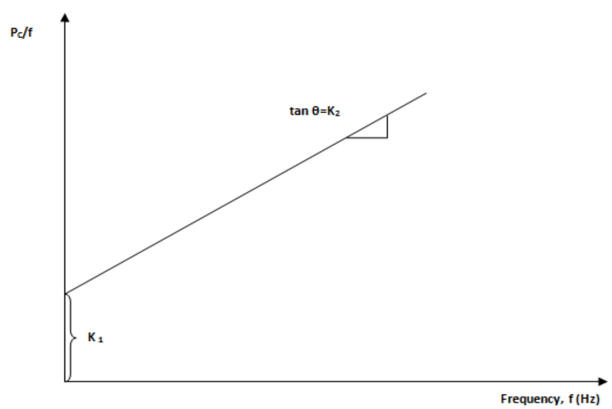
1. There should not be any loose connection in the circuit.

2. While varying the field rheostat of alternator, care must be taken so that the induced voltage does not exceed the rated voltage on LV side of the transformer.
3. In each set of reading, the V/f ratio must be constant.

TABULAR COLUMN

Sl.No	Speed, N (rpm)	Frequency, f (Hz)	Voltage V (V)	Power Pc (W)	Pc/f
1					
2					
3					
4					
5					
6					
7					

SAMPLE GRAPH



SAMPLE CALCULATION

Speed, N=……………..Rpm

N=120f/P

Frequency, f=NP/120=……………….Hz

Power, Pc=………………W

Pc/f=…………………..W/Hz

From graph,

K_1 =…………………..W/Hz

K_2= tan θ=………………W/Hz^2

Sl. No	**Speed N (rpm)**	**Frequency f (Hz)**	**$W_H = K_1 f$ (W)**	**$W_E=K_2 f^2$ (W)**	**$P_c=W_H+W_E$ (W)**
1					
2					
3					
4					
5					
6					

Hysteresis loss, $W_H = K_1 f$ =………………W

Eddy current loss, $W_E = K_2 f^2$ = ………………W

Total Loss, Pc =W_H + W_E=………..W

RESULT

Thus separated the core loss in a Single phase Transformer into hysteresis loss and eddy current loss at normal voltage and normal frequency.

Hysteresis loss =

Eddy current loss =

Experiment No:4

SEPERATION OF LOSSES IN A DC SHUNT MACHINE

AIM

To conduct no load test on the given DC shunt motor at different excitation and to separate the stray losses into the following components.

Brush friction loss, W_F

Bearing friction and windage losses, W_W

Hysteresis loss, W_H

Eddy current loss, W_E

APPARATUS REQUIRED

Sl.No	Material	Specification*	Quantity
1	Ammeter	(0-2A)MC (0-3A)MC	1 1
2	Voltmeter	(0-300V)MC	1
3	Rheostat	272Ω,1.7A 45Ω,5A	1
4	Tachometer		1

PRINCIPLE

The components of stray losses, brush friction loss, bearing friction and windage loss, hysteresis loss and eddy current loss can be separated by finding stray losses at various speeds for two different excitation (normal excitation and reduced excitation). and plotting the graphs P_s/N V_s N.

As the motor rotates, due to the friction at the bearings and brushes, a part of mechanical energy is converted into heat which accounts the frictional loss. A part of energy is spent to overcome the air resistance, which is treated as windage loss. Since the flux reversal takes place in the armature core, there are hysteresis and eddy current losses. The total losses are considered as stray losses. From the stray losses, the various components can be separated as

Brush friction loss α speed = **AN**

Bearing friction and windage loss **α** speed^2 = **BN^2**
Hysteresis loss W_H α $B_m^{1.6} f$
Eddy current loss W_E α $B_m^2 f^2$

Now for constant field excitation (I_{f1} = constant), Maximum flux density B_m is a constant.
Since N =120 f/P
f= N P/120
Frequency of flux reversal f is proportional to speed. Thus for normal excitation,
W_H α N =C N
W_E α N^2= DN^2
Again for a reduced excitation (I_{f2})
$W_H^1 = C^1 N$
$W_E^1 = D^1 N^2$
Where A, B, C, D, C1, D1 are constants.
The stray loss corresponding to normal excitation (I_{f1}) is,
P_{stray} = **$AN + BN^2 + C N + DN^2$**
i.e $Ps = (A+C)N + (B+D)N^2$
$P_S/N = (A+C) + (B+D) N$
Similarly stray loss corresponding to reduced excitation,
$P_S^1 = AN + BN^2 + C^1N + D^1N^2$
$= (A+C^1) N + (B+D^1) N^2$
$P_S^1/N = (A+C^1) + (B+D^1) N$

If graph P_S/N V_S N is plotted, we will get a straight line. The intercept of straight line gives (A+C) and its slope gives (B+D). Similarly P_S^1/N V_S N is also plotted. The intercept of straight line gives $(A+C^1)$ and its slope gives $(B+D^1)$. Since there are six unknowns A, B, C, D, C^1, D^1, we need two more equations which can be obtained as follows.
For the same speed, $W_H/W_H^1 = (B_m/B_{m1})^{1.6} = C/C^1$

Again B_m α Φ α E_{b1}

E_{b1}- back emf.

$C/C^1 = (E_b/E_b^1)^{1.6}$

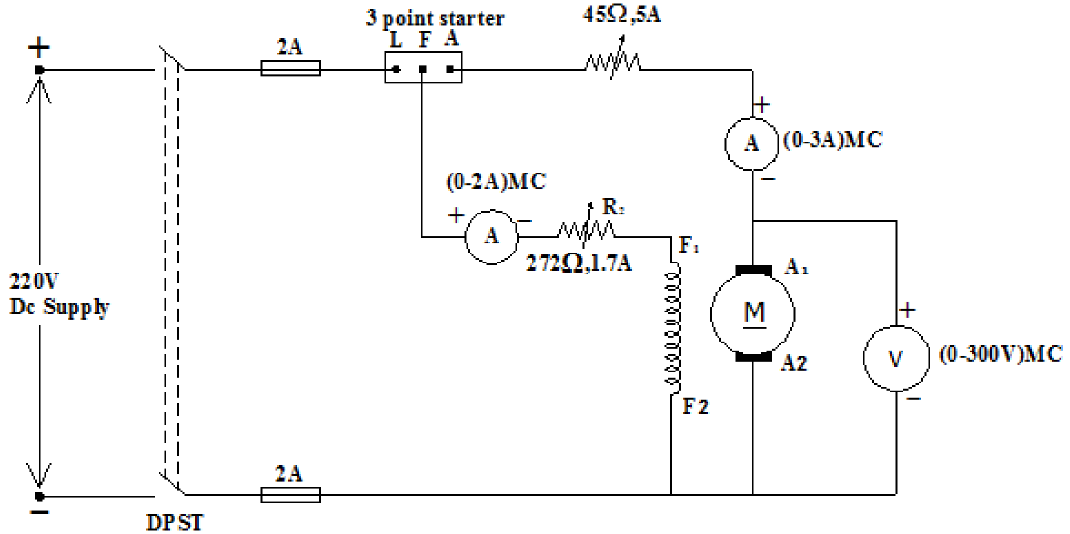
E_b corresponds to normal speed excitation

E_b^1 corresponds to reduced excitation.

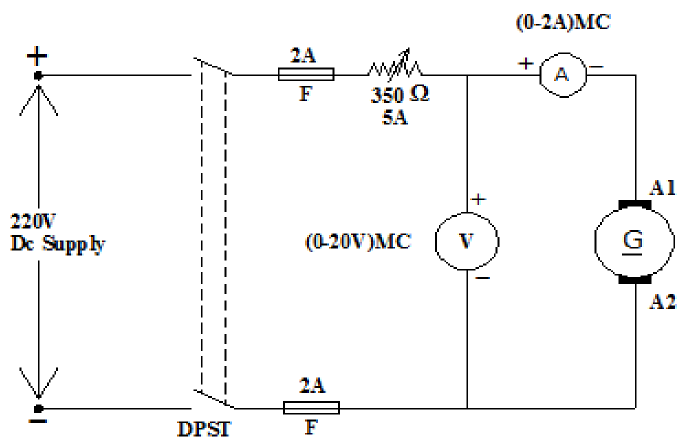
Similarly $D/D^1 = W_E/W_E^1 = (E_b/E_b^1)^2$

Solve the above equations to find constants and hence the components of stray loss can be separated.

CIRCUIT DIAGRAM



MEASUREMENT OF ARMATURE RESISTANCE



PROCEDURE

1. Connections are made as shown in the figure.
2. Keeping the field rheostat at its minimum position and the other at maximum position.
3. Switch ON the power supply.

4. Start the motor using three point starter.
5. Adjust the field rheostat to obtain rated excitation.

6. Now keeping the excitation constant, (as percentage rated value) the speed is reduced to different values in steps by adjusting the armature rheostat.
7. All the meter readings and speed are noted.
8. Tabulate the readings.
9. Now keeping the excitation constant at a reduced (.75) the procedure explained above is repeated and second set of readings are obtained.
10. These readings are tabulated.

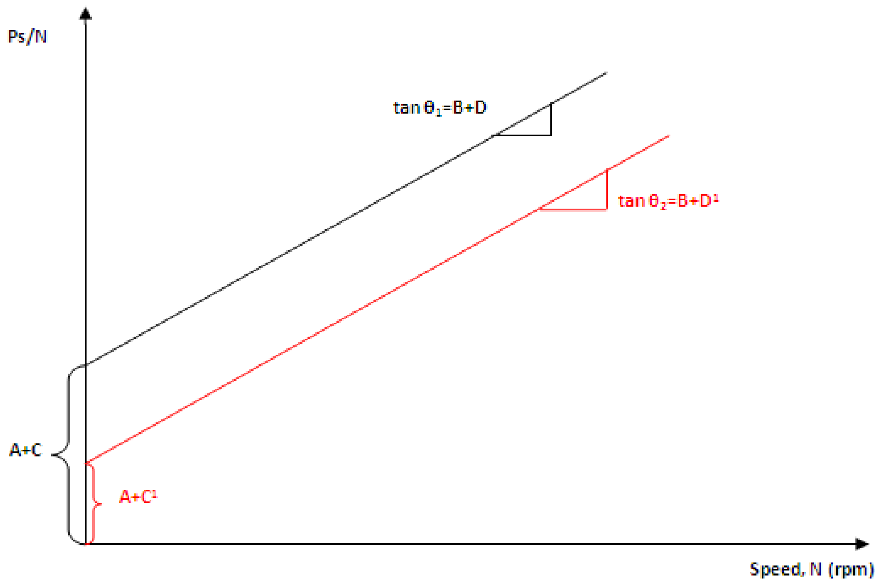
PRECAUTIONS

1. There should not be any loose connection in the circuit.
2. The machine should be at no load.
3. Test should be conducted on DC shunt machine only.
4. Care is to taken to see that at least one reading in each set must have the same speed.

TABULAR COLUMN

Sl No	N (rpm)	V (V)	Ia (A)	I_f (A)	Eb= V-IaRa (V)	Ps= Eb*Ia (W)	Ps/N
1 2 3 4 5 6							
1 2 3 4 5 6							

SAMPLE GRAPH



SAMPLE CALCULATION

From graph, A+C=…………….

$A+C^1$=……………

$C-C^1$=……………. (1)

B+D= tan θ_1…………….

$B+D^1$= tan θ_2……………

$D-D^1$=…………… (2)

Back emf at rated speed is,

For Rated Excitation

Eb=V-IaRa=…………..V

For reduced excitation

$Eb^1=V-Ia^1Ra$=…………….V

$C/C^1 = (E_b/E_b{}^1)^{1.6}$ =………….. (3)

$D/D^1=W_e/W_e{}^1= (E_b/E_b{}^1)^2$ =……………. (4)

Solve equations (1), (2), (3) & (4), we get the values of A, B, C, and D

Therefore A=……….

B=…………

C=…………….
D=………………
C^1=…………….
D^1=……………

Sl.No	Speed, N (rpm)	$W_F = AN$ (W)	$W_W=BN^2$ (W)	$W_H= CN$ (W)	$W_E= DN^2$ (W)	Stray loss, Ps (W)
1						
2						
3						
4						
5						

Brush friction loss, $W_F = AN$ =……………..W

Bearing friction and windage losses, $W_W= BN^2$=……………W

Hysteresis loss, $W_H= CN$=…………………W

Eddy current loss, $W_E= DN^2$=………………W

Total Stray loss= $AN+ BN^2+ C N+ DN^2$=…………W

RESULT

The stray losses at rated speed and rated excitation of a DC shunt machine has been separated in to following components

Brush friction loss=………………W

Bearing friction and windage loss=…………….W

Hysteresis loss=………….W

Eddy current loss=……………W

Experiment No:5

SUMPNER'S TEST

AIM

To predetermine the efficiency and regulation of transformer at various loads and power factor.

APPARATUS REQUIRED

Sl. No:	Apparatus	Specification*	Quantity
1	1Φ Transformer	240/120 V, 2 KVA	2
2	Voltmeter	0-150 V, MI	1
3	Voltmeter	0-600 V, MI	1
4	Voltmeter	0-75 V, MI	1
5	Ammeter	0-2A, MI	1
6	Ammeter	0-10A, MI	1
7	Wattmeter	150 V, 5A, LPF 75V,10A,UPF	1 1
8	Auto transformer	0-270 / 8 A, 1Φ	2

PRINCIPLE

The Sumpner's test is also called as back to back test or regenerative test. This test facilitates the collection of data for OC and SC test simultaneously through a single test. However two identical transformers are needed to perform this test.

The primary windings of the two transformers are connected in parallel to rated voltage at rated frequency. The secondary windings are connected in phase opposition. A small voltage is injected to secondary windings to circulate rated current or full load current. Now the primary side wattmeter reads core loss of the two transformers and secondary side wattmeter reads copper loss of two transformers.

Determination of efficiency

Transformer Efficiency =η = output/input

η=output/ (output +copper loss +iron loss)

Output power at full load = VICosΦ

=KVA x power factor

Output power at any load = X* VI CosΦ

= load factor* KVA x power factor

The efficiency at any load = $\frac{X*KVA\cos\Phi*100}{(X*KVA\cos\Phi + W_i + X^2 W_{cu})}$

Where Wi is the iron loss and Wcu is the copper loss.

$W_i = W_0/2$; $W_{cu} = X^2 W_{sc}/2$

Determination of Voltage Regulation

The voltage regulation of a transformer is the arithmetic difference (not phasor difference) between the no-load secondary voltage ($0V_2$) and the secondary voltage (V_2) on load expressed as percentage of no-load voltage. The change in voltage from no load to full load can be replaced by the voltage drop from no load to full load.

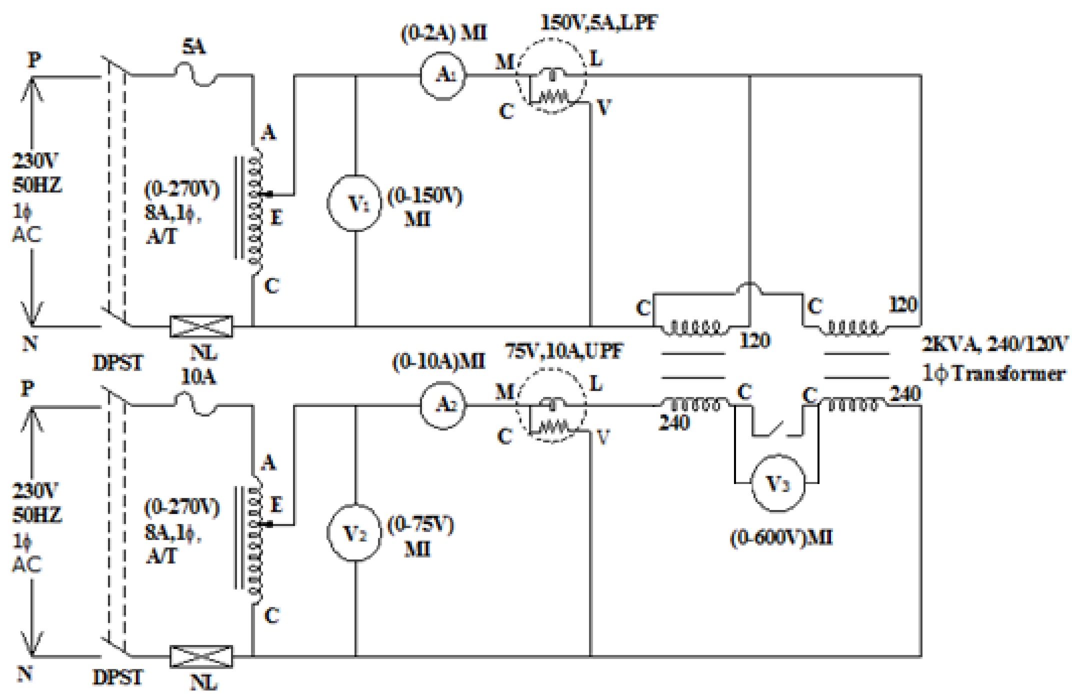
In general voltage regulation at any load and any power factor can be determined by the equation,

$$\% \text{ regulation} = \frac{X*(I_{SC}R_{02}\cos\Phi \pm I_{SC}X_{02}\sin\Phi)*100}{V2}$$

+sign indicates lagging power factor

-sign indicates leading power factor

CONNECTION DIAGRAM



PROCEDURE

1. Connections are made as per circuit diagram.
2. Keep the autotransformers in minimum position, Switch S in open position.
3. Vary the autotransformer in the primary side and set rated voltage in primary side.
4. Observe V_3.

5. If the readings show zero voltage, it means that the secondary winding connection is correct.
6. If the voltage V_3 shows double of the rated voltage, interchange the secondary winding connection.
7. Note down the readings of Voltmeter, Ammeter and Wattmeter.
8. Close the switch S.
9. Increase the voltage in the secondary by varying the autotransformer in the secondary till rated current flow through the secondary winding.
10. Note down the readings of Voltmeter, Ammeter and Wattmeter.

PRECAUTIONS

1. There should not be any loose connection in the circuit.
2. For measuring power factor at no load, a low power factor wattmeter should be used.
3. The voltmeter connected across the switch has rating twice the secondary rating of the transformer.
4. During SC test the supply voltage should be applied through an autotransformer from zero value to higher value slowly and gradually till the ammeter indicates the full load current. The measured current should not exceed the rated value.

TABULAR COLUMN

Test	Current (A)	Voltage (V)	Power (W)
OC	2Io =	Vo =	2Wo =
SC	Isc =	2Vsc =	2Wsc =

SAMPLE CALCULATION

For Efficiency

Power factor, cos Ø =……………

Load factor, X= ……………….

Output power, Po= KVA*Power factor* Load factor

=X*KVA*Cos Ø

=……………….W

Iron loss, Wi= $W_0/2$ =…………………W

Copper loss, Wcu= X^2 Wsc/2=……………….W

Input power, Pi =Po + Wi + Wcu =…………………W

Efficiency=P_0 / Pi*100

For Voltage Regulation

Power factor, cos Ø =……………

Load factor, X= ……………….

Voltage regulation for lagging power factor=X* ($I_{SC} R_{o2} \cos \Phi + I_{SC} X_{o2} \sin\Phi$)/$V_2$*100

Voltage regulation for leading power factor=X* ($I_{SC} R_{o2} \cos \Phi - I_{Sc} X_{o2} \sin\Phi$)/$V_2$*100

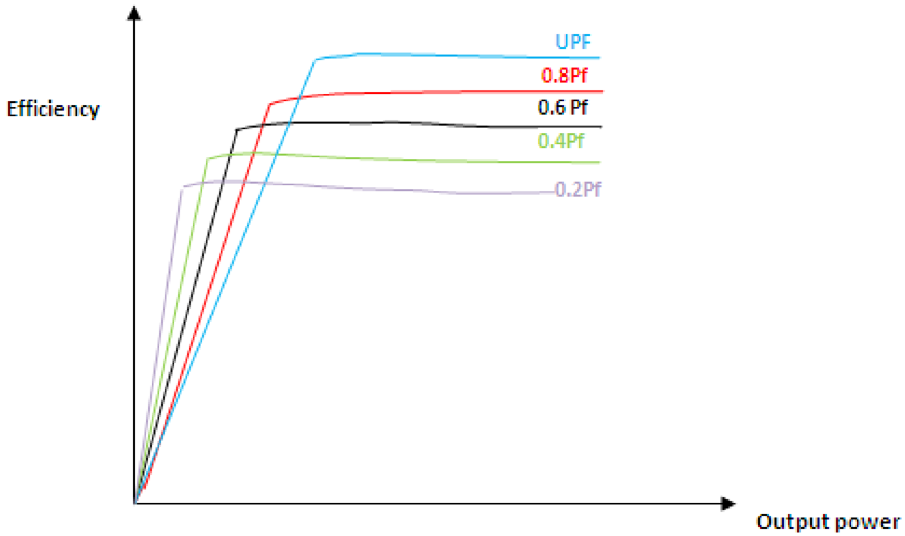
For finding efficiency of the transformer

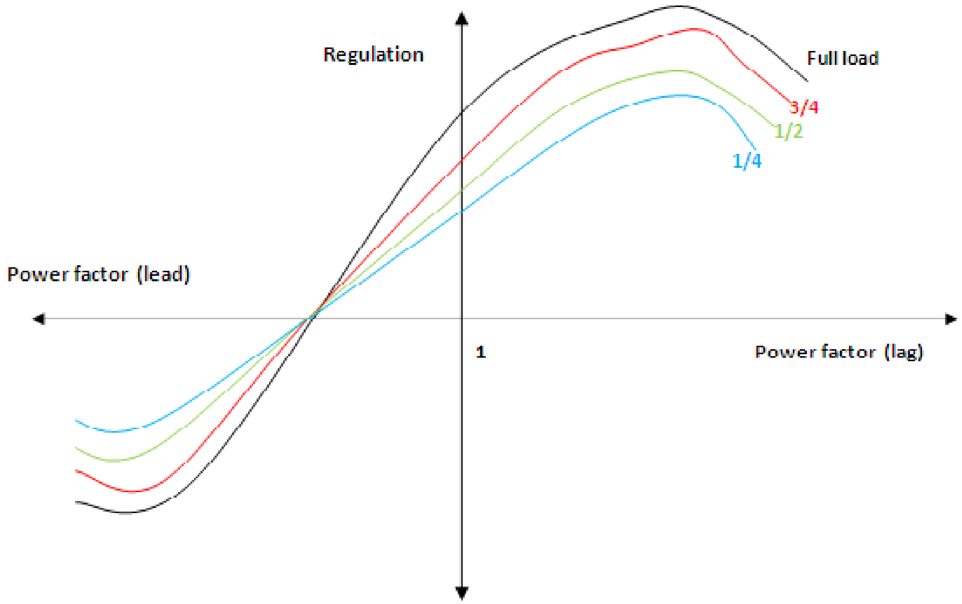
Sl No	Power factor	Load factor	Output Power (W)	Iron Loss (W)	Cu Loss (W)	Input Power (W)	Efficiency (%)
1 2 3 4	1	¼ ½ ¾ 1					
1 2 3 4	0.8	¼ ½ ¾ 1					
1 2 3 4	0.6	¼ ½ ¾ 1					
1 2 3 4	0.4	¼ ½ ¾ 1					
1 2 3 4	0.2	¼ ½ ¾ 1					

For finding Voltage Regulation of transformer

Sl No	Power factor	Load factor	Regulation (lag)	Regulation (lead)
1	1			
2	0.8			
3	0.6	1/4		
4	0.4			
5	0.2			
1	1			
2	0.8			
3	0.6	1/2		
4	0.4			
5	0.2			
1	1			
2	0.8			
3	0.6	3/4		
4	0.4			
5	0.2			
1	1			
2	0.8			
3	0.6	1		
4	0.4			
5	0.2			

SAMPLE GRAPH





RESULT

Sumpner's test has been conducted and efficiency and regulation at various loads and power factor are calculated and plotted.