Laboratory Manual

For

Electrical Machine-1
(PCEE-514)

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COURSE OUTCOME & CO/PO MAPPING OF PCEE-514

Course Outcomes:

After successful completion of course, the students should be able to

CO 1: Understand construction and working principle of single phase and auto transformers.

CO 2: Acquire the knowledge of three phase transformers, different type of winding connection, parallel operation and testing of transformers.

CO 3: Explain construction and working principle of DC generator and various method of improving commutation.

CO 4: Describe the construction, working principle and characteristics of DC motor

CO 5: Learn various method of starting and braking of DC motor.

CO/PO Mapping: (Strong(3) / Medium(2) / Weak(1)														
COs	Program Outcomes (POs)/Program Special Outcome (PSO's)													
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	2	3	2	2	1	2	1	2	1	2	2	1
CO2	2	1	2	3	2	2	1	2	1	2	2	2	2	1
CO3	3	1	2	3	2	2	2	1	1	2	2	2	1	1
CO4	3	2	2	3	2	2	1	1	1	2	2	1	1	1
CO5	3	2	2	3	2	2	1	1	1	2	2	1	2	2

List of Experiments of Electrical Machine-1 (PCEE-514)

1. **To perform Open circuit and short circuit tests on a single phase transformer and hence find equivalent circuit, voltage regulation and efficiency.**
2. **To perform Load test on a single phase transformer.**
3. **To separate core losses of single phase transformer at no-load.**
4. **To perform parallel operation of two single phase transformers.**
5. **To study the various connections of three phase transformer.**
6. **To perform Scott connections on three phase transformer to get two phase supply.**
7. **To study the constructional details of direct current (DC) machine.**
8. **To measure armature and field resistance of direct current (DC) machine.**
9. **To draw the open circuit characteristics (OCC) of DC shunt generator.**
10. **To draw the Load characteristic of DC shunt generator.**
11. **To perform speed control of a DC motor using field control and armature control method.**
12. **To perform Swinburne's test (no load test) to determine losses of direct current (DC) shunt motor.**
13. **To perform Hopkinson Test on DC machine.**

To understand the practicability of Electrical Machine-I, the list of experiments is given below to be performed (at least 10) in the laboratory.

Experiment-01

Aim: To Perform Open Circuit and Short Circuit on A Single Phase Transformer.

Apparatus Required:

S. No.	Apparatus Required	Specifications	Quantity
1.	Transformer	115/230V	1
2.	Variac	230V, 1-phase, 50Hz	1
3.	Wattmeter	0-440V, 0-2.5A.(for OC) 0-150V,0-20A(for SC)	1
4.	Voltmeter	300V	1
5.	Ammeter	15A	1

Circuit Diagram:

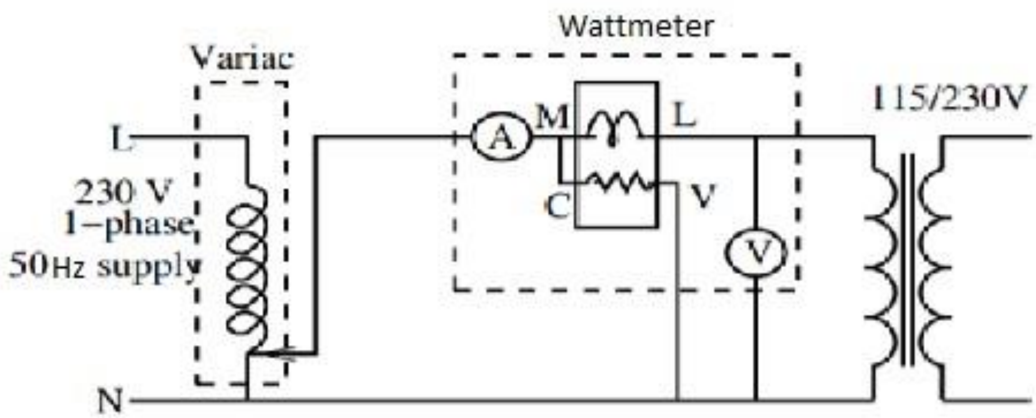


Fig1. Circuit Diagram for Open Circuit Test.

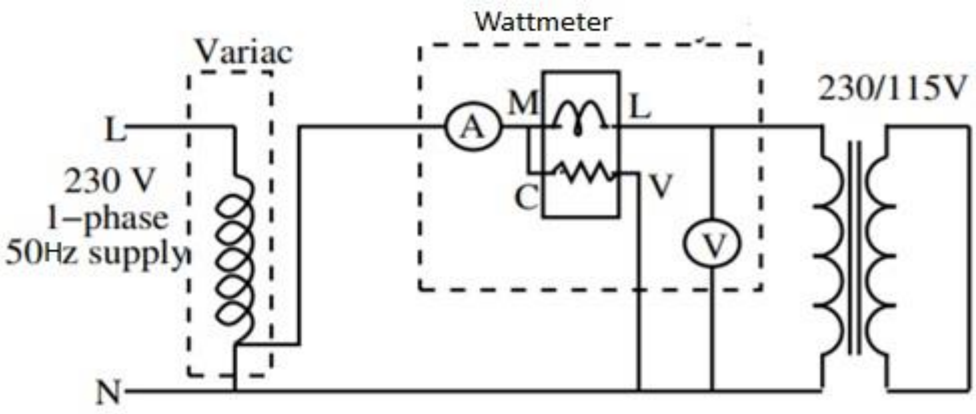


Fig2. Circuit Diagram for Short Circuit Test.

Theory:

1. Open Circuit (OC) or No-Load Test

The purpose of this test is to determine the shunt branch parameters of the equivalent circuit of the transformer. One of the windings is connected to supply at rated voltage, while the other winding is kept open - circuited. From the point of view of convenience and availability of supply the test is usually performed from the LV side, while the HV side is kept open circuited.

V_o= Rated Voltage applied.

I_o= No load current (it is usually 2-6% of the rated current)

P_o= Power input (No load losses)

Then the relation is

$$P_o = V_o \times I_o \times Cos(\emptyset_o)$$

$Cos(\emptyset_o)$- No load power factor.

$$Cos(\emptyset_o) = \frac{P_o}{V_o \times I_o}$$

Therefore, magnetizing current,

$$I_m = I_o Sin(\emptyset_o)$$

Energy component of current

$$I_w = I_o Cos(\emptyset_o)$$

R_0 and X_0 are also small, that V_o can be regarded as = E_1 by neglecting the series impedance. This means that for all practical purposes the power input on no-load equals the core (iron) loss i.e.

$$Z_o = \frac{V_o}{I_o}$$

$$R_o = \frac{V_o}{I_w}$$

$$X_o = \sqrt{Zo^2 - Ro^2}$$

2. **Short Circuit (SC) Test**

This test serves the purpose of determining the series parameters of a transformer. For convenience of supply arrangement and voltage and current to be handled, the test is usually conducted from the HV side of the transformer while the LV side is short-circuited. Since the transformer resistance and leakage reactance are very small, the voltage Vsc needed to circulate the full load current under short circuit is as low as 5-8% of the rated voltage. The exciting current under these conditions is only about 0.1to 0.5% of the full load current Thus the shunt branch of the equivalent circuit can be altogether neglected. While conducting the SC test, the supply voltage is gradually raised from zero till the transformer draws full load current. The meter readings under these conditions are: Since the transformer is excited at very low voltage, the iron loss is negligible (that is why shunt branch is left out), the power input corresponds only to the copper loss, i.e

V_{sc}= Voltage applied.

I_{sc}= Rated load current

P_{sc}= Power input (Copper loss)

Then the relation is

$$P_{sc} = V_{sc} \times I_{sc} \times Cos(\emptyset)$$

$Cos(\emptyset)$- full power factor.

$$Cos(\emptyset) = \frac{P_{sc}}{V_{sc} \times I_{sc}}$$

Equivalent resistance, $R_{eq} = P_{sc} / (I_{sc})^2$

Equivalent reactance, $X_{eq} = \sqrt{\left(Z_{eq}^2 - R_{eq}^2\right)}$

Procedure:

OC Test:

1. Make the connections as per the circuit diagram in fig. 1.
2. By using 1-ϕ variac apply rated voltage.
3. Measure voltage , current & power input from voltmeter, ammeter and wattmeter resp.
4. Evaluate no load power factor, I_w , I_m , R_0 and X_0
5. Verify the results

SC Test:

1. Make the connections as per the circuit diagram in fig. 2.
2. By using 1-ϕ variac apply voltage and increase till the rated current starts flowing.
3. Measure voltage , current & power input from voltmeter, ammeter and wattmeter resp.
4. Evaluate no load power factor, Z_{eq} ,R_{eq} and X_{eq}
5. Verify the results

Observations and calculations:

OC Test:

S. No.	V_o(Volts)	I_o(Amps)	W_o(Watts)
1.			
2.			
3.			

SC Test:

S. No.	V_{sc}(Volts)	I_{sc}(Amps)	W_{sc}(Watts)
1.			
2.			
3.			

Evaluate the no load and full load parameters.

Precautions:

1. Open circuit test is performed on LV side i.e. meter are connected LV and HV side will be open circuited.
2. For short circuit test is connect meters on HV side and LV side will be short circuited.
3. Rated voltage and rated current must be maintained in OC test and SC test respectively.
4. All the connections should be tight.

Viva Questions:

1. What are the advantages of OC and SC test?
2. Why the SC test is normally done on HV side?
3. Why the OC test is normally done on the LV side?
4. What are the components of iron loss?

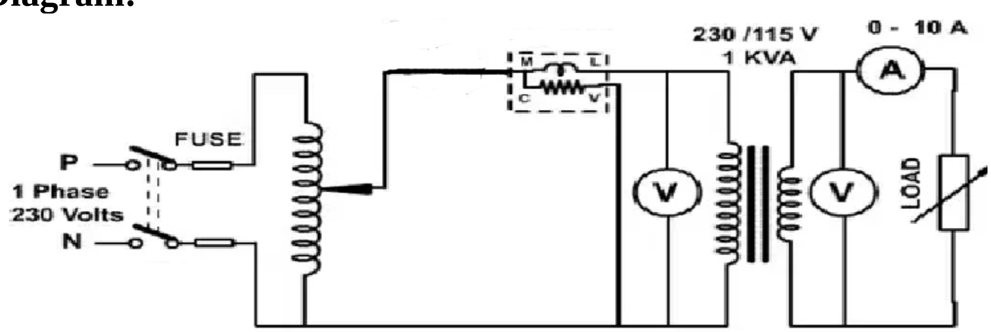
Experiment-02

Aim: To Perform Load Test on a Single Phase Transformer.

Apparatus Required:

S. No.	Equipment	Specification	Quantity
1.	Transformer	1KVA, 230V/115V	1
2.	Wattmeter	(0-300)V, 5/10 A,150/300/600 V	1
3.	Ammeter	(0-20)Amp	1
4.	Voltmeters	(0-300) Volt	1
5.	Lamp Bank Load	Resistive 1 KW, 230 V	1

Circuit Diagram:



Theory:

The transformer is a device which transfers energy from one electrical circuit to another electrical circuit through magnetic field as coupling medium without change in frequency. It works on the principle of electromagnetic induction (mutually induced e. m. f.). Being a static device it has a very high efficiency as compared to rotating machine of same rating as the losses are less.

Power input to the transformer, P_1 = sum of delivered power, iron losses and copper losses

Power output of the transformer, $P2 = V_2 I_2 \cos\Phi$

Percentage Efficiency, $\eta = \frac{P_2}{P_1} \times 100$

When primary winding of transformer is energized with source of voltage V_1 an e.m.f. E_2 is induced across the secondary winding which is equal to secondary terminal voltage V_2 at no load. On loading the transformer, the terminal voltage decreases from E_2 to V_2 this changing the voltage per unit no load voltage is called "voltage regulation".

Percentage voltage regulation given by the relation.

$$V.R.=\frac{E_2-V_2}{E_2}\times 100$$

The voltage regulation should be as small as possible. Transformer being highly inductive device works on lagging power factor unless the load of highly capacitive nature is connected across the secondary winding to make overall circuit resistive purely or capacitive in nature.
The load test will be performed at different load, then find the efficiency of the transformer at different loads evaluate the maximum efficiency, voltage regulation and satisfy the condition maximum efficiency.

Procedure:

1. Make the connections as per the circuit diagram.
2. Keep the switch on secondary side open so that load is zero to measure no load voltage. Also keep knob of auto transformer at zero output voltage position.
3. Now Switch on the supply and increase the voltage from auto transformer till voltage in voltmeter
   V_2 reads rated value of secondary winding which is the no load voltage E_2.
4. Switch on certain lamps from the lamp load such that secondary winding current be approximately
   10% of the rated current of secondary side.
5. Take the readings from Wattmeter W_2, Voltmeter V_2, & Ammeter I_2.
6. Increase the load current in steps of 10% of the rated value by switching on few more lamps & take the readings of the Wattmeter, Ammeter & Voltmeter upto full load.
7. Reduce the load to zero by switching of the lamps one-by-one.

Observation Table:

S.No.	W_1(watts)	E_2(volts)	V_2(volts)	I_2(Amps)	P_2(Watts)	Efficiency(η)
1.						
2.						
3.						
4.						

Calculations.

Calculate the efficiency and voltage regulation of the transformer at different loads using the relations.

Precautions:

1. Instruments used should be of proper range.
2. All the connections should be tight.
3. The parallax error should not be there.

4. Give constants supply through the auto Transformer.
5. Never touch live conductors or Terminals.

Viva Questions:

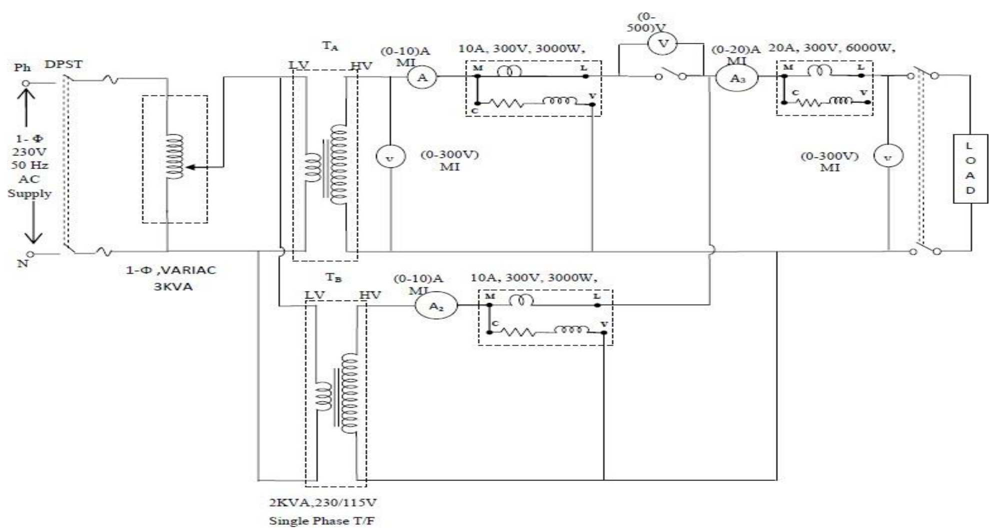
Q1. Explain the regulation of a transformer?
Q2. What is the condition for maximum efficiency of a transformer?
Q3. Explain all day efficiency and commercial efficiency of a transformer?
Q4. What are the various losses occurring in the transformer?

Experiment -04

Aim: To Study the Parallel Operation of Single Phase Transformers

Apparatus:

S.No.	Apparatus	Range	Quantity
1	transformers	2KVA,230/115V	2
2	Wattmeter	300V,10A	3
4	Autotransformer	0-270V	1
5	Single phase load	2KW,1.5A step	1
6	Voltmeter	0-300V	3
7	Ammeter	0-10A 0-20A	2 1



Theory:

Parallel operation of transformers is used for load sharing. The transformers are connected in parallel onboth primary and secondary side. Following conditions to be satisfied during the parallel operation of transformers

- Same polarities should be connected.
- The two transformers should have same voltage ratio.
- The percentage impedance should be same.

There should be no circulating current

Procedure:

1. connect the circuit as shown in the diagram.
2. Note down the readings of all wattmeters, ammeters and voltmeters for given load.
3. Repeat the above test for different values of load
4. Take at least three readings

Observation Table:

S.NO.	I_1 (AMPS)	W_1(WATTS)	I_2(AMPS)	W_2(WATTS)	$I_L=I_1+I_2$ (AMPS)	$W_L=W_1+W_2$ (WATTS)
1.						

Result:

The two transformers connected in parallel share the load equally.

Discussion:

The total load current is distributed on two transformers accordingly.

I1+I2=I l

The total wattmeter readings are distributed on two wattmeters accordingly.

W1+W2=Wl

Precautions:

1. Transformers should be connected in such a way that they have same polarity.
2. All connections should be neat and tight.
3. Connecting leads should be perfectly insulated.

Quiz:

Q.1 What is the minimum no. of transformers needed to conduct this exp.?
A1 Two
Q.2 What is the effect of circulating current in the circuit having two transformers in parallel ?
A2 produces additional copper losses
Q.3 when does the circulating current flow in a circuit of two transformers connected in parallel?
A3 If the two transformers have different voltage ratios
Q.4 How much circulating current can be tolerated for parallel operation of transformers?
A4 10% of rated value
Q.5 why the transformer are needed to be operated in parallel.
A5 If the load is more than rated load
Q.6 What will happen if two transformers are connected in parallel with wrong polarity?
A6 Dead short circuit on the transformers

Experiment-05

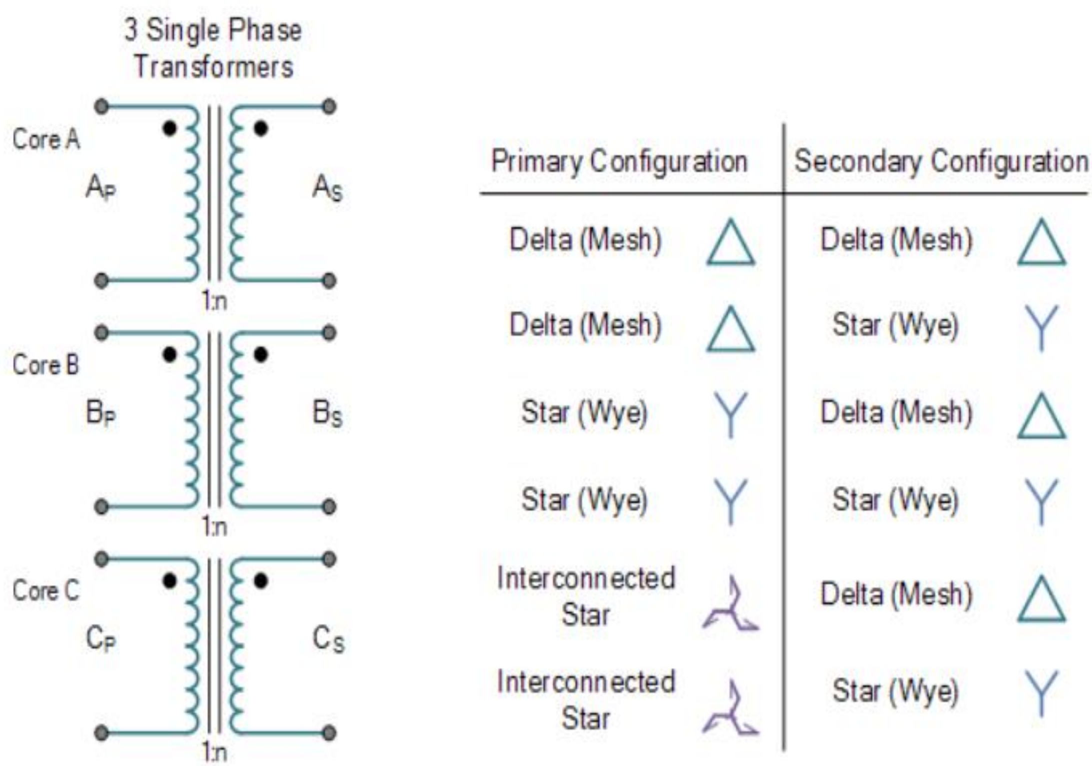
Aim: To Study the Various Connections of Three Phase Transformer.

Theory:

Three Phase Transformer Configuration.

A *three phase transformer* or 3φ transformer can be constructed either by connecting together three single-phase transformers, thereby forming a so-called three phase transformer bank, or by using one pre-assembled and balanced three phase transformer which consists of three pairs of single phase windings mounted onto one single laminated core.

The advantages of building a single three phase transformer is that for the same kVA rating it will be smaller, cheaper and lighter than three individual single phase transformers connected together because the copper and iron core are used more effectively. The methods of connecting the primary and secondary windings are the same, whether using just one **Three Phase Transformer** or three separate *Single Phase Transformers.* Consider the circuit below:



The primary and secondary windings of a transformer can be connected in different configuration as shown to meet practically any requirement. In the case of three phase transformer windings, three forms of connection are possible: "star" (wye), "delta" (mesh) and "interconnected-star" (zig-zag)

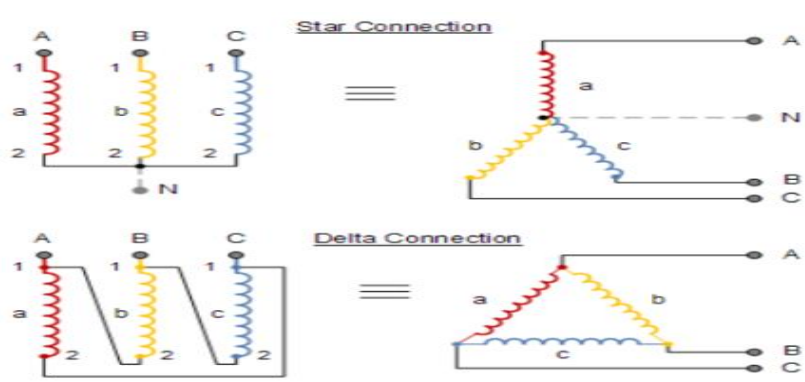
The combinations of the three windings may be with the primary delta-connected and the secondary star-connected, or star-delta, star-star or delta-delta, depending on the transformers use. When transformers are used to provide three or more phases they are generally referred to as a Polyphase Transformer.

Three Phase Transformer Star and Delta Configurations

But what do we mean by "star" (also known as Wye) and "delta" (also known as Mesh) when dealing with three-phase transformer connections. A three phase transformer has three sets of primary and secondary windings. Depending upon how these sets of windings are interconnected, determines whether the connection is a star or delta configuration. The three available voltages, which themselves are each displaced from the other by 120 electrical degrees, not only decided on the type of the electrical connections used on both the primary and secondary sides, but determine the flow of the transformers currents. With three single-phase transformers connected together, the magnetic flux's in the three transformers differ in phase by 120 time-degrees. With a single the three-phase transformer there are three magnetic flux's in the core differing in time-phase by 120 degrees.

The standard method for marking three phase transformer windings is to label the three primary windings with capital (upper case) letters A, B and C, used to represent the three individual phases of RED, YELLOW and BLUE. The secondary windings are labeled with small (lower case) letters a, b and c. Each winding has two ends normally labeled 1 and 2 so that, for example, the second winding of the primary has ends which will be labeled B1 and B2, while the third winding of the secondary will be labeled c1 and c2 as shown.

Transformer Star and Delta Configurations



Symbols are generally used on a three phase transformer to indicate the type or types of connections used with upper case Y for star connected, D for delta connected and Z for interconnected star primary windings, with lower case y, d and z for their respective secondaries.

Then, Star-Star would be labeled Yy, Delta-Delta would be labeled Dd and interconnected star to interconnected star would be Zz for the same types of connected transformers.

Transformer Winding Identification

Connection	Primary Winding	Secondary Winding
Delta	D	d
Star	Y	y
Interconnected	Z	z

We now know that there are four different ways in which three single-phase transformers may be connected together between their primary and secondary three-phase circuits. These four standard configurations are given as: Delta-Delta (Dd), Star-Star (Yy), Star-Delta (Yd), and Delta-Star (Dy).

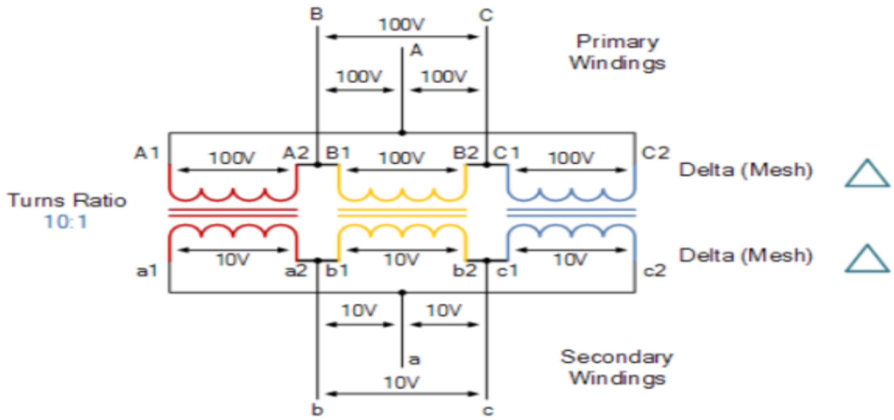
Transformers for high voltage operation with the star connections has the advantage of reducing the voltage on an individual transformer, reducing the number of turns required and an increase in the size of the conductors, making the coil windings easier and cheaper to insulate than delta transformers.

The delta-delta connection nevertheless has one big advantage over the star-delta configuration, in that if one transformer of a group of three should become faulty or disabled, the two remaining ones will continue to deliver three-phase power with a capacity equal to approximately two thirds of the original output from the transformer unit.

Transformer Delta and Delta Connections

In a delta connected (Dd) group of transformers, the line voltage, V_L is equal to the supply voltage, $V_L = V_S$. But the current in each phase winding is given as: $1/\sqrt{3} \times I_L$ of the line current, where I_L is the line current.

One disadvantage of delta connected three phase transformers is that each transformer must be wound for the full-line voltage, (in our example above 100V) and for 57.7 per cent, line current. The greater number of turns in the winding, together with the insulation between turns, necessitate a larger and more expensive coil than the star connection. Another disadvantage with delta connected three phase transformers is that there is no "neutral" or common connection.



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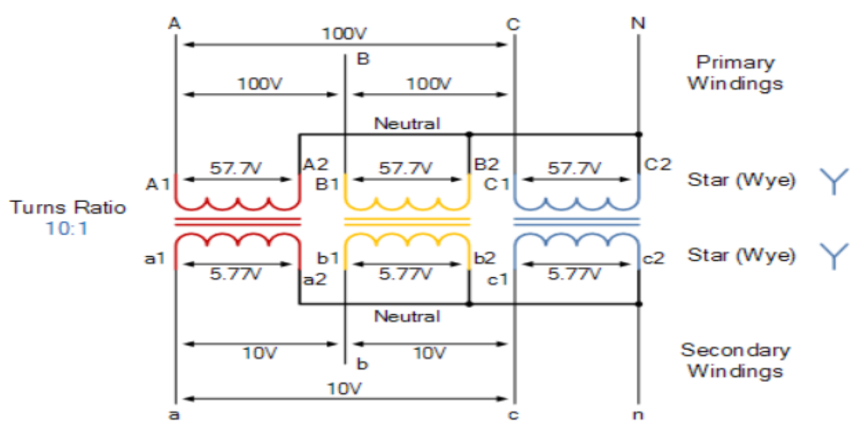
In the star-star arrangement (Yy), (wye-wye), each transformer has one terminal connected to a common junction, or neutral point with the three remaining ends of the primary windings connected to the three-phase mains supply. The number of turns in a transformer winding for star connection is 57.7 per cent, of that required for delta connection.

The star connection requires the use of three transformers, and if any one transformer becomes fault or disabled, the whole group might become disabled. Nevertheless, the star connected three phase transformer is especially convenient and economical in electrical power distributing systems, in that a fourth wire may be connected as a neutral point, (n) of the three star connected secondary's as shown.

Transformer Star and Star Connections

The voltage between any line of the three-phase transformer is called the "line voltage", V_L, while the voltage between any line and the neutral point of a star connected transformer is called the "phase voltage", V_P. This phase voltage between the neutral point and any one of the line



connections is $1/\sqrt{3} \times V_L$ of the line voltage. Then above, the primary side phase voltage, V_P is given as.

$$V_p = \frac{1}{\sqrt{3}} \times V_L = \frac{1}{\sqrt{3}} \times 100 = 57.7\ volts$$

The secondary current in each phase of a star-connected group of transformers is the same as that for the line current of the supply, then $I_L = I_S$.

Then the relationship between line and phase voltages and currents in a three-phase system can be summarized as:

Three-phase Voltage and Current:

Connection	Phase Voltage	Line Voltage	Phase Current	Line Current
Star	$V_P = V_L \div \sqrt{3}$	$V_L = \sqrt{3} \times V_P$	$I_P = I_L$	$I_L = I_P$
Delta	$V_P = V_L$	$V_L = V_P$	$I_P = I_L \div \sqrt{3}$	$I_L = \sqrt{3} \times I_P$

Where again, V_L is the line-to-line voltage, and V_P is the phase-to-neutral voltage on either the primary or the secondary side.

Other possible connections for three phase transformers are star-delta Yd, where the primary winding is star-connected and the secondary is delta-connected or delta-star Dy with a delta-connected primary and a star-connected secondary.

Delta-star connected transformers are widely used in low power distribution with the primary windings providing a three-wire balanced load to the utility company while the secondary windings provide the required 4th-wire neutral or earth connection.

When the primary and secondary have different types of winding connections, star or delta, the overall turns ratio of the transformer becomes more complicated. If a three-phase transformer is connected as delta-delta (Dd) or star-star (Yy) then the transformer could potentially have a 1:1 turns ratio. That is the input and output voltages for the windings are the same.

However, if the 3-phase transformer is connected in star–delta, (Yd) each star-connected primary winding will receive the phase voltage, V_P of the supply, which is equal to $1/\sqrt{3} \times V_L$.

Then each corresponding secondary winding will then have this same voltage induced in it, and since these windings are delta-connected, the voltage 1/√3 × VL will become the secondary line voltage. Then with a 1:1 turns ratio, a star–delta connected transformer will provide a √3:1 step-down line-voltage ratio.

Star-Delta Turns Ratio:

$$TR = \frac{N_P}{N_S} = \frac{V_P}{\sqrt{3}V_S}$$

Likewise, for a delta–star (Dy) connected transformer, with a 1:1 turns ratio, the transformer will provide a 1:√3 step-up line-voltage ratio.

Delta-Star Turns Ratio:

$$TR = \frac{N_P}{N_S} = \frac{\sqrt{3}V_P}{V_S}$$

Then for the four basic configurations of a three-phase transformer, we can list the transformers secondary voltages and currents with respect to the primary line voltage, V_L and its primary line current I_L as shown in the following table.

Three-phase Transformer Line Voltage and Current:

Primary-Secondary Configuration	Line Voltage Primary or Secondary	Line Current Primary or Secondary
Delta – Delta	$V_L \Rightarrow nV_L$	$I_L \Rightarrow \frac{I_L}{n}$
Delta – Star	$V_L \Rightarrow \sqrt{3}.nV_L$	$I_L \Rightarrow \frac{I_L}{\sqrt{3}.n}$
Star – Delta	$V_L \Rightarrow \frac{nV_L}{\sqrt{3}}$	$I_L \Rightarrow \sqrt{3}.\frac{I_L}{n}$
Star – Star	$V_L \Rightarrow nV_L$	$I_L \Rightarrow \frac{I_L}{n}$

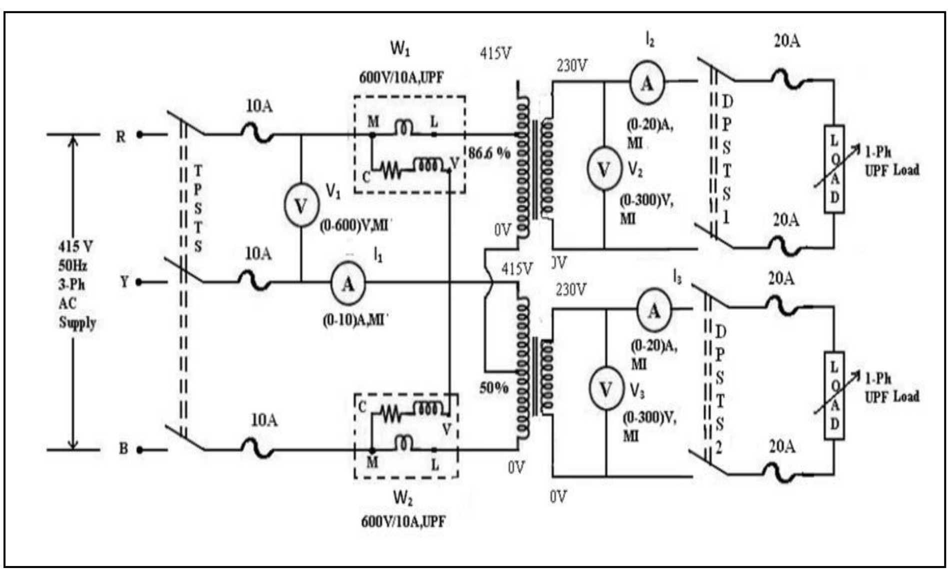
Experiment-06

Aim: To perform Scott Connections on three phase transformer to convert it into two phase supply

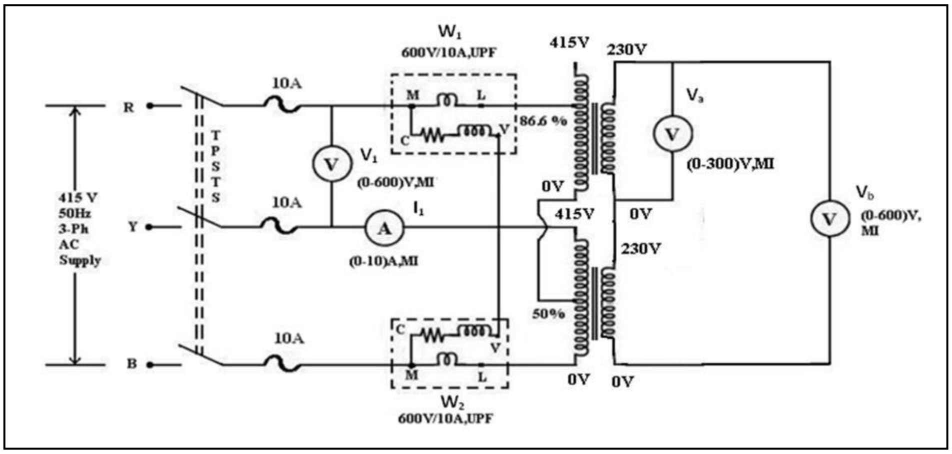
Apparatus Required:

S.N	Apparatus	Specifications	Quantity
1	Main Transformer	Input: 0-200V (50%) ±10%, 50Hz Input: 0-200V (50%) ±10%, 50Hz Output:0-230V±10%, 50Hz	1
2	Teaser Transformer	0-115.6V (28.9%)±10%, 50Hz 346.4V (86.6%)±10%,50Hz 400V ±10%, 50Hz 0-230V ±10%, 50Hz	1
3	Wattmeter	600V/10A,UPF	1
4	Voltmeters	0-600V, 0-300V	1 2
5	Ammeter	0-10A(MI) 0-20A(MI)	1 2
6	Load	1PH UPF	1

CIRCUIT DIAGRAM:



Circuit diagram for scott connection



Circuit diagram for finding phase relation

Theory:

To convert 3-ϕ to2-ϕ power, Scott connection is one by which 3-phase to 2-phase transformation is accomplished with the help of two identical 1-ϕ 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 0.866 tap 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 transformers is not at all used. Refer to the fig. The main transformer primary winding center tap point D is connected to one end of the primary of the teaser transformer 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 transformers.

Name Plate Details:

a) Main Transformer:

KVA rating	:
LV Side Voltage	:
HV Side Voltage	:
Frequency	:
Number of Phases	:

b) Teaser Transformer:

KVA rating	:
LV Side Voltage	:
HV Side Voltage	:
Frequency	:
Number of Phases	:

Observations:

for Scott connection

S.No.	V_1 (V)	I_1 (A)	W_1 (W)	W_2 (W)	V_2 (V)	I_2 (A)	V_3 (V)	I_3 (A)	Input (kW)	Output (kW)	%η

for phase relation

V_a (V)	V_b (V)

Model Calculations:

For reading 2:

Input Power = $(W_1 + W_2)/1000$

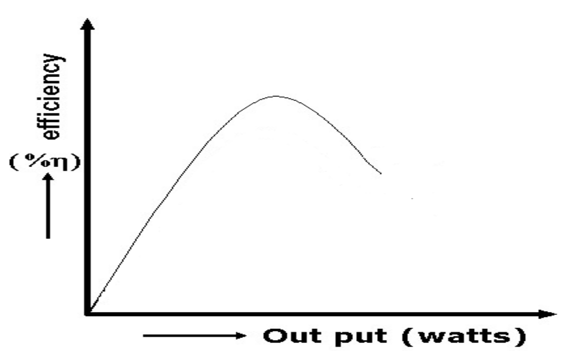
Output Power = $(V_2 I_2 + V_3 I_3)/1000$

% efficiency = Output/Input*100

To Calculate Phase Relationship:

$(V_b)^2 = (V_a)^2 + (V_a)^2 + 2(V_a)(V_a)\cos(\Phi)$

Model Graph:



Result:

Procedure:

1. Connect the circuit diagram as shown in fig 8.1.
2. Close the TPST Switch. Note down the readings of all meters.
3. Close the DPST Switches 1&2 and vary both the loads in steps up to rated load and notedown the readings of all meters in each step. Open the TPST Switch.
4. Connect the circuit diagram as shown in fig 8.2 to verify the phase relationship of the twophase voltages.
5. Close the TPST Switch and note down all meter readings in secondary side.

Precautions:

1. Connections must be tight and avoid wrong connections.
2. Readings are to be taken without any parallax error.
3. Initially all the knife switches should be in OPEN position.

Questions/Answers:

Q.1 What is the effect on the frequency in the transformer?
A. No change

Q.2 What is the medium for the energy conversion from the primary to secondary in the transformer?
A. By the flux.
Q.3 What is the main reason for the generation of harmonics in the transformer?
A. Saturation of the core.
Q.4 Why are the ferrite cores used in the high frequency transformer?
A. High resistance
Q.5 What type of winding is used in the 3-phase shell type transformer?
A. Sandwich type
Q.6 What is increased in step up transformer?
A. Voltage
Q.7 What is the effect on voltage in step down transformer?
A. Voltage is decreased
Q.8 What is the function of bushings in the transformer?
A. To make the external connections
Q 9 What is the principal of transformer?

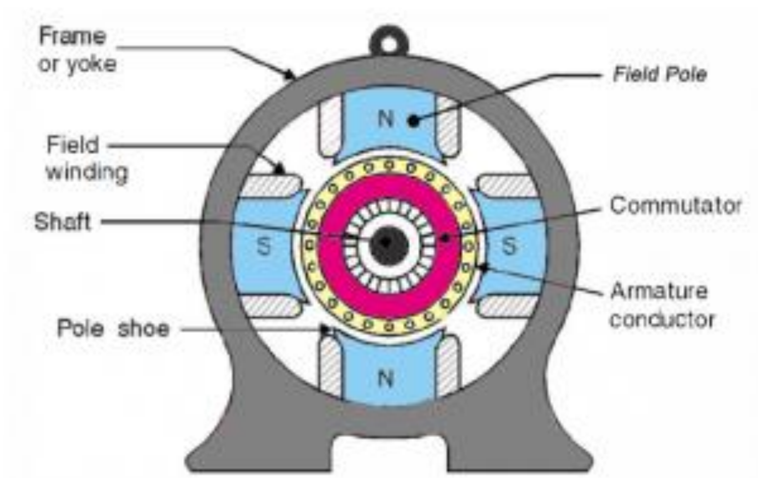
Experiment-07

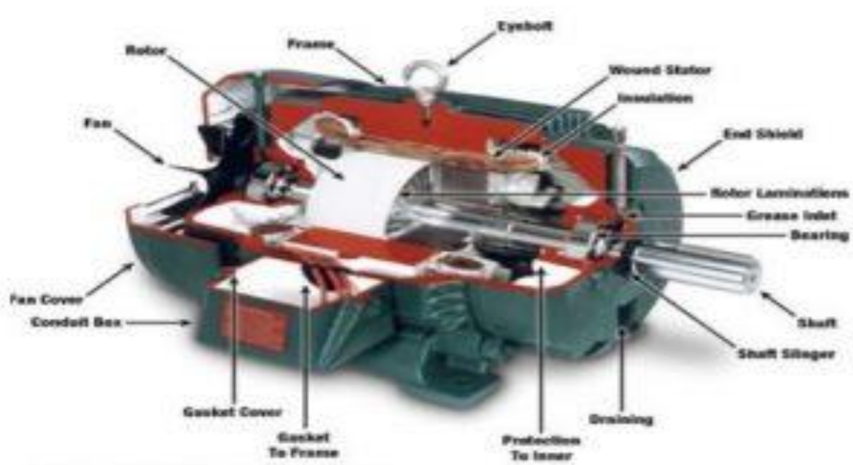
Aim: To study the constructional details of direct current (DC) machine.

Apparatus Required:

S.No.	Apparatus Required	Specifications	Quantity
1.	DC Machine	Four pole section	1

Diagram:





Constructional Detail:

Yoke
Another name of a yoke is the frame. The main function of the yoke in the machine is to offer mechanical support intended for poles and protects the entire machine from moisture, dust, etc. The materials used in the yoke are designed with cast iron, cast steel otherwise rolled steel.

Pole and Pole Core
The pole of the DC machine is an electromagnet and the field winding is winding among pole. Whenever field winding is energized then the pole gives magnetic flux. The materials used for this are cast steel, cast iron otherwise pole core. It can be built with the annealed steel laminations for reducing the power drop because of the eddy currents.

Pol Shoes
Pole shoe in the DC machine is an extensive part as well as to enlarge the region of the pole. Because of this region, flux can be spread out within the air-gap as well as extra flux can be passed through the air space toward armature. The materials used to build pole shoe is cast iron otherwise cast steed, and also used annealed steel lamination to reduce the loss of power because of eddy currents.

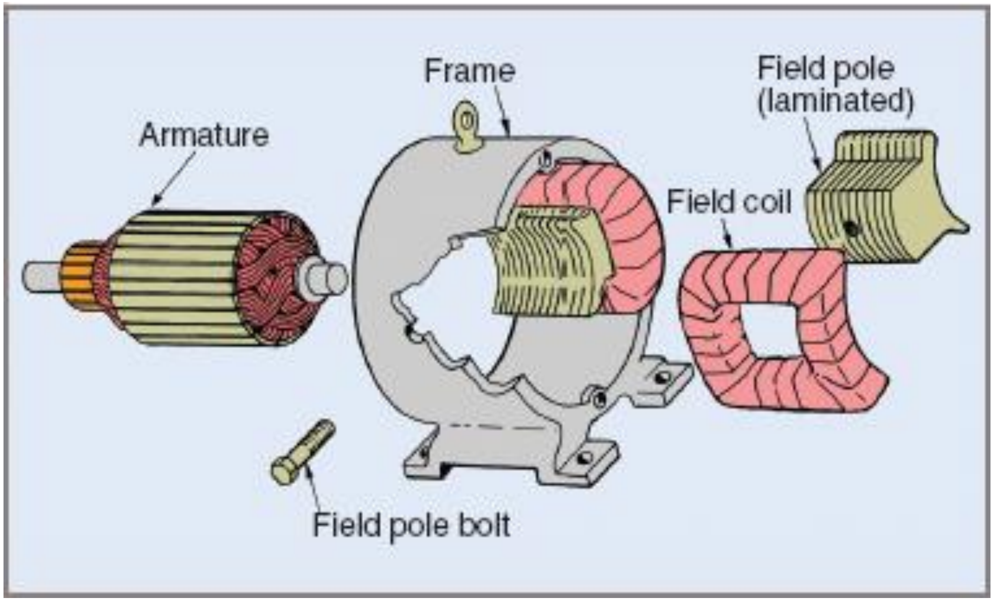
Field Windings
In this, the windings are wounded in the region of pole core & named as field coil. Whenever current is supplied through field winding than it electromagnetics the poles which generate required flux. The material used for field windings is copper.

Armature Core
Armature core includes a huge number of slots within its edge. The armature conductor is located in these slots. It provides the low-reluctance path toward the flux generated with field winding. The materials used in this core are permeability low-reluctance materials like iron otherwise cast. The lamination is used to decrease the loss because of the eddy current.

Armature Winding
The armature winding can be formed by interconnecting the armature conductor. Whenever an armature winding is turned with the help of prime mover then the voltage, as well as magnetic flux, gets induced within it. This winding is allied to an exterior circuit. The materials used for this winding are conducting material like copper.

Commutator

The main function of the commutator in the DC machine is to collect the current from the armature conductor as well as supplies the current to the load using brushes. And also provides unidirectional torque for DC-motor. The commutator can be built with a huge number of segments in the edge form of hard drawn copper. The Segments in the commutator are protected from the thin mica layer.



Parts of DC Machine

Brushes

Brushes in the DC machine gather the current from the commutator and supply it to the exterior load. Brushes wear with time to inspect frequently. Graphite or carbon brushes, sometimes mixed with copper dust, are used to provide a low resistance electrical connection between the armature windings and the external circuit. The brush makes a sliding contact with the commutator

The brush is usually connected to the brush holder with a flexible lead called a ‘pigtail’ and held down by a spring. The same connection terminal is used to connect to the external circuit.
The brushes must maintain contact with the commutator at a constant loading. By adjusting the spring tension, correct brush pressure can be obtained. Some brushes are tensioned by a spiral spring that provides a more constant pressure, thereby avoiding the need for adjustment.
The brush gear must be suitably insulated from the frame and in many cases the position of the brush around the commutator must also be adjustable.

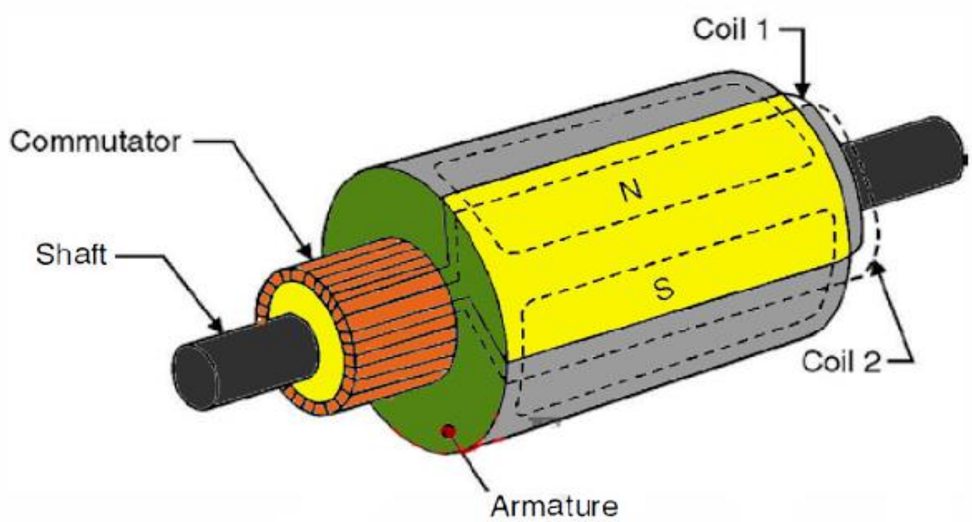
Types of DC Machines

The excitation of the DC machine is classified into two types namely separate excitation, as well as self-excitation. In a separate excitation type of dc machine, the field coils are activated with a separate DC source. In the self-excitation type of dc machine, the flow of current throughout the field-winding is supplied with the machine. The principal kinds of DC machines are classified into four types which include the following.

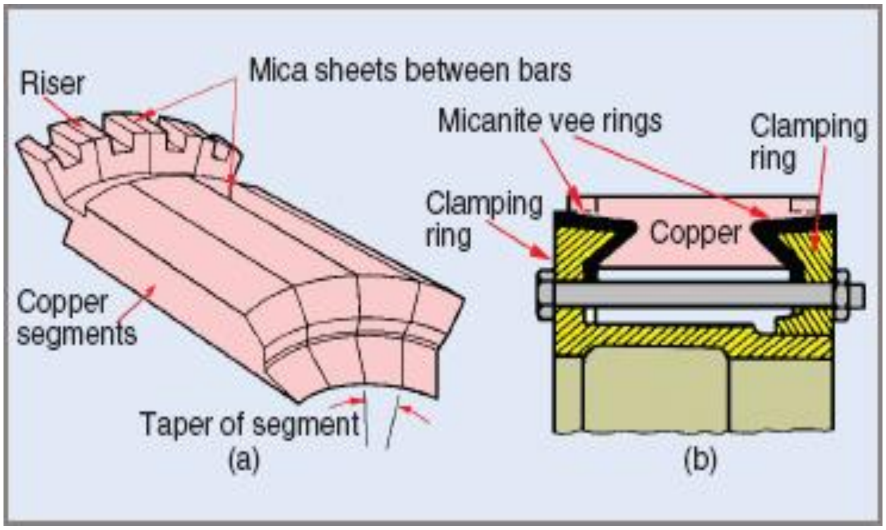
1. Separately excited DC machine
2. Shunt-wound/shunt machine.
3. Series wound/series machine.
4. Compound wound / compound machine.

Separately Excited

In Separately Excited DC Machine, a separate DC source is utilized for activating the field winding.



Armature Assembly



Commutator Segments

Brush Assembly

Shunt Wound

In Shunt wound DC Machines, the field coils are allied in parallel through **the armature**. As the shunt field gets the complete o/p voltage of a generator otherwise a motor supply voltage, it is normally made of a huge number of twists of fine wire with a small field current carrying.

Series Wound

In series-wound D.C. Machines, the field coils are allied in series through the armature. As series field winding gets the armature current, as well as the armature current is huge, due to this the series field winding includes few twists of wire of big cross-sectional region.

Compound Wound

A compound machine includes both the series as well as shunt fields. The two windings are carried-out with every machine pole. The series winding of the machine includes few twists of a huge cross-sectional region, as well as the shunt windings, include several fine wire twists.

The connection of the compound machine can be done in two ways. If the shunt-field is allied in parallel by the armature only, then the machine can be named as the 'short shunt compound machine' & if the shunt-field is allied in parallel by both the armature as well as series field, then the machine is named as the 'long shunt compound machine.

Viva Questions:

1. What is the principle of operation of a DC Motor?
2. What is back E.m.f or counter E.m.f?
3. When DC Generator fails to build up the voltage, what are the reasons?
4. What is field flashing?
5. Why do we use starter for dc machine?

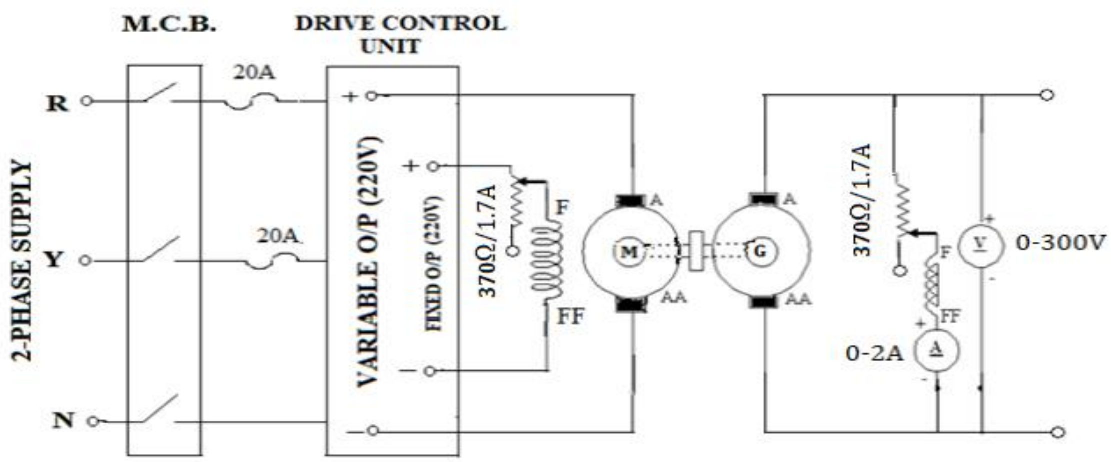
Experiment-9

Aim: To Draw the Open Circuit Characteristics (OCC) of DC Shunt Generator

Apparatus Required:

S.No.	Apparatus Required	Specifications	Quantity
2.	DC Shunt Generator		1
3.	DC Shunt Motor	3H.P,230V,16A,1500rpm	1
4.	Voltmeter	300V	1
5.	Ammeter	15A	1
6.	Rheostat	370Ω,1.7A	1
7.	Tachometer	10000rpm	1

Circuit Diagram:



Theory:

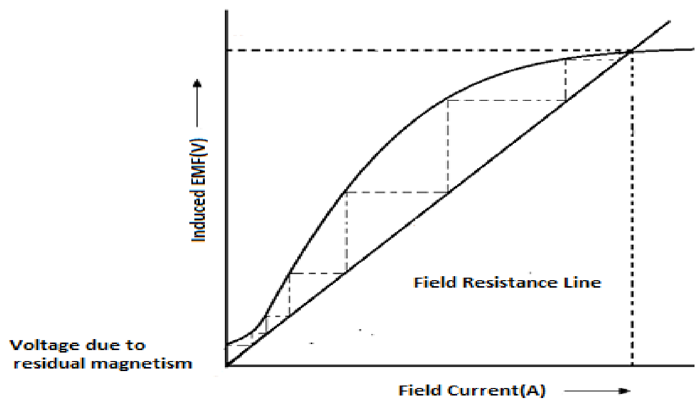
The emf generated by the DC generator is given by the relation

$$E_o = \frac{\emptyset ZNP}{60A}$$

∅ , Z, N,P and A are the magnetic flux per pole, number of conductors, speed in rpm, number of poles and number of parallel paths respectively.

In case of DC shunt generator as the field winding is connected in parallel to the armature winding, the magnetic flux will be the function of field current. So, the magnetization characteristics is plot of induced emf with field current as shown in the figure. The nature of OCC is due to the following points

1. When the field current is zero, there is some generated e.m.f which is due to residual magnetism in the field poles
2. Over a fairly wide range of field current (in the initial portion) the curve is linear. It is because in this range reluctance of iron is negligible as compared with that of air gap. The air gap reluctance is constant and hence linear relationship.
3. After that the reluctance of iron also comes into picture. Consequently, the curve deviates from linear relationship.
4. Finally the magnetic saturation of poles begins and E_0 tends to level off.



Procedure:

1. Connections are made as per the circuit diagram.
2. Before starting the motor, ensure that both field rheostat and Pot meter of Drive Control Unit are in minimum position and the field rheostat of Generator should be in its maximum position. Similarly the load resistance connected to the Generator should be in its minimum position (No load).
3. Observing all the precautions, the motor is started using Drive Control Unit and the speed is increased until the rated armature voltage (of motor) is reached. At this instant the speed would be slightly lesser than the rated speed.
4. Now by adjusting the field rheostat, the motor is brought to the rated speed.
5. Now the field Rheostat of generator is varied and the field resistance is gradually decreased in steps thus increasing the field current. At each step the field current (If) and the corresponding induced EMF (Eg) are recorded in the tabular column. This procedure is continued until the generator voltage reaches its rated value.
6. After the experiment is completed the various rheostats are brought back to their original position in sequence and then main supply is switched off.

Observation Table:

S. No.	Field Current (I_f) amps	Armature voltage (V_o) volts
1.		
2.		
3.		
4.		

Precautions:

1. The field rheostat of motor should be in minimum resistance position at the time of starting to start the machine from minimum speed.
2. The field rheostat of generator should be in maximum resistance position at the time of starting and stopping the machine.
3. Residual voltage should be taken under no field current.
4. The characteristics should be drawn at constant rated speed by adjusting the drive unit or motor filed resistance as required.

Viva Questions:

1. What is the principle of generator?
2. What is meant by residual magnetism?
3. What is critical field resistance?
4. What is meant by saturation?
5. What is the difference between a separately excited dc generator and shunt generator?

Experiment-10

Aim: To Draw the Load Characteristics of DC Shunt Generator.

Apparatus Required:

S.No.	Apparatus Required	Specifications	Quantity
1.	DC gen set (MG)	GEN.:3KW,230V,14A Mot.: 4HP,230A, 16A,1500rpm	1
2.	Voltmeter(V)	0-300V	1
3.	Ammeters(A1,A2)	0-20A , 0-2A	1
4.	Tachometer	0-10000rpm.	1
5.	Variable Load Resistance	300 ohm , 20A	1

Circuit Diagram:

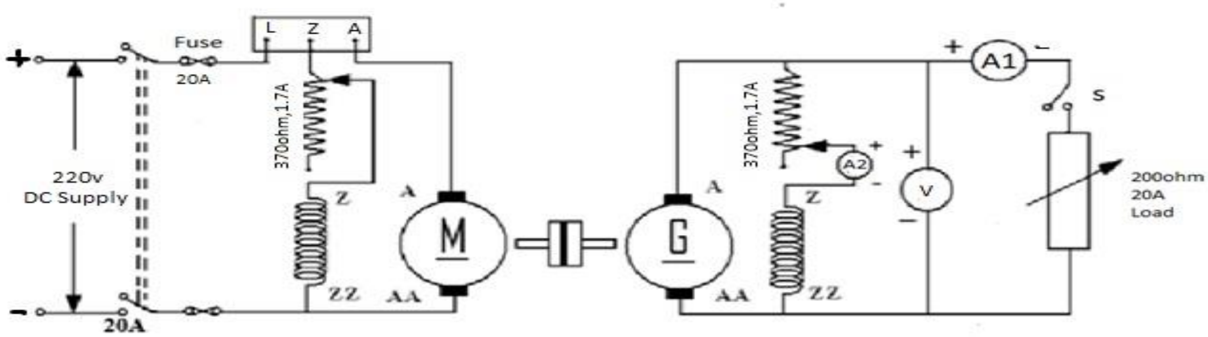


Figure 1: DC shunt Generator on Load Test Diagram

Theory:

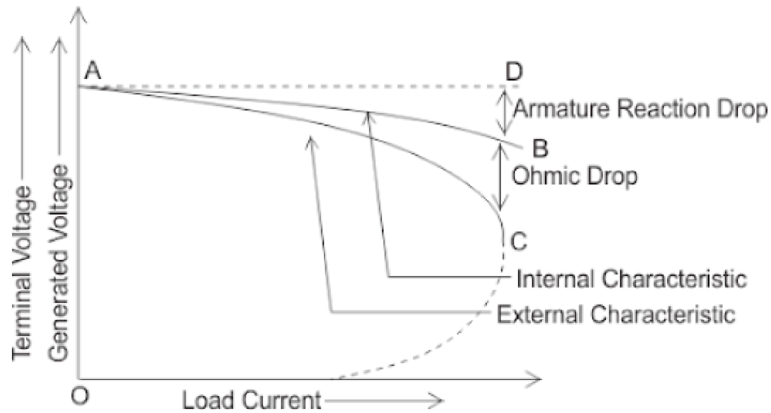
I_a - armature current(A)
I_L-load current(A)
I_f - Field Current(A)
R_a -Armature resistance(ohm) measured by ammeter- voltmeter method.
R_{fc} -Shunt field resistance (ohm) measured by ammeter- voltmeter method
V - Terminal voltage(V)
E - Generated emf(V).

$$I_a = I_L + I_f$$

$$E = V + I_a R_a$$

Load Characteristics

1. The voltage drop across the armature winding and the contact resistance of the brushes increases with the increase in armature current.
2. As the load is increased, the current in armature conductors increases, so the effect of armature reaction increases and, therefore, field is weakened. Due to weakening of field the induced emf is reduced and, therefore, terminal voltage falls.
3. The decrease in terminal voltage as a result of the first two factors causes decrease in field current. This will in turn cause the emf and, therefore, terminal voltage of the generator to drop too.



Procedure:

1. Make the connections as shown in the circuit diagram. Keep the motor field rheostat in the minimum position and the generator field rheostat in the maximum position at starting.
2. Start the MG set and bring it to the rated speed of the generator by adjusting the motor field rheostat.
3. Adjust the terminal voltage to rated value by means of the generator field rheostat. Keep the rheostat in this position throughout the experiment as its variation changes the field circuit resistance and hence the generated emf.
4. Put on the load and measure the values of the load current, I_L from A1 terminal voltage, V and field current, If at different values of the load until full load current is obtained.
5. Calculate the armature current: $Ia = I_L + I_f$.
6. Armature resistance in each case is calculated Ra= Va / I. Measure the voltage drop Va across the armature for different values of current I passing through it. resistance in each case is calculated. Ra = Va / I., Ra (Hot) = 1.25 Ra. Take the mean of the values which are close together as the resistance of the armature, Ra. Measure the
7. Calculate the generated emf. E at each value of the load current. E= V+ Ia Ra.

8. Draw external characteristics, V_T versus I_L and internal characteristic, E versus I_L.

Observation Table:

S.No.	I_f(amp)	I_a(amp)	V_T(volts)
1.			
2.			
3.			
4.			

Plot the graph from the observation table.

Precautions:

1. Avoid parallax errors and loose connections
2. Take care while using the starter.
3. The speed should be adjusted to rated speed.
4. There should be no loose connections.

Viva Questions:

1. Specify the applications of DC shunt generators.
2. Differentiate between DC shunt Motor and DC shunt generator.
3. Which method is suitable for testing of high rating DC generator?
4. Why the terminal voltage decreases when load is increased on the generator?

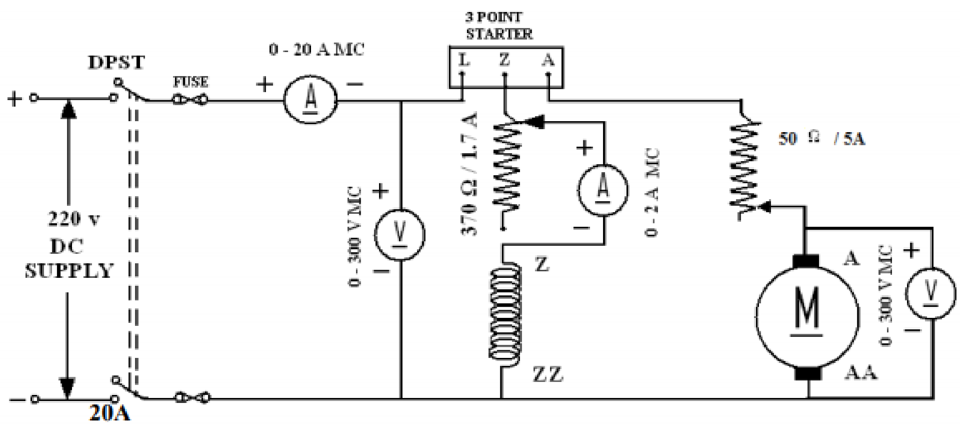
Experiment-11

Aim: To Perform Speed Control of a DC Motor using Field Control and Armature Control Method.

Apparatus Required:

S.No	Meter	Range	Qty
1	DC machine	4HP,230V16A,1500RPM	1
2	Ammeter	(0-2A)	1
3	voltmeter	(0-300V)	1
4	Tachometer	0-10000RPM	1
5	Rheostat	110Ω, 3A	1

Circuit Diagram:

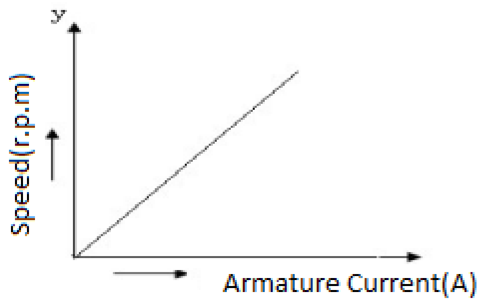


Speed of Dc shunt motor is given by the relation

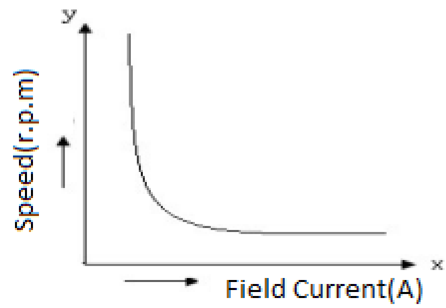
$$N = \frac{V - I_a R_a}{\emptyset Z}$$

1. For armature control operation Ø is constant and the speed is function of armature current
2. For field current control method the armature current is kept constant and the speed is function of magnetic flux which in turn field current

Armature Control



Field Control



Procedure:
1. Make the connections as per the circuit diagram.
2. Keep the field rheostat in the minimum resistance position and the armature resistance in the maximum resistance position.
3. Start the motor by moving the handle of the starter slowly.

Field control:
1. Vary the Armature rheostat resistance until voltmeter across the armature reads 200 Volts.
2. Increase the Field resistance in steps.
3. Note down the values of Ish, the shunt field current, speed.

Armature control:
1. Keep the field rheostat at a selected field current value at the rated field current such that it shows Base speed
2. Decrease the armature resistance from the maximum position in steps keeping the field current at the set value.
3. Note down the speed for each value of armature voltage and armature current.

Observations:

Flux control:

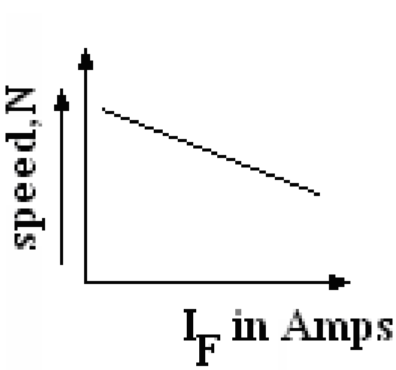
S.NO	Field current I_f (A)	Speed N (rpm)

Armature control:

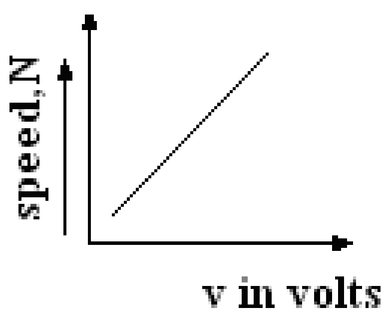
S.NO	Voltage V (V)	Speed N (rpm)

Model Graph:

1. Plot **I_F** Vs speed **N**



2. plot **voltage Va** speed **N**



Result:

Precautions:

1. Take care while using the starter.
2. Keep the armature and field rheostats at proper positions.
3. The speed should be adjusted to rated speed.
4. There should be no loose connections.

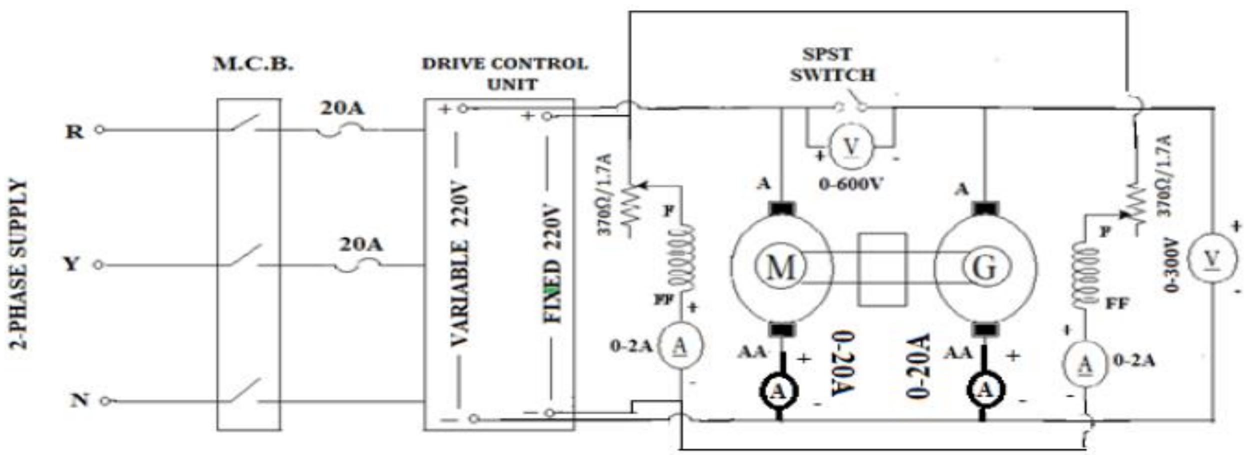
Experiment-13

Aim: To Perform Hopkinson Test on DC Machine.

Apparatus Required:

S. No.	Equipment	Range	Quantity
1.	DC Generator	4HP,230V,16A,1500rpm.	1
2.	DC Motor	4HP,230V,16A,1500rpm.	1
3.	Ammeters	(0-2)A (0-20)A	2 1
4.	Voltmeters	(0-300)V (0-600)V	1 1
5.	Rheostat	370Ω,1.7A	1
6.	Resistive load		

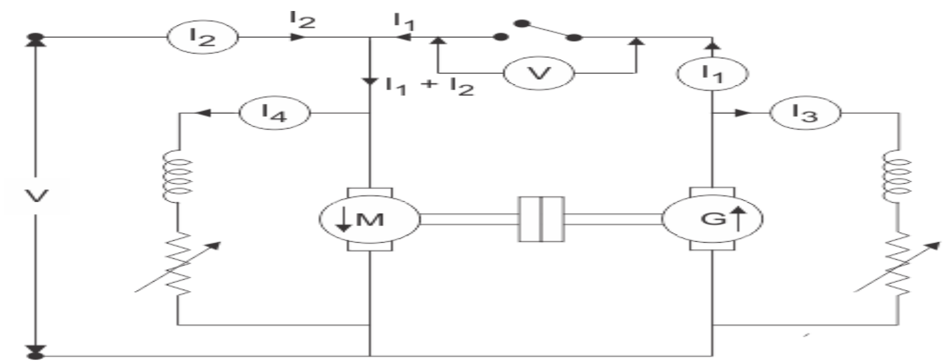
Circuit Diagram:



Theory:

Hopkinson's Test is another useful method of testing the efficiency of a DC machine. It is a full load test and it requires two identical machines which are coupled to each other. One of these two machines is operated as a generator to supply the mechanical power to the motor and the other is operated as a motor to drive the generator. For this process of back to back driving the motor and the generator, Hopkinson's test is also called back-to-back test or regenerative test. If there are no losses in the machine, then no external power supply would have needed. But due to the drop in the generator output voltage we need an extra voltage source to supply the proper input voltage to the motor. Hence, the power drawn from the external supply is therefore used to overcome the internal losses of the motor-generator set. Hopkinson's test is also called regenerative test or back to back test or heat run test.

Here is a circuit connection for the Hopkinson's test shown in figure below. A motor and a generator, both identical, are coupled together. When the machine is started it is started as motor. The shunt field resistance of the machine is adjusted so that the motor can run at its rated speed. The generator voltage is now made equal to the supply voltage by adjusting the shunt field resistance connected across the generator. This equality of these two voltages of generator and supply is indicated by the voltmeter as it gives a zero reading at this point connected across the switch. The machine can run at rated speed and at desired load by varying the field currents of the motor and the generator.



Procedure:

1. Connections are made as per the circuit diagram.
2. Before starting the motor, ensure that the field rheostat of motor and Pot meter of Drive Control Unit are in minimum position and the SPST switch is kept in open condition.
3. Observing all the precautions, the motor is started using Drive Control Unit and the speed is increased until the rated armature voltage (of motor) is reached. At this instant the speed would be slightly lesser than the rated speed.
4. By adjusting the motor field rheostat, the motor is brought to rated speed.
5. Then the generator field rheostat is adjusted until the volt meter connected across the SPST switch is zero.
6. The SPST switch is closed and all meter readings are measured.
7. After the experiment is completed the various rheostats are brought back to their original position in sequence and then main supply is switched off.

Observation Table:

Motor			**Generator**		**Armature Cu Loss of Gen.**	**Armature Cu Loss of Motor**	**Shunt Cu loss of Gen.**	**Shunt Cu loss of motor**	**Efficiency of Gen.**			**Efficiency of motor**		
V	**Ia(A)**	**If(A)**	**Iag(A)**	**Ifg(A)**	$I_{ag}{}^2 R_{ag}$	$I^2{}_{am}R_{am}$	$I_{fg}{}^2R_{fg}$	$I_{fm}{}^2 R_{fm}$	**I/P**	**O/P**	**%eff.**	**I./P**	**O/P**	**%eff.**

Calculations:

Let I_a=Supply current to both the armatures from Drive Control Unit.

Then $I_{am} = I_a + I_{ag}$

where I_{am} & I_{ag} are motor and generator armature currents respectively.

Total input power to armature circuit = VI_a = Total Stray losses + Total copper losses (since net output from M-G set is zero)

Generator armature copper loss = $I_{ag}^2R_{ag}$

Motor armature copper loss = $I_{am}^2R_{am}$

Generator field copper loss = $I_{fg}^2R_{fg}$

Motor field copper loss = $I_{fm}^2R_{fm}$

Total Stray losses = Total input power - Total copper losses

$= VI_a - I_{ag}^2R_{ag} - I_{am}^2R_{am}$

Stray loss of each Machine = Total Stray losses2

Total motor losses = PLM = Stray losses of motor + $I_{fm}^2R_{fm} + I_{am}^2R_{am}$

Total generator losses = PLG = Stray losses of generator + $I_{fg}^2R_{fg} + I_{ag}^2R_{ag}$

Motor input = Pin, M = $V\,I_{am} + I_{fm}^2R_{fm}$

Generator output = Pout, G = $V\,I_{ag}$

Motor efficiency = $(P_{inM} – P_{LM}) / P_{inM}$

Generator efficiency = $(P_{outG}) / (P_{outG} + P_{LG})$

Viva Questions:

1. What is the purpose of Hopkinson’s test?
2. What are the advantages of Hopkinson’s test?
3. What are the conditions for conducting the test?
4. How the power taken from the mains has to supply (is utilized) in this test?
5. Why the adjustments are done in the field rheostat of generator and motor?
6. If the voltmeter across the SPST switch reads zero, what does it indicate?
7. What is the draw back in this test?
8. What are the parameters obtaining in the Hopkinson’s test?