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OCC OF DC SHUNT GENERATOR

Expt. No: **Date:**

Objective:

To obtain the open circuit characteristics of the given DC shunt generator at its rated speed and determine the Critical resistance and Critical speed.

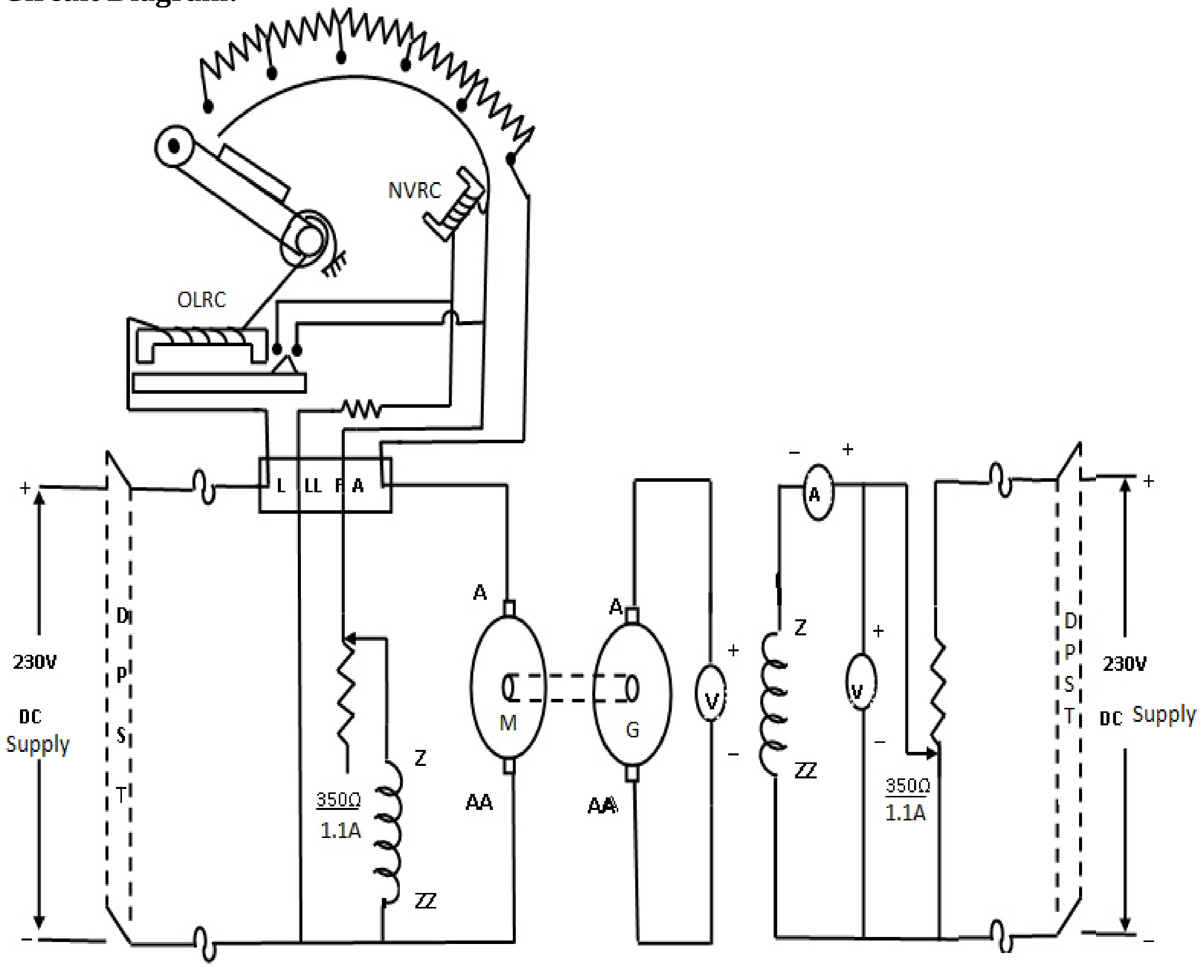
Apparatus:

S.No	Name of the Equipment	Range	Number

Name plate details:

Fuse ratings:

Circuit Diagram:



Theory:

The O.C.C is a curve showing the relationship between the no load emf generated and the shunt field current (Eo and I_f). Even when the field current is zero there is some residual magnetism present in the poles. Hence there is a small voltage generated even at zero field current, which is called the residual voltage. As the field current is increased, Eo also increases and the curve traced is almost a straight line. As I_f is further increased the poles start getting saturated, the straight line relation no longer holds good and the curve bends and becomes almost horizontal.

In a D.C. generator, for any given speed, the induced emf in the armature is directly proportional to the flux per pole.

$E_g = (\Phi ZNP)/60A$ Volts

Where Φ is the flux per pole in webers,
Z is the no. of conductors in the armature,
N is the speed of the shaft in rpm,
P is the no. of poles and
A is the no. of parallel paths.

A = 2 (wave)
A = P (lap)

Critical resistance:

It is that value of resistance in the field circuit at which the generator will just excite (or voltage build up begins). If the resistance is higher, the machine will fail to build up voltage. It is given by the slope of the tangent drawn to the linear portion of the magnetization curve from the origin.

Conditions for voltage build up in a d.c shunt generator

1. There should be some residual magnetism in the poles.
2. For the given direction of rotation, the shunt field coils should be properly connected.
3. The coils should be so connected that the flux generated by the field current aids the residual flux.
4. When excited at no load, the shunt field circuit resistance should be less than the critical resistance.

Critical speed:

It is that value of speed at which the given shunt field resistance represents the critical resistance.

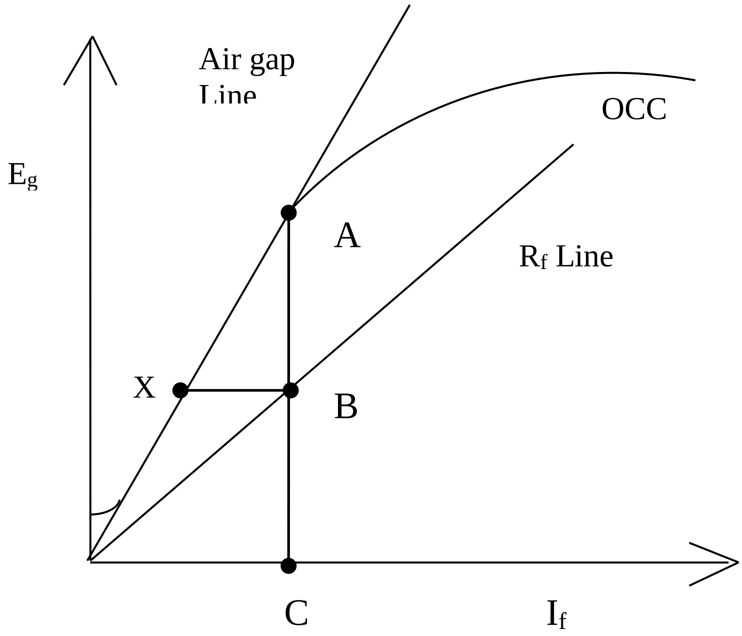
Procedure:

1. Connections are made as per the circuit diagram.
2. Motor field rheostat is kept in minimum position.
3. Generator field rheostat is kept in maximum position.
4. D.C. Generator is driven at its rated speed with the help of prime mover (DC shunt motor).
5. Gradually the field rheostat of generator is varied in steps to get field current in steps and armature terminal voltage is measured in each step.
6. Step 5 is repeated till 120% of rated voltage is obtained.
7. Then, the field current of generator is decreased and the armature terminal voltage is noted in each step.
8. The O.C.C curve is plotted

Observations:

I_f (A)			V_f (V)			E_g(V)		
Forward	Reverse	Average	Forward	Reverse	Average	Forward	Reverse	Average

GRAPHS:



Critical Speed N_C =(BC/AC)*N_S

Critical Resistance=AB/BX

RESULT:

REMARKS IF ANY:

Viva Questions:

1. What is residual voltage? How is it measured?
2. What is critical resistance? How can it be determined?
3. What are the conditions necessary for voltage build up in a d.c shunt generator?
4. What is critical speed?
5. Mention the characteristics of dc generators?

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BRAKE TEST ON DC COMPOUND MOTOR

Expt. No: **Date:**

Objective:

To conduct brake test on DC compound motor for long shunt cumulative & differential connections and to draw the performance characteristics.

Apparatus:

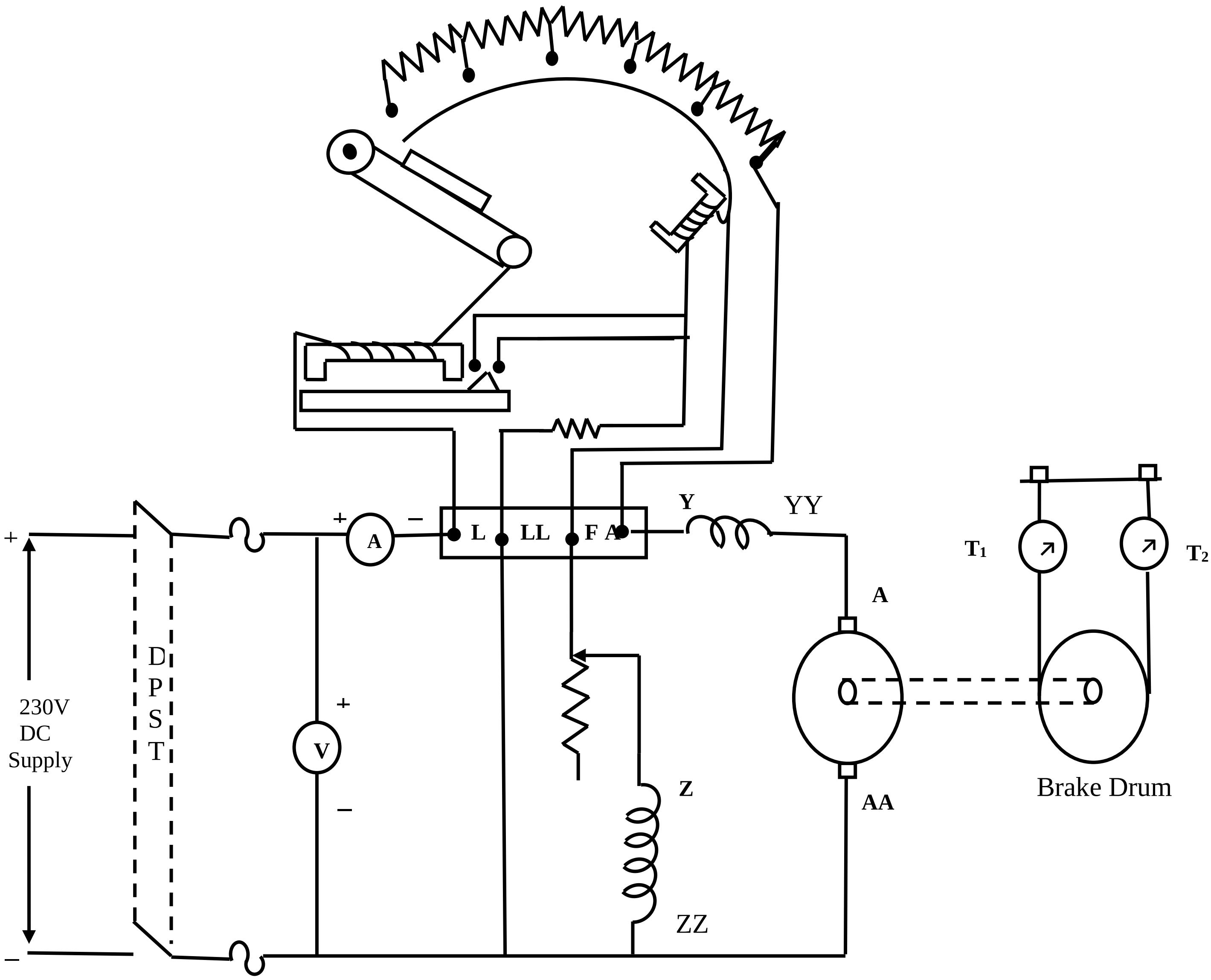
S.No	Name of the Equipment	Range	Number

Name plate details:

Fuse ratings:

Circuit Diagram:

Cumulative Compound Motor:



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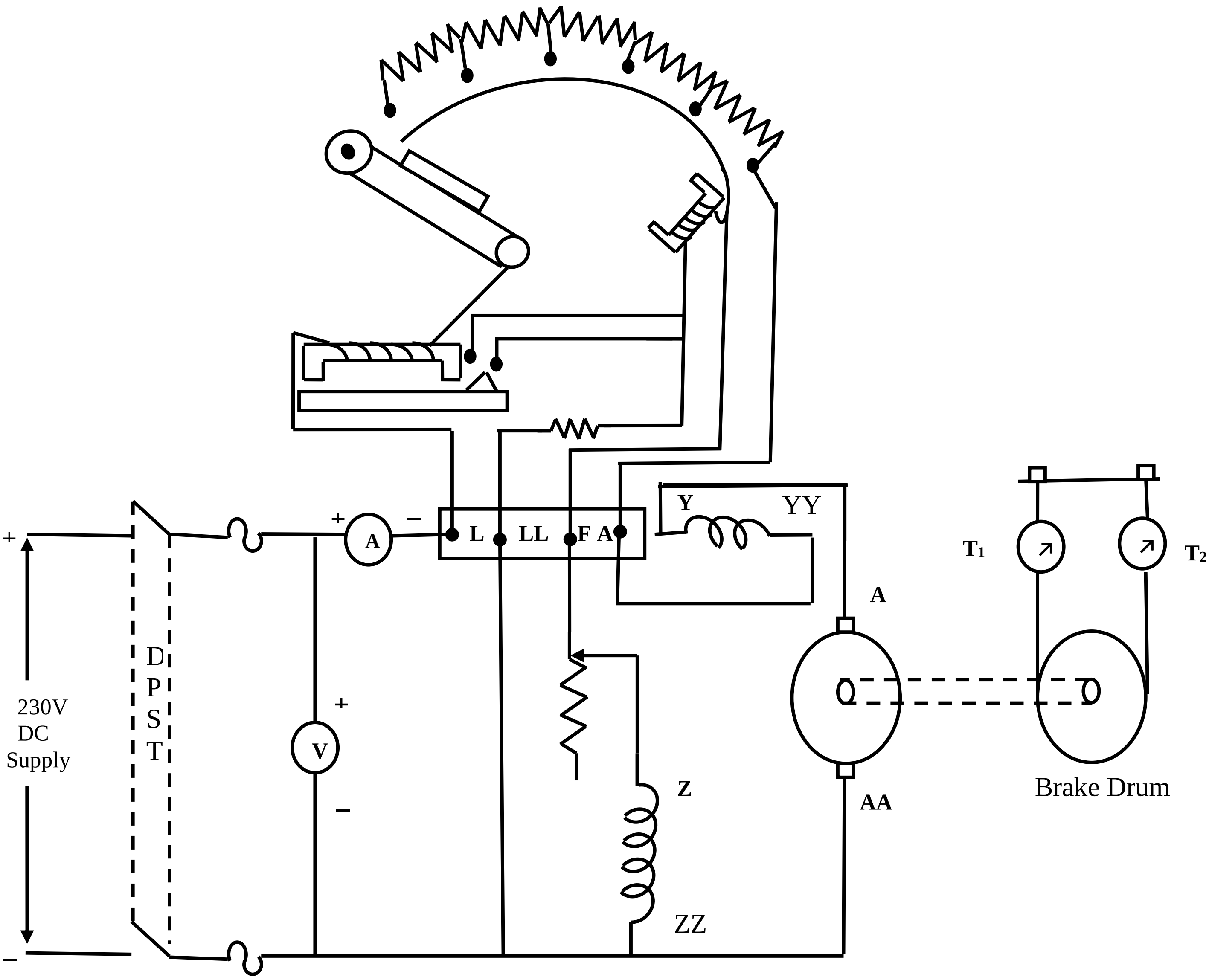
Differential Compound Motor:



Theory:

This is a direct method of testing a dc compound motor as a cumulative and as a Differential compound motor. In this method, a rope is wound round the pulley and its two ends attached to two spring balances S_1 and S_2. The tensions on the rope T_1 and T_2 can be adjusted with the help of swivels. The force acting tangentially on the pulley is equal to the difference between the readings of the two spring balances.
Power developed in the motor at the shaft = Pout = T × ω watts
where $\omega= (2\pi N)/ 60$ (N is speed in r.p.m)
T_{shaft} = F× r Newton-meter= $(T_1 \sim T_2)$ Kg * 9.8* r
Motor output $P_{out} = T_{shaft} \times \omega = (2\pi N T_{shaft})/ 60$
(R is radius of the pulley in meter and 1kg wt = 9.8 Newton)
Total power input to the motor P_{in}=Power input to the field
$P_{in} = V I_L$
% Efficiency = $(P_{out} / P_{in}) * 100$
In a separately excited cumulatively compound motor Φ_{sh} is constant. Hence, Φ_{se} increases with increase in the load or armature current. Thus, the speed drops at a faster rate in a cumulative compound motor than in a shunt motor.
$T_a=K\Phi I_a$.
Where $\Phi = \Phi_{sh} + \Phi_{se}$; Φ_{sh} is constant. Φ_{se} increases with increase in I_a. Hence T_a increases.

If Φ_{sh} is stronger than Φ_{se}, the $T_a \sim I_a$ characteristic and Speed ~Torque characteristic approaches to the shunt motor characteristics. If Φ_{se} is stronger than Φ_{sh}, above characteristics approaches to the series motor characteristics.

In a Differential Compound motor, the series flux opposes the shunt flux. With increase in Ia, the net flux in the air gap deceases. Thus, the motor speed increases slightly with load.

Hence, it can be designed to give a constant speed under all load conditions.
Procedure:

1) Circuit is connected as per the circuit diagram.
2) The field rheostat of motor is kept at minimum position.
3) Machine is started at no load initially, speed is adjusted with the help of its rheostat at the rated speed and meter readings are noted.
4) By increasing load on the brake drum and by tightening the belt the corresponding meter readings are noted.
5) The same procedure is followed for differential compound motor also.

Observations:

Cumulative Compound Motor:

Voltage(V)	I_L (A)	Speed (N) (RPM)	Balance		Torque $T=(T_1 \sim T_2)rg$	O/p= $\frac{2\pi NT}{60}$	I/p= $V\ I_L$	%η= (O/p / I/p)*100
			T_1 Kg	T_2 Kg				

Differential Compound Motor:

Voltage(V)	I_L (A)	Speed (N) (RPM)	Balance		Torque $T=(T_1 \sim T_2)rg$ (Nm)	O/p= $\frac{2\pi NT}{60}$	I/p= V I_L	%η= [O/p / I/p]*100
			T_1 Kg	T_2 Kg				

Sample Calculations:

Cumulative compounding:

Input Voltage (V)= 224 V

Input current = I_L= 4.8 A

N= 1602 rpm

T1 = 0.3 kg; T2 =2.7 kg.

T=(T1-T2)rg = (2.7-0.3)80.155*9.8 = 3.64 Nm

Output = O/p= (2πNT)/60 = (2*3.14*1602*3.64)/60= 610.65 W

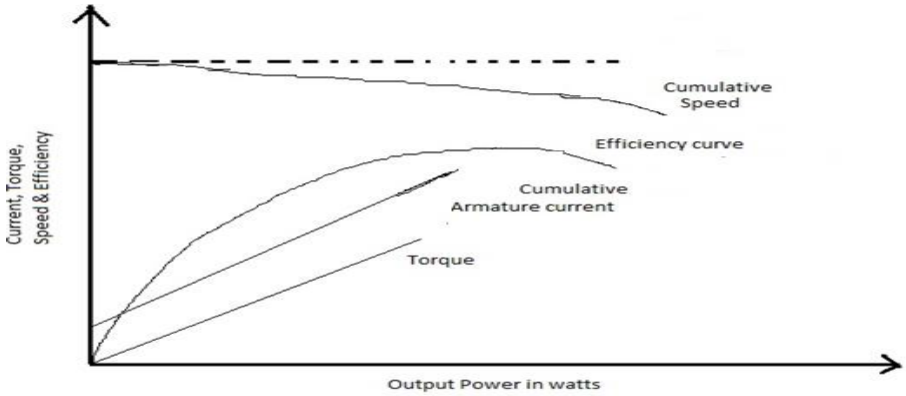
Input = VI_L= 224*4.8 = 1075.2W

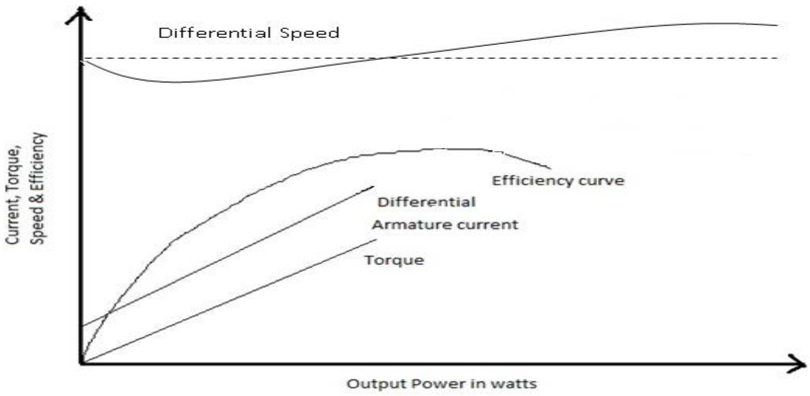
%Efficiency = %η=[(O/p) / (I/p)]*100 = 610.65/1075.2 = 56.2%

Differential Compounding:

Input Voltage (V)= 225 V
Input current = I_L= 3.2 A
N= 1670rpm
T_1 = 0.2 kg; T_2 =0.9 kg.
T=(T_1-T_2)rg = (0.9-0.2)*0.155*9.8 = 1.06 Nm
Output = O/p= (2πNT)/60 = (2*3.14*1670*1.06)/60 = 185.67W
Input = VI_L= 225*3.2 = 720W
%Efficiency = %η = [(O/p) / (I/p)]*100 = 185.67/720 = 25.7%

Graphs:





Result:

Remarks if any:

Viva Questions:

1. On what principle does DC motor operates?
2. What are the applications of DC Compound motors?
3. What is the typical brush drop in DC motors?
4. Draw different characteristic curves of DC compound motors?
5. Write the difference between cumulative compound and differentially compound dc motor?

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SWINBURNE'S TEST

Expt. No: **Date:**

Objective:
To conduct Swinburne's test on DC shunt machine and to predetermine its efficiency both as a Generator and Motor.

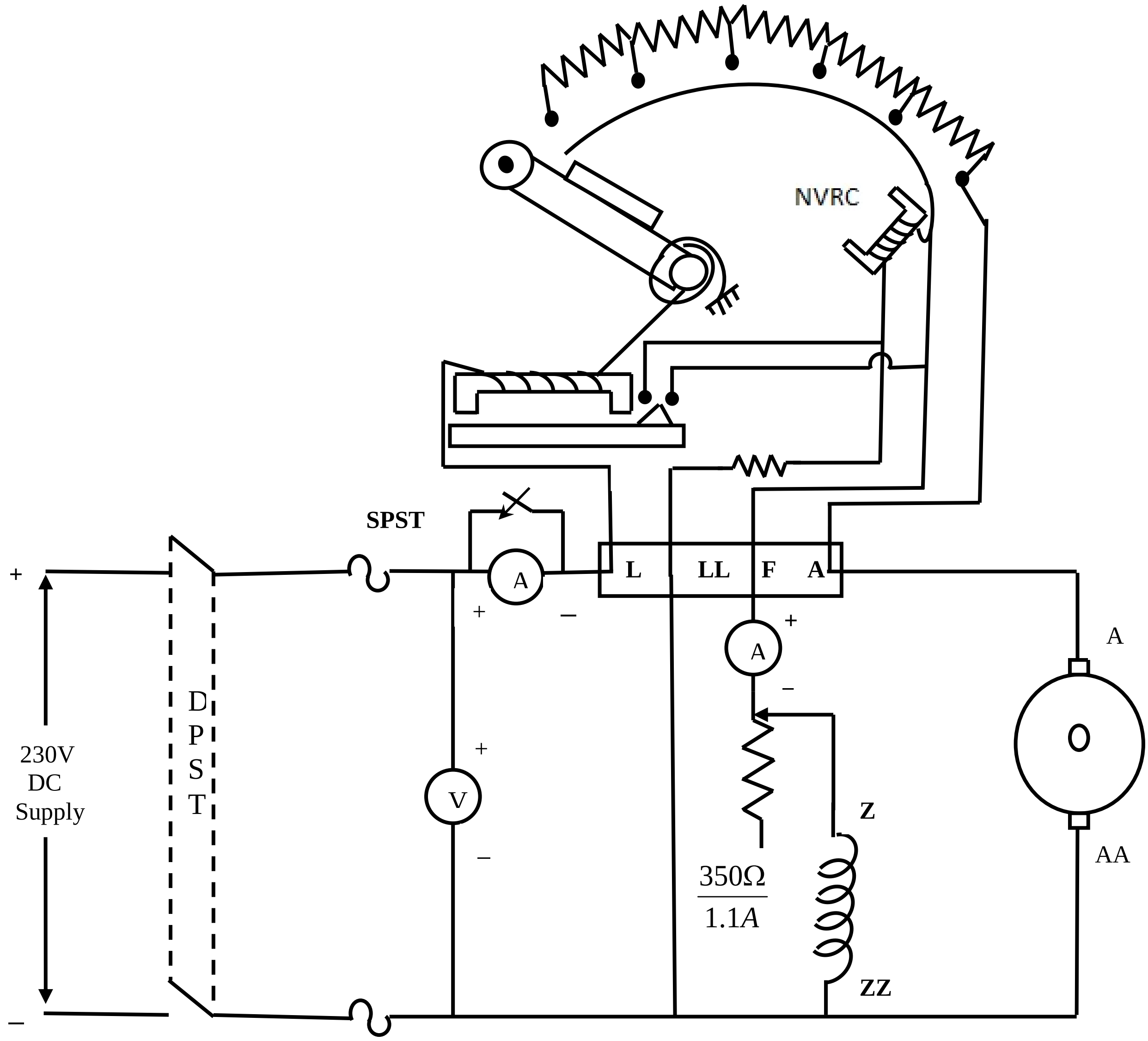
Apparatus:

S.No	Name of the Equipment	Range	Number

Name plate details:

Fuse rating:

Circuit Diagram:



Theory:

Testing of D.C. machines can be divided into three methods: (a) direct, (b) regenerative, and (c) indirect Swinburne's Test is an indirect method of testing a D.C. machine. In this method, the constant losses of the D.C. machine are calculated at no-load. Hence, its efficiency either as a motor or as a generator can be pre-determined. In this method, the power requirement is very small. Hence, this method can be used to pre-determine the efficiency of higher capacity D.C. machines as a motor and as a generator.

Disadvantages:

(1) Efficiency at actual load is not accurately known.

(2) Temperature rise on load is not known.

(3) Sparking at commutator on load is not known.

Losses in a D.C. Machine:

The losses in a D.C. machine can be divided as 1) Constant losses, 2) Variable losses, which changes with the load.

Constant losses:

Mechanical Losses: Friction and Windage losses are called mechanical losses. They depend upon the speed. A D.C. shunt machine is basically a constant speed machine both as a generator and as a motor. Thus, the mechanical losses are constant.

Iron Losses: For a D.C. shunt machine, the field current hence the flux. Hence, hysteresis and eddy current losses (which are also called as iron losses) remain constant.

Field Copper Losses: Under normal operating conditions of a D.C. shunt machine, the field current remains constant. Thus, power received by the field circuit (which is consumed as field copper losses) is constant. Constant losses in a D.C. shunt machine = Mechanical losses + Iron Losses + Field copper losses

Variable Losses:

The power lost in the armature circuit of s D.C. machine increases with the increase in load. Thus, the armature copper losses are called as variable losses.

Procedure:

1. Connections are made as per the circuit diagram.
2. Motor field rheostat is kept in minimum position.
3. The SPST switch is kept in closed position on no load.
4. Supply is given & motor is started with the help of four-point starter.
5. The field rheostat is adjusted till the rated speed is achieved.
6. Switch is opened and currents I_L, I_F & Voltmeter reading are noted.
7. The efficiency of machine is calculated both as motor and generator by assuming the load to be increased in steps from no-load to rated value.

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Observations:

Motor:

V	I_L (A)	I_F(A)	$I_a = I_L - I_f$	P_L	Input (VI_L)	Output ($VI_L - P_L$)	%Efficiency= (Output/input)*100

Generator:

V	I_L (A)	I_F (A)	$I_a = I_L + I_F$	P_L	Output (VI_L)	Input ($VI_L + P_L$)	%Efficiency= (Output/input)*100

Formulae used:

No Load armature current = I_{ao} = 2.02A

No Load input = VI_{Lo} Watts = 220* 2.8 =616W

No Load armature Cu loss = $I_{ao}^2 R_a$ = 2.02*3.5 =44.88W

Shunt field losss = VI_f = 220*0.78 = 171.6W

Constant losses of machine, Pc= $VI_{Lo} - I_{ao}^2 R_a - VI_f$ = 616 – 44.88 -171.6 =399.52W

Where I_a = Armature current (at any load) R_a = Armature resistance = 3.5Ω

As Motor:

Load current = I_L amps = 6A

Field current = I_f amps = 0.78A

Armature cu loss= $I_a^2 R_a$ watts = $(5.722)^2$ *3.5 =114.59W

$I_a = I_L - I_f$ = 6-0.78 = 5.22A

Total losses, $P_L=P_C$+ armature 'cu' loss + Shunt field losses =399.52+114.59+171.6 =685.71W

Input power = V I_L watts = 220*6 =1320W

Output power = input-total losses=VI_L-P_L Watts = 1320-685.71 =634.29W

Efficiency = (output/input) * 100 = (VI_L-P_L / VI_L)*100 = (634.29/1320)*100=48.05%

As Generator:

Load current =I_L amps=6A

Field current =I_f amps=0.78A

$I_a = I_L + I_f$ = 6.78A

Armature cu loss= $I_a^2 R_a$ watts = $(6.78)^2$*3.5 = 160.88W

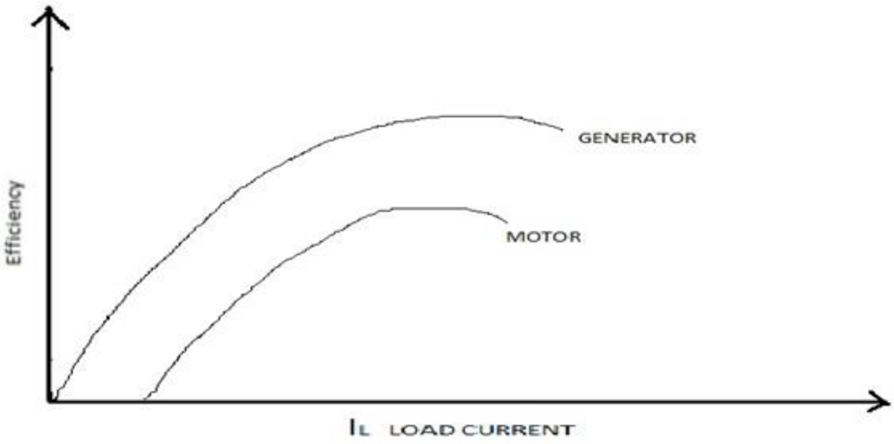
Total losses, $P_L=P_C$+ Armature 'cu' loss + Shunt field losses = 399.52+160.88+171.6= 732W

Output power =V I_L watts = 220* 6 = 1320W

Input power=Output + total losses=VI_L+P_L =1320+732= 2052Watts

Efficiency = (output/input) * 100 = (VI_L/ VI_L+P_L)*100 =(1320/2052)*100 = 64.32%

Graphs:



Result:

Remarks if any:

Viva Questions:

1. What is the purpose of Swinburne's test?
2. What are constant losses in a DC machine?
3. What are the assumptions made in Swinburne's test?
4. Why is the indirect method preferred over direct loading test?
5. The efficiency of DC machine is generally higher when it is working as a generator than when is working as a motor. Is this statement true or false? Justify your answer with proper reasons

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SPEED CONTROL OF DC SHUNT MOTOR

Expt. No: **Date:**

Objective:

To conduct an experiment on DC shunt motor for its speed control using (i) Flux control method (ii) Armature control method.

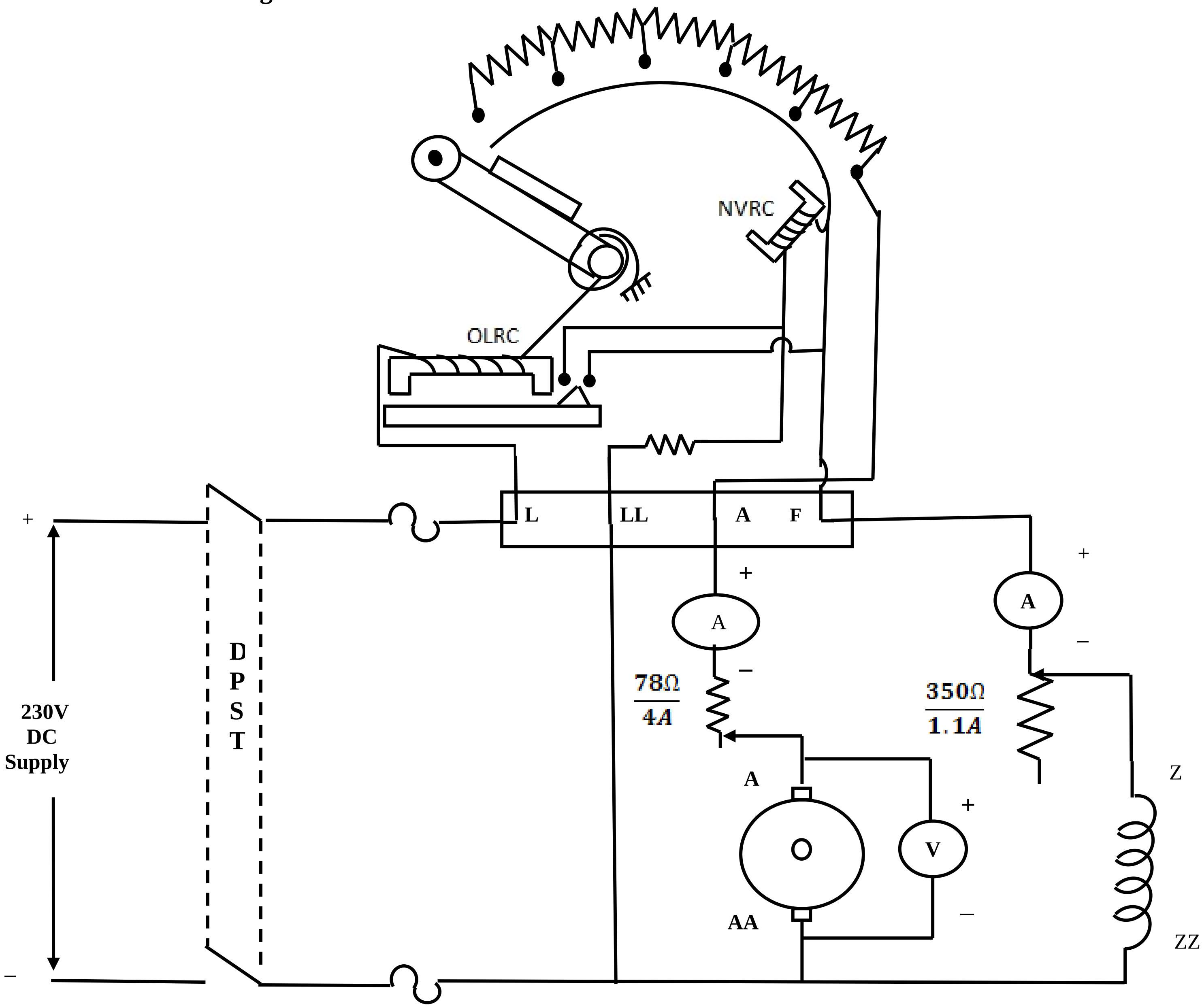
Apparatus:

S.No	Name of the Equipment	Range	Number

Name plate details:

Fuse ratings:

Circuit diagram:



Theory:

Any D.C. motor can be made to have smooth and effective control of speed over a wide range. The shunt motor runs at a speed defined by the expressions.

$E_b = \Phi ZNP/60A$ and $E_b = V - I_aR_a$

$N = (V - I_aR_a)/K\Phi$ where $K = ZP/60A$

Since I_aR_a drop is negligible $N \alpha 1/\Phi$ or $N \alpha 1/I_f$

Where N is the speed, V is applied voltage, Ia is the armature current, and Ra is the armature resistance and Φ is the field flux.

Speed control methods of shunt motor:

1. Applied voltage control.
2. Armature rheostat control.
3. Field flux control.

Applied voltage control:

In the past, Ward-Leonard method is used for Voltage control method. At present, variable voltage is achieved by SCR controlled AC to DC converter unit is used to control the speed of a motor. In this method, speed control is possible from rated speed to low speeds.

Armature rheostat control:

Speed control is achieved by adding an external resistance in the armature circuit. This method is used where a fixed voltage is available. In this method, a high current rating rheostat is required.

Disadvantages:

(a) Large amount of power is lost as heat in the rheostat. Hence, the efficiency is low.

(b) Speed above the rated speed is not possible. The motor can be run from its rated speed to low speeds.

Field flux control:

Speed control by adjusting the air gap flux is achieved by means of adjusting the field current i.e., by adding an external resistance in the field circuit. The disadvantage of this method is that at low field flux, the armature current will be high for the same load. This method is used to run the motor above its rated speed only.

Procedure:

Armature Control Method:

1. Connections are made as per the circuit diagram.
2. Motor field rheostat is kept in minimum position.
3. Armature rheostat is kept in maximum position.
4. The DC supply is switched on and the motor is started with the help of starter.
5. The speed of the motor is measured with the help of the tachometer and the voltage across the armature and the field current is noted.
6. The speed is changed by varying the rheostat in the armature circuit. During this period, the field current is constant.
7. The voltage across the armature, the field current and the speed are noted down.

Flux Control Method:

1. Connections are made as per the circuit diagram.
2. Armature rheostat is kept in minimum position.
3. Motor field rheostat is kept in minimum position.
4. The speed of the motor is changed by varying the motor field rheostat above the rated speed and meter readings are noted.
5. The above step is repeated for different speeds.

Observations:

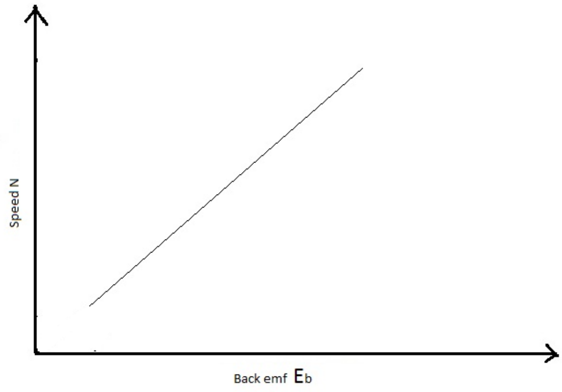
Flux control method:

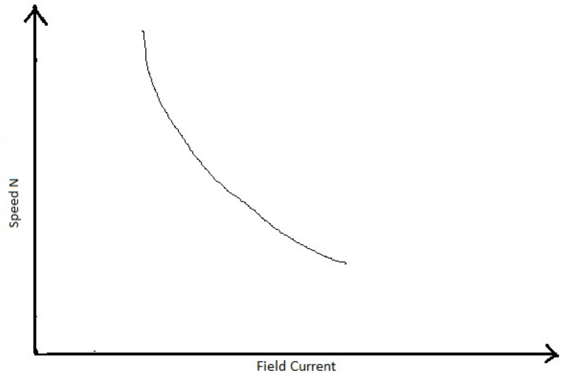
S.No	Back emf(E_b)	Field current (I_f)	Speed (N)

Armature control method:

S.No	V volts	Armature current (I_a)	Field current (I_f)	E_b=V- I_a R_a	Speed (N)

Graphs:





Result:

Remarks if any:

Viva Questions:

1. How does the speed of a DC shunt motor vary with armature voltage and field current?
2. Compare the resistance of the armature and field winding.
3. What is the importance of speed control of DC motor in industrial applications?
4. Which is of the two methods of speed control is better and why?
5. Why is the speed of DC shunt motor practically constant under normal load condition?

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HOPKINSON'S TEST

Expt. No: **Date:**

Objective:

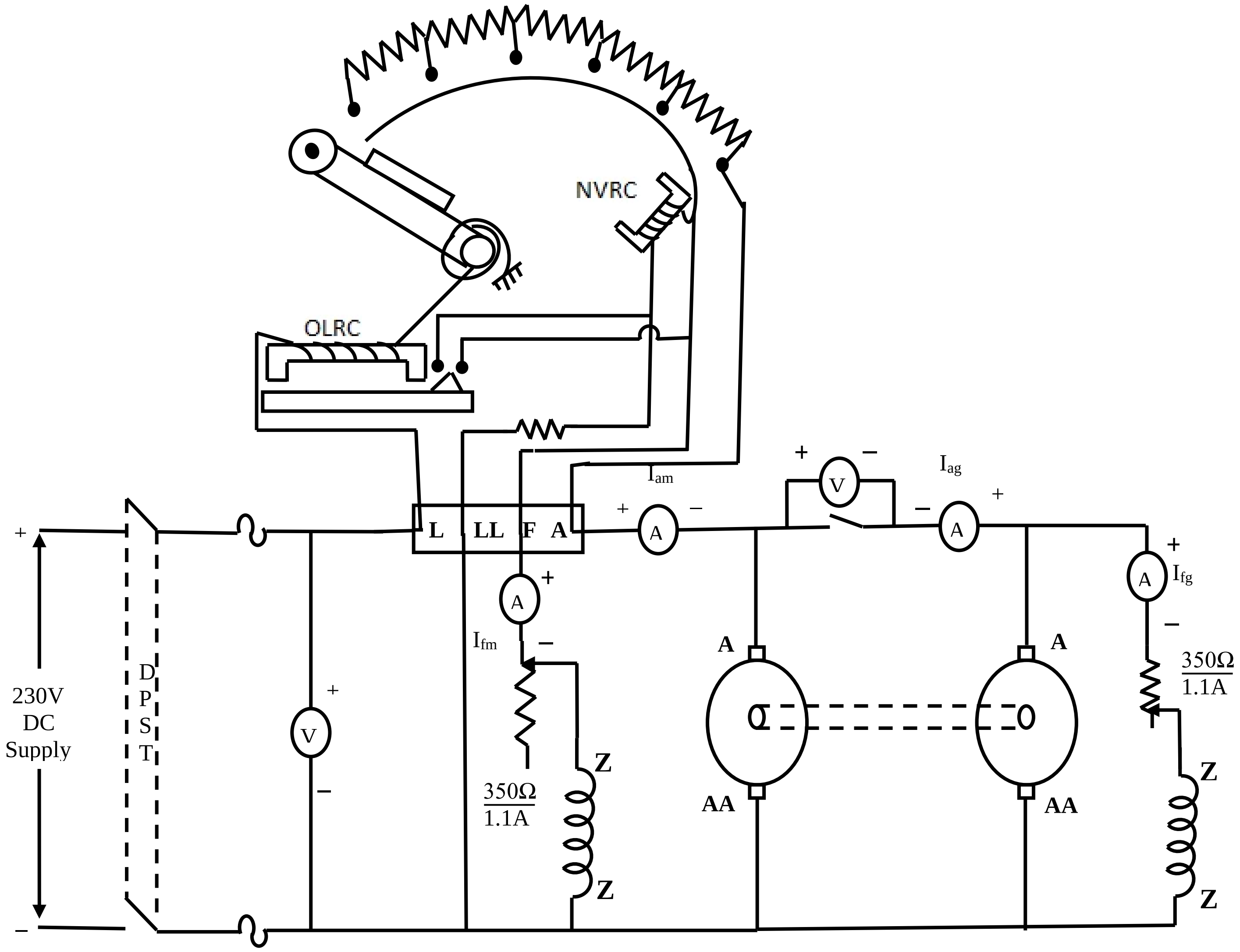
To conduct Hopkinson's test on two identical DC machines and determine their efficiencies.

Apparatus:

S.No	Name of the Equipment	Range	Number

Name plate details:

Circuit Diagram:



Theory:

To find efficiency of a dc shunt machine, the best method is to directly load it and measure its output and input. For large rating machines the direct load test method is difficult to conduct due to a) It is costly to obtain a suitable load and b) The amount of energy to be spent for testing is too large. For, these reasons, electrical engineers use indirect methods like Swinburne's test, Separation of losses, and the Retardation test etc, are used to determine the efficiency. These tests are simple to carry out but they offer no information about how the machine performs under actual load conditions. Also, because of assumptions the results obtained are not so accurate.

Hopkinson's test (also called Regenerative or Back-to-Back test) offers the advantages of load test without its disadvantages. By this method, full-load test can be carried out on two identical shunt machines without wasting theirs outputs. The two machines are mechanically coupled and are so adjusted that one of them runs as a motor and the other as a generator. The mechanical output of the motor drives the generator. The generator emf value is brought to the bus bar voltage and then paralleled it to bus bars. The electrical output of the generator is used in supplying the greater part of input to the motor. If there were no losses in the machines, then they would have run without any external power supply. But due to losses, generator output is not sufficient to drive the motor and vice versa. Thus, these losses in the machines are supplied electrically from the supply mains.

Procedure:

1. Circuit is connected as shown in the circuit diagram.
2. The motor field rheostat is kept at minimum position and generator field rheostat is kept at maximum position.
3. Motor is started with the help of starter at no load.
4. The motor is to be made to run at rated speed by adjusting the motor field rheostat value.
5. The generator field resistance is varied so that voltmeter reads zero volts across the SPST switch, at that moment SPST switch is closed.
6. The generator field resistance is varied in steps and corresponding readings are noted.

Observations:

V	I_{fm}	I_{fg}	I_{am}	I_{ag}	$I_{ag} + I_{fg}$	$I_{am}+I_{ag}$	$(I_{ag} + I_{fg})^2R_{ag}$	$(I_{am}+ I_{ag})^2R_{am}$	P_0	$\%\eta_m$	$\%\eta_g$

Sample Calculations:

Calculation of Efficiencies:

I_{am}= Current drawn by the motor from the mains=3.5A

I_{ag} = Current supplied by the generator to the motor=2A

I_{fm} = Field current of motor=0.7A

I_{fg} = Field current of generator=0.64A

V = Supply voltage=220V

The electrical output of the generator plus the small power taken from the supply, equal to the power drawn by the motor as a mechanical power after supplying the motor losses.

Motor input = $V(I_{am}+ I_{ag}+ I_{fm})$ = 220(3.5+2+0.7) = 1364W

Generator output = VI_{ag} = 220*2 =440W

Ra = armature resistance of each machine

Armature copper losses in a generator = $(I_{ag}+ I_{fg})^2 * R_{ag}$ =$(2+0.64)^2$*2.04 = 14.21W

Armature copper losses in a motor = $(I_{am}+ I_{ag})^2 * R_{am}$ = $(3.5+2)^2$*2.09 =63.22W

Shunt copper losses in a generator = $V * I_{fg}$ =220* 0.64 = 140.8W

Shunt copper losses in a motor = $V * I_{fm}$=220* 0.7 = 154W

Motor and Generator losses are equal to the power supplies by the mains.

Power drawn from supply = VI_{am} =220* 3.5 = 770W

Stray losses of both the machines = W_{TS}= VI_{am} -[$(I_{am}+ I_{ag})^2 * R_{am}$

+ $(I_{ag}+ I_{fg})^2 * R_{ag}$+$(I_{fg})^2$* R_{shg}]= 770-(63.22 +14.21+140.8) = 692.7W Watts

Therefore, total stray losses for the set W_{Ts} = 692.7 Watts

The stray losses are approximately equal in two machines.

Stray losses per machine = Ws = W_{TS} / 2 = 346.35W

For Generator:

Total losses W_g = $(I_{ag}+ I_{fg})^2 * R_{ag}$ +I_{fg} V + Ws = 14.21+140.8+346.35 = 501.26W

Output = VI_{ag} =220*2 = 440W

Therefore % efficiency (η_g) = (VI_{ag} / (VI_{ag} + Wg))*100= [440/(440+501.26)]*100 =46.74%

For Motor:

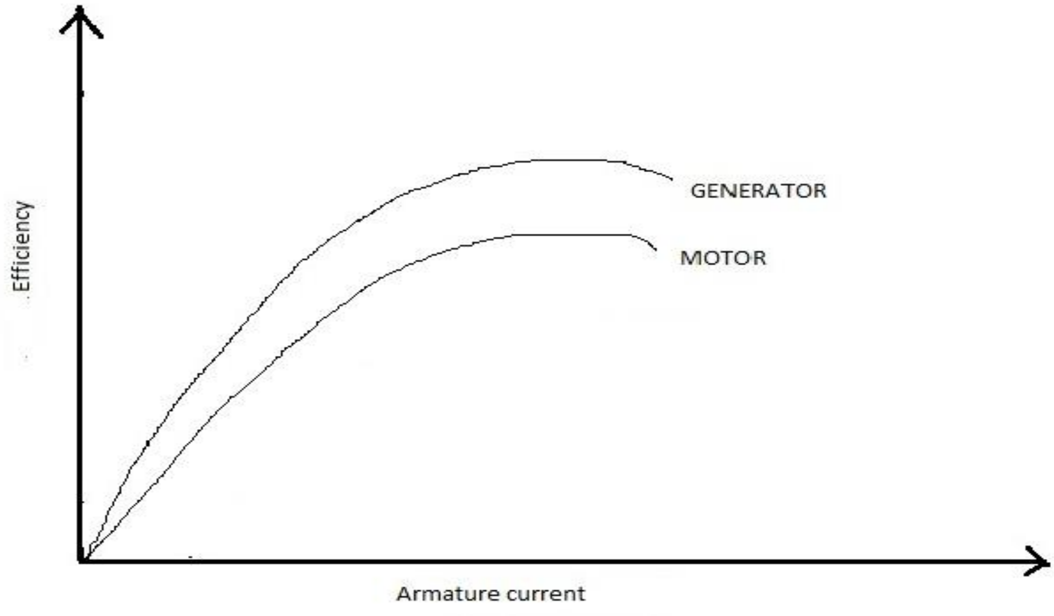
Total losses = W_m = $(I_{am}+ I_{ag})^2 * R_{am}$ + $V * I_{fm}$ +Ws = 63.22+154+346.35 = 563.57W

Input Pin = $V(I_{am}+ I_{ag}+ I_{fm})$= 1364W

Output $P_o = P_{in} – W_m$ = 1364 – 563.57 = 800.47W

Therefore % efficiency(η_m) = (P_o / P_{in})*100= (800.47/1364)*100= 58.69%

Graphs:



Result:

Remarks if any:

Viva Questions:

1. What is the need of conducting Hopkinson's test?
2. Why this test is known as regenerative test?
3. What is the purpose of voltmeter connected across the SPST switch?
4. The efficiency is more for dc machine when working as a generator than when working as a motor operation. Explain why?
5. What is the significance of back emf in DC motors?

FIELD'S TEST ON TWO IDENTICAL DC SERIES MACHINES

Expt. No: **Date:**

Objective:

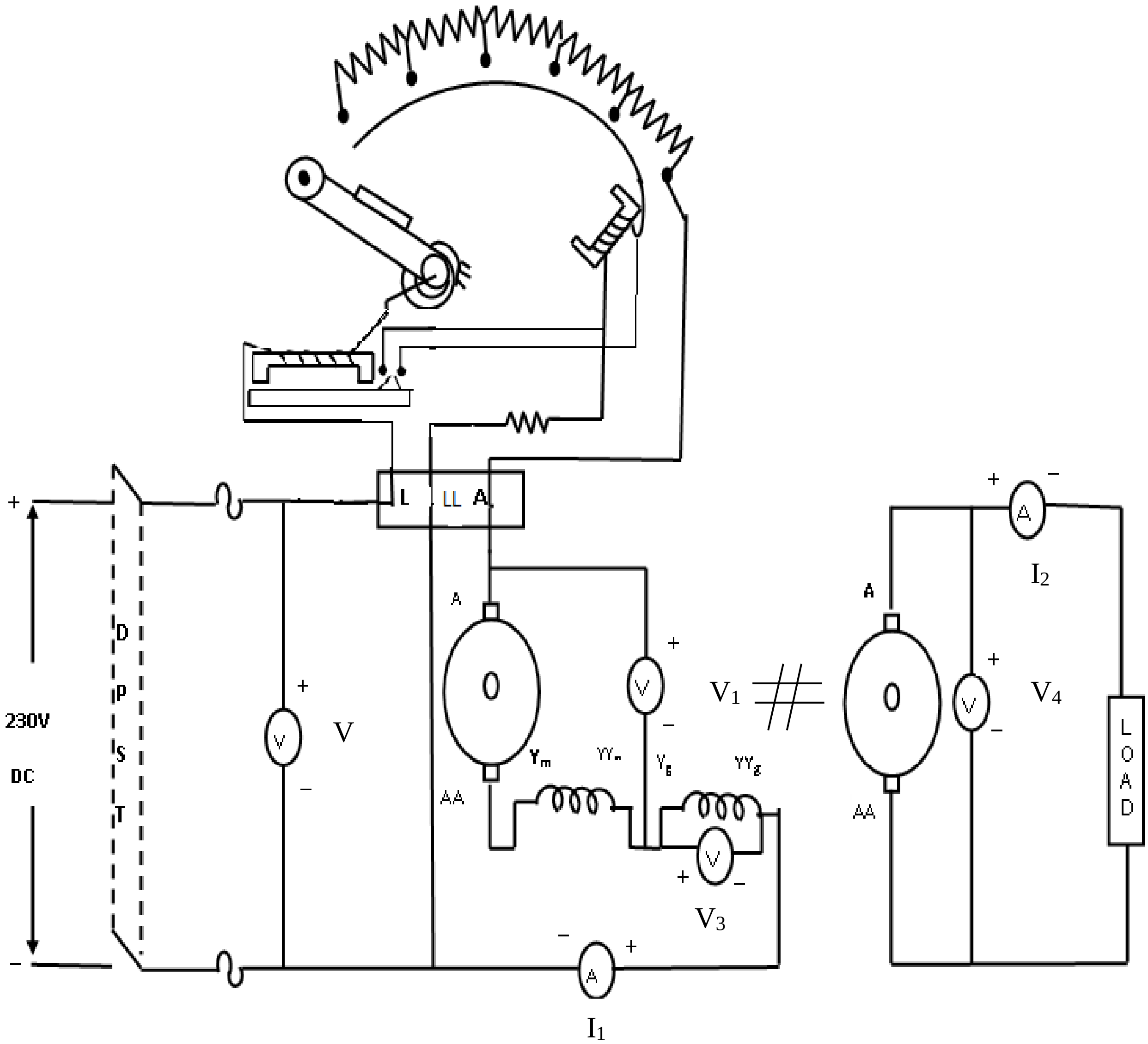
To conduct Field's test on two identical DC series machines and to calculate the efficiency of a given DC series machine.

Apparatus:

S.No	Name of the Equipment	Range	Number

Name plate details:

Circuit Diagram:



Theory:

In a series motor, the field winding is connected in series with the armature winding. Thus the same current flows through the field and armature windings.

Electrical characteristics(T vs I_a) :-

It shows the variation of torque with the armature current. We have T α ΦI_a where Φ is the flux/pole α Ia (as Φ α I_a up to the point of magnetic saturation)

Thus T α I^2_a

However after magnetic saturation Φ remains almost constant, Hence T α I_a. Thus the curve is a parabola up to magnetic saturation and shows a linear variation after the point.

Mechanical Characteristics: (N vs T):- It shows the variation of speed with torque.
We have $N \alpha E_b / \Phi$ as E_b is almost constant where E_b is back emf
In a series motor $\Phi \alpha I_a$ and therefore $N \alpha 1/ I_a$
That is, as I_a increases, Speed decreases.
The same pattern is followed in the N-T characteristics. The curve traced is a rectangular hyperbola.
A series motor should never be started at no load. At no load, I_a is very small, hence the speed of the motor becomes dangerously high(as $N \alpha 1/ I_a$).

Formulae used:

Total input = VI_1

Total output = V_4I_2

Total Losses = input – output

Armature copper losses = $(R_{am}+R_{sem}+R_{seg})I_1^2 +I_2^2 R_{ag}$

Stray losses of each machine=(Total losses-Armature copper losses)/2

Motor efficiency = $[V_1I_1-I_1^2 (R_a+R_{se})\text{-Stray losses}] / V_1I_1$

Generator efficiency = $V_4I_2 / [V_4I_2 + I_2^2R_a+ I_1^2R_{seg} + \text{stray losses}]$

R_{am} = Motor Armature resistance
R_{sem} = Motor series field winding resistance
R_{seg} = Generator series field winding resistance
R_{ag} = Generator Armature resistance

Procedure:

1. The mechanical coupled machines are connected as shown in the circuit diagram.
2. Before switching on the supply, sufficient load on generator is ensured.
3. Supply is given and the machine set is started gradually using a 3 –point starter.
4. The load is adjusted on generator until rated speed is obtained.
5. Ammeter and voltmeter readings are taken and efficiency is calculated.

Observations:

V (V)	V_1 (V)	V_3 (V)	V_4 (V)	I_1 (A)	I_2 (A)	Speed (rpm)

Sample Calculations:

Total input = VI_1 Watts= 200* 13.6 = 2720W

Total output = V_4I_2 Watts = 230* 7.2 = 1656W

Total Losses = input – output Watts = 2720 – 1656 = 1064W

Armature copper losses = $(R_{am}+R_{sem}+R_{seg})I_1^2 + I_2^2 R_{ag}$ Watts = (1.3+0.38+1.16)*13.6^2 +7.2^2*2.17=637.77W

Stray losses of each machine = (Total losses-Armature copper losses)/2 Watts=(1064-637.77)/2= 213.115W

Motor efficiency = ([V_1I_1-I_1^2 (R_a+R_{se})-Stray losses] / V_1I_1)x 100 =[(180*13.6 – 13.6^2*1.68 -213.115)/180*13.6]*100= 78.6

Generator efficiency = (V_4I_2 / [V_4I_2 + $I_2^2R_a$+ $I_1^2R_{seg}$ +stray losses])x 100 = 230*7.2/[(230*7.2+7.2^2*2.17+213.115+13.6*1.16)]*100=75.4

Result:

Remarks if

Viva Questions:

1. Why a DC series motor/generator should never be stared on no - load?
2. Why a DC series motor has a high starting torque?
3. Compare the resistances of the field windings of DC shunt and series motor?
4. What are the applications of DC series motors and generators?
5. Comment on the Speed – Torque characteristics of a DC series motor.

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OC, SC TESTS ON 1-Φ TRANSFORMER

Expt. No: **Date:**

Objective:

To conduct OC, SC test on a 1-Φ transformer and hence pre-determine its efficiency and % regulation at different loads and also to determine the equivalent circuit parameters.

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Apparatus:

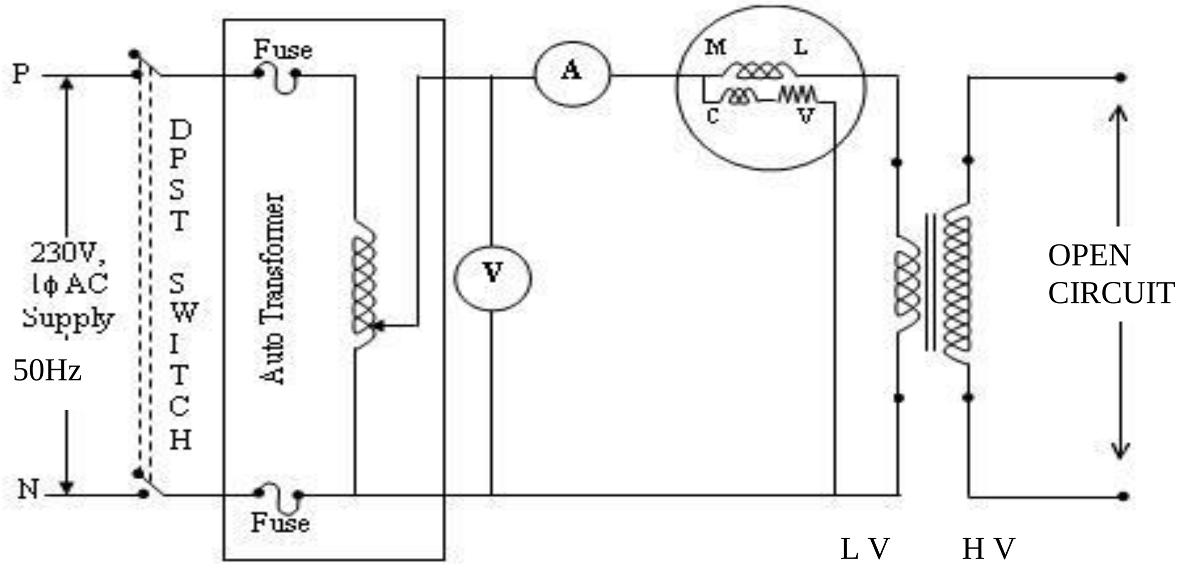
S.No	Name of the Equipment	Range	Number

Name plate details:

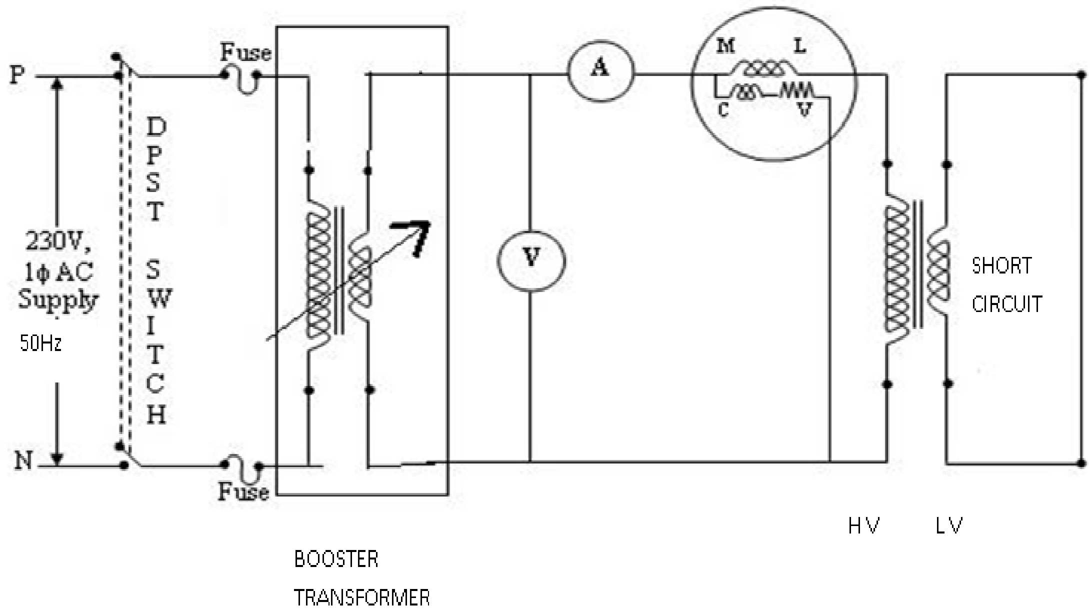
Fuse ratings:

CIRCUIT DIAGRAM:

OPEN CIRCUIT TEST:



SHORT CIRCUIT TEST:



Theory:

A transformer is a static device which transfers the electrical energy from one circuit to another circuit without any change in the frequency. The transformer works on the principle of electromagnetic induction between two windings placed on a common magnetic circuit. These two windings are electrically insulated from each other and also from the core. The losses in a transformer are (i) magnetic losses or core losses (ii) ohmic losses or copper losses. The losses of a transformer, magnetic losses and ohmic losses can be determined by performing (a) open circuit test and (b) short circuit test. From the above tests, the efficiency and regulation of a given transformer can be predetermined at any given load. The power consumed during these tests is very less as compared to the load test.

Open Circuit Test:

In open circuit test, usually HV side is kept open and meters are connected on LV side as shown in the circuit diagram. When rated voltage is applied to the LV side, the ammeter reads the no-load current I_o and wattmeter reads the power input. The no load current I_0 is 2 to 5% of full load current. Hence, the copper losses at no-load are negligible. Iron losses are the sum of hysteresis and eddy current losses.

$W_o = V_{LV}\ I_0\ \text{Cos}\phi_0$

Short Circuit Test:

This test is performed to determine the equivalent resistance and leakage reactance of the transformer and copper losses at full – load condition. In this test usually LV side is shorted and meters are connected on HV side. A variable low voltage is applied to the HV winding with the help of booster transformer. This voltage is varied till the rated current flows in the HV side or LV side. The voltage applied is 5 to 10 percent of rated voltage, while the rated current flows in the windings. The wattmeter indicates the full load copper losses and core losses at V_{SC}. But the iron losses at this low voltage are negligible as compared to the iron losses at the rated voltage.

Procedure:

O.C.TEST:

1. Connect the circuit as per the circuit diagram.
2. Rated voltage is applied to circuit on low voltage side with the help of auto transformer with high voltage side open.
3. All meter readings are taken.

S.C. TEST:

1. Connect the circuit as per the circuit diagram.
2. Rated current is applied to circuit on high voltage side with the help of booster transformer with low voltage side short-circuited.
3. All meter readings are taken.

Observations:

O.C. Test:

S.No	Input Voltage (V_0)	No load current (I_0)	Power (I/p) W_o

S.C Test:

S.No	Voltage (V_{SC})	Rated current (I_{SC})	Power (I/p) W_{sc}

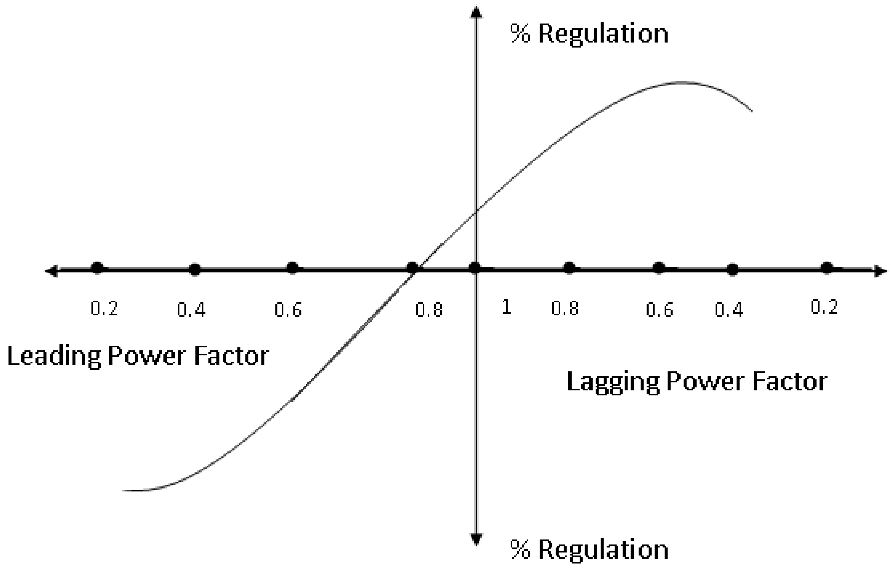
Efficiency Table:

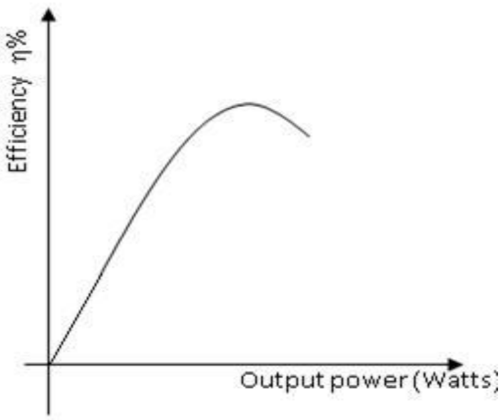
Cos Φ → ↓ Load (x) 0 to 1	0.3	0.4	0.6	0.8	1
X=1/4					
X=1/2					
X=3/4					
X=1					

Regulation Table:

Cos Φ → ↓ Load (x)	0.3		0.4		0.6		0.8		1	
	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag	Lead	Lag

GRAPHS:





Load (x)

SAMPLE CALCULATIONS:

Calculation of Ro and Xo of equivalent circuit from O.C test

V_0 = 230V, I_0 =0.4 A , W_0 = 38.4 Watts

Iron losses = $W_0 = V_0 I_0 \cos\phi_0$

Cos $\phi_0 = W_0 / V_0 I_0 =$ 38.4/220*0.42 = 0.417

Cos ϕ_0 =0.417 sin ϕ_0 = 0.9095

$I_m = I_0 \text{Sin } \phi_0$ = 0.4*sin(65.33)= 0.3635A, $I_w = I_0 \text{Cos } \phi_0$=0.4*0.417=0.167A

LV SIDE:

$R_0 = V_0 / I_w$ = 230/0.167 = 1377.24Ω

, $\mathbf{X_0} = V_0 / I_m$ =230/0.3635 = 632.737Ω

$K = V_2/V_1$ = 400/230 =1.73

HV Side: $\mathbf{R_0}$ = LV side $\mathbf{R_0 \times K^2}$ = 1377.24*1.73^2 = 4121.96Ω ; HV side $\mathbf{X_0}$ = LV side $X_0 \times K^2$ =632.737*1.73^2=1893.72Ω

Where K = Turns ratio

<u>SC TEST:</u>

Calculation of R_{01} and X_{01} for equivalent circuit

I_{sc} = 5A , V_{SC} = 25.2V , W_{sc} = 120Watts

Full load copper losses or variable losses = $W_{sc} = I^2_{sc} R_{02}$= 120

$R_{02} = W_{sc} / I^2_{sc}$ = 120/5^2= 4.8Ω $Z_{02} = V_{sc}/I_{sc}$= 25.2/5= 5.04Ω

$X_{02} = \sqrt{(Z^2_{02} - R^2_{02})}$ = 2.014Ω

Calculation of percent regulation from SC test (%Voltage Regulation)

At full load current, I_2 =8.6 A, V_2 = 230V, p.f = CosΦ= 0. 8 lag

Percent regulation (%V.R) = $(I_2 R_{02}\cos\Phi \pm I_2 X_{02}\sin\Phi)/ V_2$

(Note: + for lagging and – for leading power factors)

%V.R = [8.6*4.8*0.8 +8.6*2.014*0.6]/230 = 3.61

%V.R = [8.6*4.8*0.8 -8.6*2.014*0.6]/230 = 5.89

Efficiency Calculation from O.C and S.C tests

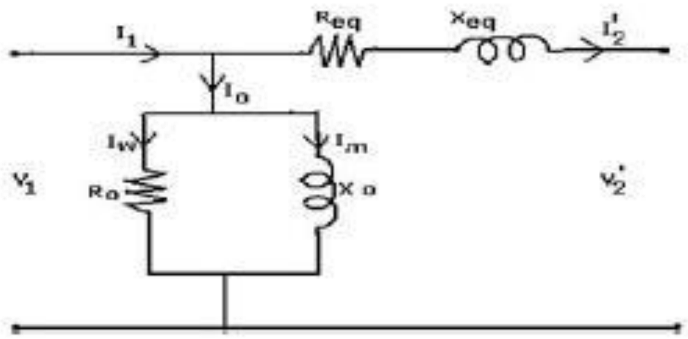
$\%\eta = (XV_2I_2Cos\Phi)/(XV_2I_2Cos\Phi + \text{Iron losses } (W_0) + \text{Copper losses at load } X\ (X^2W_{sc}))$

At full load 0.8 power factor where **X** = load (varies from 0 to 1)

$\%\eta = (\frac{1}{4} * 230 * 8.6 * 0.8)/(\frac{1}{4} * 230 * 8.6 * 0.8 + 38.4 + (1/4)^2 * 120) = 395.6/441.5$

=89.6

Diagram of Equivalent circuit of the transformer:



RESULT:

REMARKS IF ANY:

Viva Questions:

1. In OC test power supply is connected to low voltage side but in SC test power supply is connected to high voltage side of the transformer. Why?
2. How we will find (or) Identify the L.V winding and H.V winding of the transformer just by observing the outer part of the transformer. [Here number of turns are not known]
3. Why R_1, X_1 and R_0, X_m in equivalent circuit of transformer are called as linear parameters and non-linear parameters?
4. Why R_1, X_1 and R_0, X_m are connected in respective positions? Can't they be interchanged?
5. Why OC test is to be conducted at rated voltage and SC test at rated current? What will happen if tests are conducted at other than those rated voltages.

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SCOTT CONNECTION OF TRANSFORMERS

Expt. No: **Date:**

Objective:

To make Scott connection of transformers and to draw characteristics at balanced and unbalanced loads.

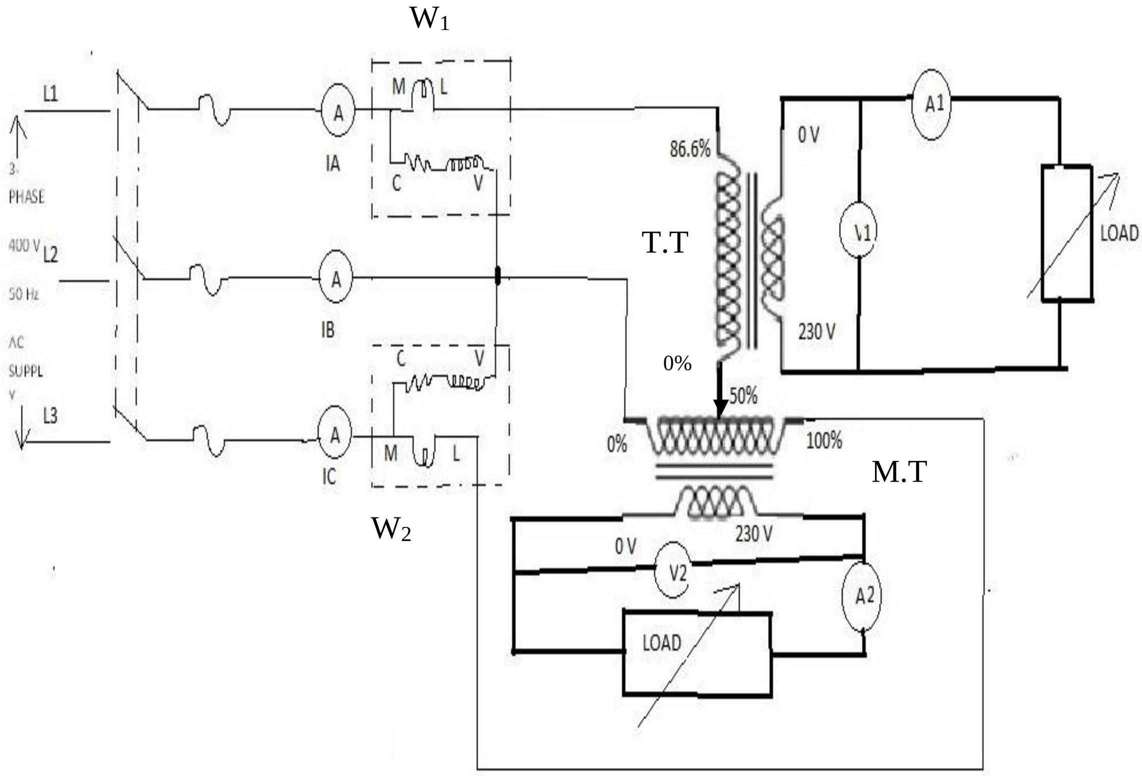
Apparatus:

S.No	Name of the Equipment	Range	Number

Name plate details:

Fuse ratings:

CIRCUIT DIAGRAM:



Theory:

Scott connection is one by which 3-phase to 2-phase transformation is accomplished with the help of two identical Transformers having same current rating. One Transformer has a center tap on primary side and it is known as Main transformer. It forms the horizontal member of the connection. Another Transformer has 0.866tap on primary side and known as Teaser transformer. The 50% tap point on primary side of the main Transformer is joined to 86.6% tap on primary of the teaser Transformer. Obviously full rating of the Transformer is not at all used. Refer to the Fig.1. The main Transformer primary winding center tap point D is connected to one end of the primary of the teaser on secondary side, both the main & teaser Transformer turns are used (not only 86.6%). Hence the voltage per turn will be equal for both Transformer. Since point D is located midway on CB, V_{AD} leads V_{CB} by 90^0 i.e, voltages across primary are 90^0. Similarly, the phase angle difference between two secondary voltages V_{ad} & V_{bc} will be 90^0 which confirms 2-Φ system on the secondary. Position of Neutral point N on primary side: Remember point D is not the neutral on primary, since its voltages w.r.t A, B, C are not equal to $V_L/\sqrt{3}$ i.e, the neutral point is that one which gives equal voltage with A, B, C. The neutral point is one third the way down the teaser transformer winding from A to D or point N divides the teaser primary winding in the ratio of 1:2. Hence the neutral must be at 86.6/3=28.8% from D. The secondaries of the two transformers gives two phase supply with 90^0 phase difference.

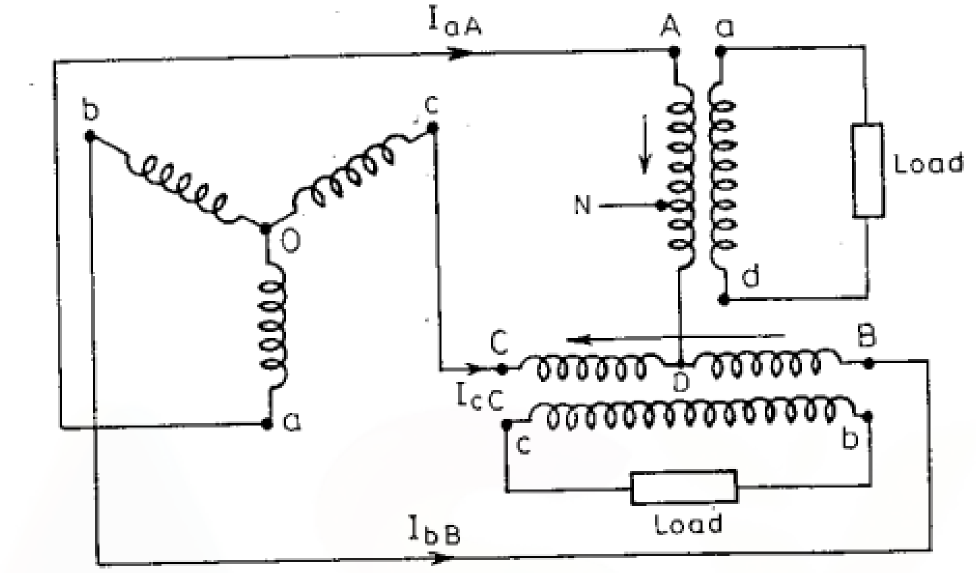


Figure 1 Schematic connection diagram

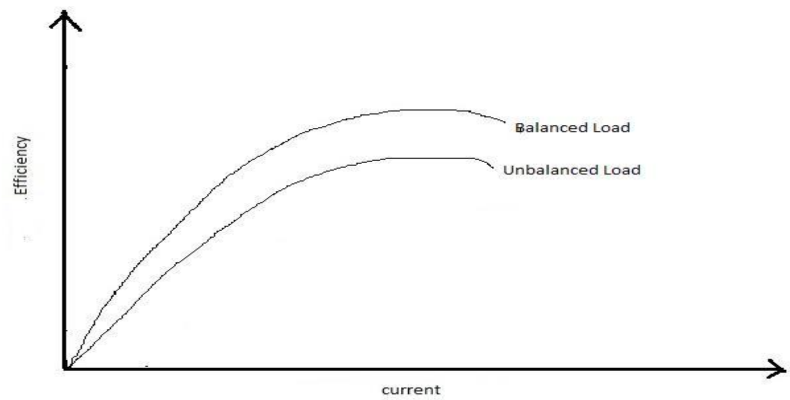
Procedure:

1. Circuit is connected as per the circuit diagram.
2. One of the two transformers primary is tapped at 86.6% and is connected to 3-phase supply.
3. 3-phase supply is fed to the circuit and readings are noted down under no load condition.
4. Loads are connected at secondary side to the two transformers and balanced loads are applied gradually then currents are balanced i.e. $I_1 = I_2$. Readings of V, I, W are noted down.
5. Unbalanced loads are applied, and then the currents I_1 & I_2 are also different. Again the readings of V, I, W are noted down.
6. Efficiencies of balanced and unbalanced loads are found.
7. A graph between efficiency and current I_A are plotted.

Observations:

	Voltage(V)	I/P Power(W_1+W_2)			I_A	I_B	I_C	V_1	I_1	V_2	I_2	% $\eta = (V_1I_1+V_2I_2)$/Input Power (W)
		W_1	W_2	W								
Balanced Loads												
Unbalanced Loads												

Graphs:



SAMPLE CALCULATIONS:

Input Power = W_1+W_2 = Watts;

Output Power = $V_1I_1+V_2I_2$ = Watts

Efficiency (η) = (Out Power / Input Power) X 100

Result:

Remarks if any:

Viva Questions:

1. What is phase displacement for 3-ø to 2-ø system. Give any two applications of scott connection.
2. What is tapping point for Teaser and Main transformer? Teaser and Main transformers must be identical (or) not?
3. What about the position of neutral point in scott connected transformers.
4. What about KVA rating of scott- connected transformers?
5. Derive the conversion of 3-ø to 2-ø by the vector diagram?

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SEPARATION OF CORE LOSSES OF A 1-Φ TRANSFORMER

Expt. No: **Date:**

Objective:

To separate the iron losses of a single-phase transformer i.e. hysteresis and eddy current losses.

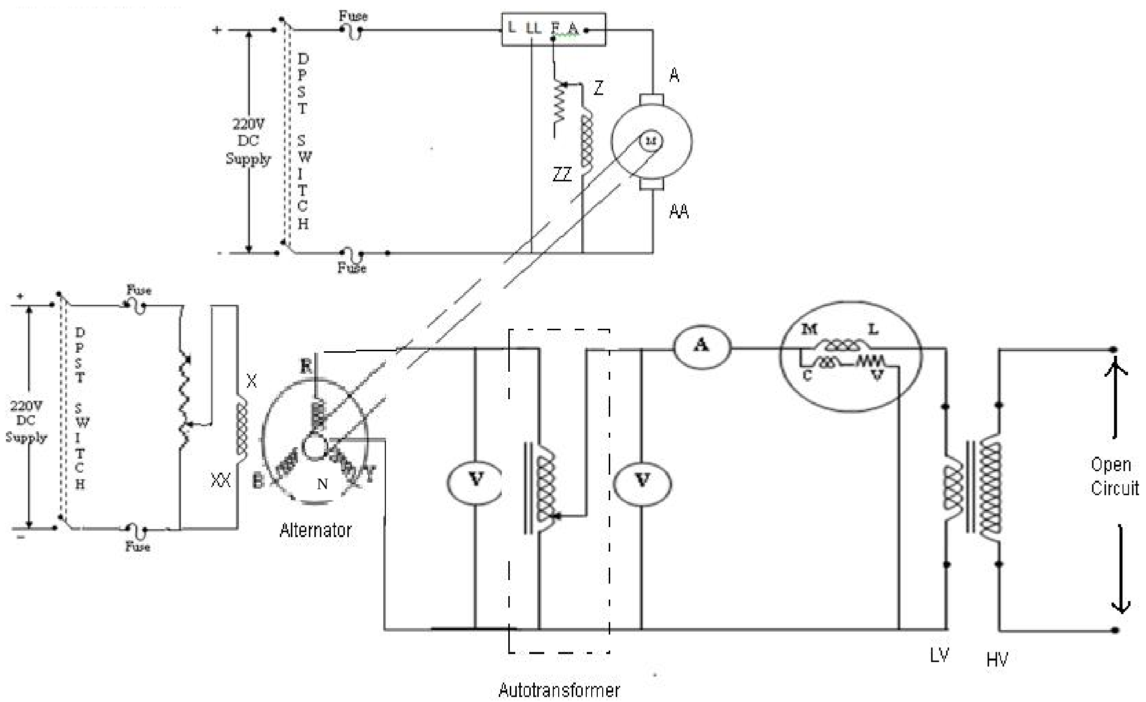
Apparatus:

S.No	Name of the Equipment	Range	Number

Name plate details:

Fuse ratings:

CIRCUIT DIAGRAM:



Theory:

There are mainly two types of losses in a transformer. i.e. Core loss (Iron losses) and Ohmic (Copper) losses. Core loss mainly depends on frequency and maximum flux density when the volume and thickness of core laminations are given.

Hysteresis and eddy current losses are called iron losses and takes place in the core of the transformer. i.e. $P_c = P_h + P_e$. Also it is known that $P_h = K_h f B^x m$ and $P_e = K_e f^2 B^2{}_m$

K_h is proportionality constant that depends upon the volume and quality of the material. K_e is proportionality constant that depends upon the volume, resistivity of the core materials, thickness of the laminations and the units employed.

Eddy current loses also depends on the frequency f is given by $W_e = K\, B_{max}{}^2 f^2 t^2 = Bf^2$

Where B_{max} = Maximum flux density in the core weber/m^2

f = Frequency (cycles / seconds) in Hz

The iron losses will be expressed by

$P_C = P_h + P_e = K_h f B^x m + K_e f^2 B^2 \quad m = Af + Bf^2$

$Pc/f = A + Bf$

This is a equation of straight line y=mx+c, when $y=P_c/f$, C=A and m=B Eddy current & hysteresis losses can be separated when A & B are found

The variable frequency supply is obtained from an alternator when frequency can be varied.

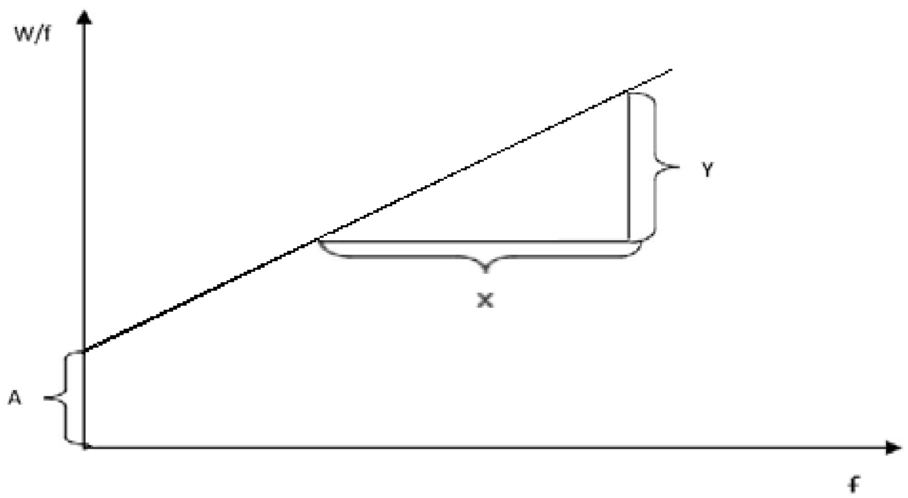
Procedure:

1. Connections are made as per the circuit diagram.
2. DPST switch is closed and the motor is started with the help of four – point starter.
3. Initially keep the motor field rheostat in minimum position and alternator field rheostat in maximum position.
4. By varying the field rheostat, the motor speed is adjusted until rated speed is obtained.
5. The field rheostat of the alternator is varied till the rated voltage of the transformer is obtained.
6. The rated voltage is given to the transformer by varying auto transformer.
7. Frequency is varied by running the alternator at different speeds by varying field rheostat.
8. To make the transformer flux constant voltage should be proportional to the variable frequency such that v/f ratio is constant.
9. Hence, by maintaining V/f constant, the readings of the voltmeter, ammeter, wattmeter and speed of the alternator are taken.

Observations:

Speed (N) rpm	Voltage V volts	Current I Amp	Power W Watts	Frequency f= pN/120	V/f	W/f

Graphs:



SAMPLE CALCULATIONS:

From the graph
K_1 =A = C=
K_2=m= B= y/x = slope of the line=

Therefore P_h= Af; P_e = Bf^2

For a frequency of 50 Hz then P_h = ; P_e =

Result:

Remarks if any:

Viva Questions:

1. What are the conditions to perform the test separation of losses why?
2. If the thickness of laminations is reduced in a transformer what will be effect on core loss.
3. Transformer designed to operate at 50Hz is operated at rated voltage and 60Hz. How it will change core loss of transformer?
4. What will happen in core loss, if a part of transformer core is replaced by a wood?
5. What are the assumptions made for ideal transformer?

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