Experiment No: 1

Parallel operation of two single phase transformer of different KVA rating and find the variation of current shared by each transformer vs load current.

Contents

1. Objectives

This experiment is designed in such a way to meet the following objectives: -

- To ensure proper connection of two parallel transformers. Polarity test is to be done.
- Parallel operation of two transformers of different KVA rating.one of them is 2KVA and other is 1 KVA.
- To obtain variation of source current versus load current.

2. **Expected outcome of experiment**

On successful completion of experiment the students will be able to know:

- About the necessary condition of parallel operation of transformers.
- Variation in load sharing with respect to source current.

3. Theory:

Introduction

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

- Same polarities should be connected.
- The two transformers should same voltage ratio.
- The percentage impedance should be same.
- There should be no circulating current.

Polarity Test

This is needed for identifying the primary and secondary phasor polarities. It is a must for poly phase connections. Both a.c. and d.c methods can be used for detecting the polarities of the induced emfs. The dot method discussed earlier is used to indicate the polarities. The transformer is connected to a low voltage a.c. source with the connections made as shown. A supply voltage Vs is applied to the primary and the readings of the voltmeters V1, V2 and V3 are noted. The voltages V1: V2 gives the turn ratio. If the volt meter V3 reads V1−V2 then assumed dot locations are correct (for the connection shown).

The beginning and end of the primary and secondary may then be marked by A1 −A2 and a1 −a2 respectively. If the voltage rises from A1 to A2 in the primary, at any instant it does so from a1 to a2 in the secondary. If more secondary terminals are present due to taps taken from the windings they can be labelled as a3, a4, a5, a6.

It is the voltage rising from smaller number towards larger ones in each winding. The same thing Fig. 2 shows the D.C. method of testing the polarity. When the switch S is closed if the secondary voltage shows a positive reading, with a moving coil meter, the assumed polarity is correct. If the meter kicks back the assumed polarity is wrong.

Parallel Operation of Transformer:

The reason that necessitates parallel operation as follows: -

1. Non-availability of a single-phase transformer to meet the load requirement.
2. The power demand might have increased over a time necessitating augmentation of the capacity. More transformers connected in parallel will then be pressed into service.
3. To ensure improved reliability. Even, if one of the transformers gets into fault or is taken out for maintenance/repair the load can be continued to service.
4. When transportation problems limit installation of large transformers at site, it may be easier to transport smaller ones to site and work them in parallel.

When the load outgrows the capacity of an existing transformer, it may be economical to install another one in parallel with it rather than replacing it with a single larger unit. Also, sometimes in a new installation, two units in parallel, though more expensive, may be preferred over a single unit for reason of reliability half the load can be supplied with one unit out.

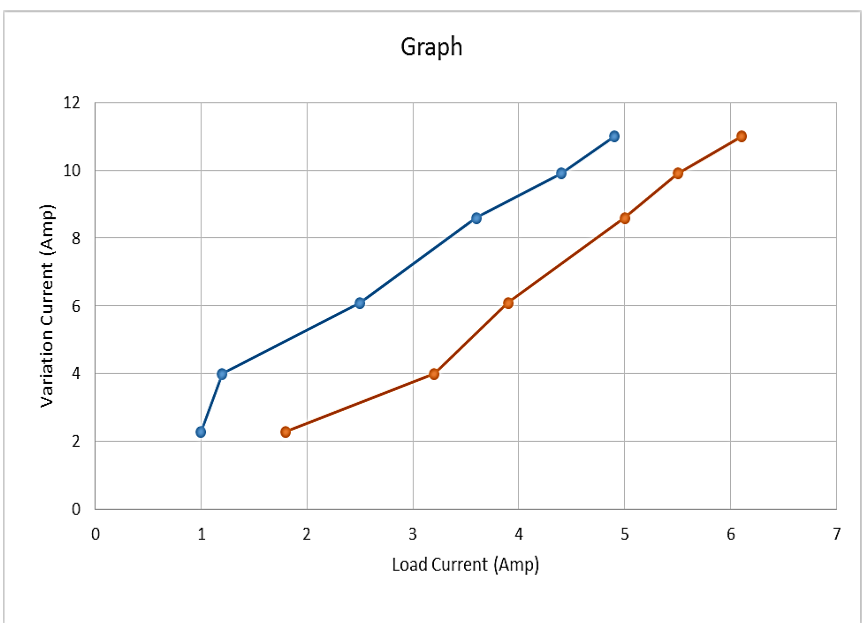


Fig.1: Graph of variation of transformer currents vs load current

4. Equipment required

S.No.	Name	Range	Remark	Qty.
1	Voltmeter	0-300V	AC	2
2	Voltmeter	0-600V	AC	1
3	Ammeter	0-10	AC	3
4	Transformer 1	230V/230V	-	1
5	Transformer 2	230V/115V	-	1
6	Variac	230 V	AC	1

5. Methodology for Measurements

Polarity Test:

1. Connections are made as per the circuit diagram.
2. Apply primary voltage of approximately 50-100 V.
3. Measure voltage across the secondary terminals.
4. If voltage across VA-a is equal to V1+V2 then it is Additive polarity.
5. If voltage across VA-a is equal to V1-V2 then it is Subtractive polarity.
6. Mark the terminals (Dot convention) after the polarity test.

Parallel Operation:

Connections are made as per the circuit diagram shown in figure 1.

1. Switch on the power supply.
2. Slowly increase the voltage up to its rated value of transformer primaries.
3. Gradually increase the load in steps and note the values of A2, V2, A1 & A.
4. Tabulate the readings as shown.
5. Decrease the load and switch off the mains supply.
6. Plot the graph of variation of current shared by each transformer vs load current.

6. Measurements

The figure below shows the connection diagrams for polarity test:

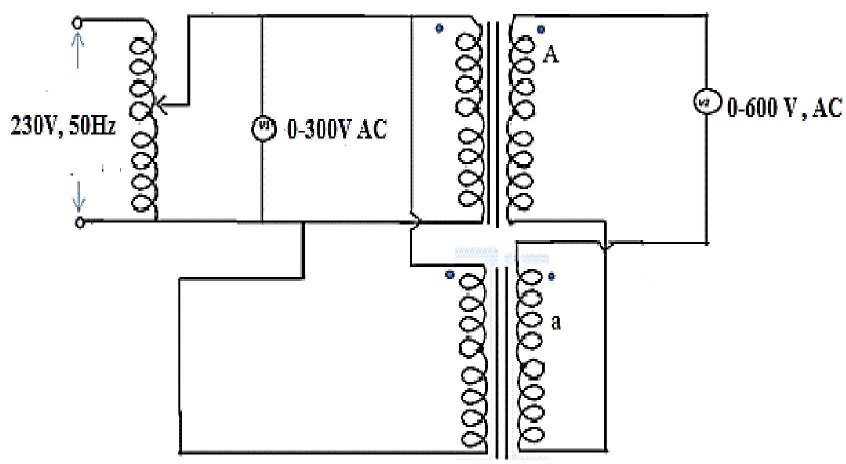


Fig.2: Connection diagram for polarity Test

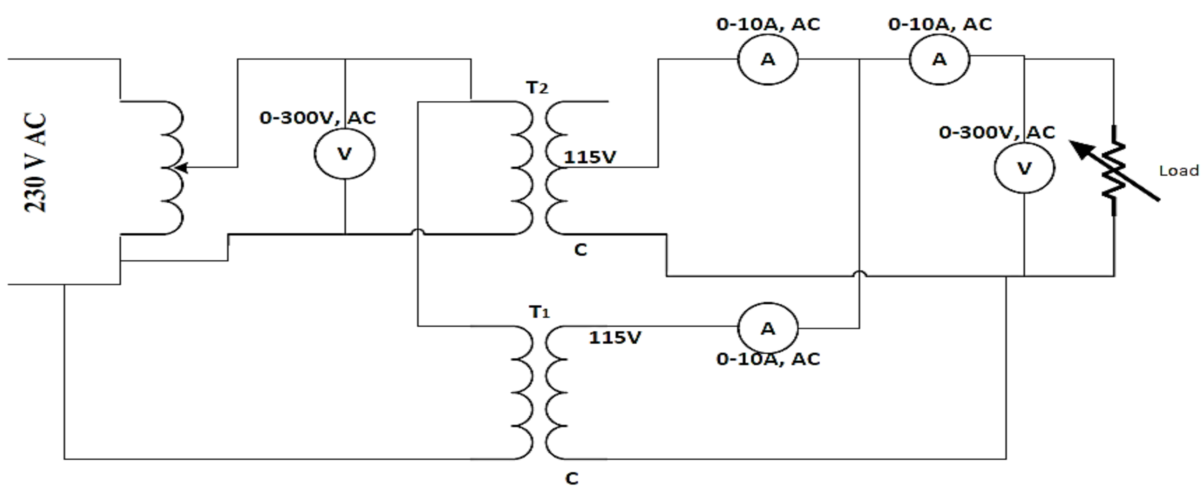


Fig.3: Connection diagram for parallel operation

Transformers specifications: -

Transformer 1	Transformer 2
KVA = 2 LV Voltage =115v HV Voltage =230v Frequency =50Hz	KVA = 1 LV Voltage = 230v HV Voltage = 230v Frequency = 50Hz

Using the above set up note down your observations in the following Table:

Table: Table to be used for recording the measurements:

S. No.	V1(volt)	I_1 Amps	I_2 Amps	I Amps
1.				
2.				
3.				
4.				

<u>Calculations:</u>

For a given load current IL at an angle ϕ the current and power supply by each transformer can be found out by the following formula:

$$I_1 = (I_L) * \{(Z_2) / (Z_1+Z_2)\}; \quad I_2 = (I_L) * \{(Z_1) / (Z_1+Z_2)\}; (I_L) = I_1 + I_2$$

Check the result obtained with the Theoretical calculations.

<u>Precautions</u>:

1. Circuit connections should not be made while power is ON.
2. Ensure variac position is zero before starting the experiment.
3. Ensure the correct connections of the transformer
4. Check the KVA ratings of the transformers.
5. All connections should be tight and loose connections are to be avoided.
6. Do polarity test before proceeding to parallel operation.
7. Readings of meters must be taken without parallax error.
8.

7. Results and Discussion

Based on your measurements, let us now discuss the results that you obtained. Please provide responses to following points:

A. What is parallel operation of transformer?

....
....

B. What is the advantage of parallel operation of transformer?

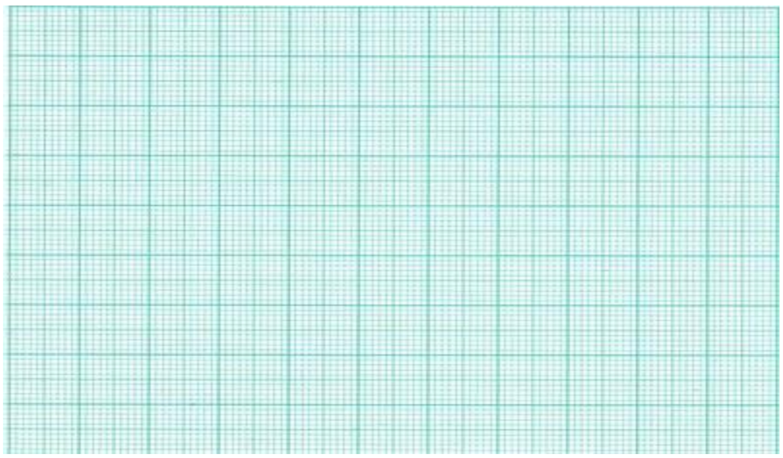
....
……………………………………………………………………………………………

C. What are the conditions for parallel operation in transformer?

....
....
………
……
.

D. Plot the graph of variation of current shared by each transformer *vs* load current.

Variation of current shared by each transformer



Load current

E. What will happen if two transformers are connected in parallel with wrong polarity?

....
....

8. Conclusions

Write in your own words the conclusion of performing this experiment. Write about what you learned from this experiment, what you can tell about the parallel operation of two single phase transformer that you did in experiment.

....
....
....
....
....

Experiment No: 2

Parallel operation of two single phase transformer of different KVA rating and find the variation of current shared by each transformer vs load current.

Contents

1. Objectives

This experiment is designed in such a way to meet the following objectives: -

- To ensure proper connection of two parallel transformers. Polarity test is to be done.
- Parallel operation of two transformers of different KVA rating.one of them is 2KVA and other is 1 KVA.
- To obtain variation of source current versus load current.

2. **Expected outcome of experiment**

On successful completion of experiment the students will be able to know:

- About the necessary condition of parallel operation of transformers.
- Variation in load sharing with respect to source current.

3. Theory:

Introduction

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

- Same polarities should be connected.
- The two transformers should same voltage ratio.
- The percentage impedance should be same.
- There should be no circulating current.

Polarity Test

This is needed for identifying the primary and secondary phasor polarities. It is a must for poly phase connections. Both a.c. and d.c methods can be used for detecting the polarities of the induced emfs. The dot method discussed earlier is used to indicate the polarities. The transformer is connected to a low voltage a.c. source with the connections made as shown. A supply voltage Vs is applied to the primary and the readings of the voltmeters V1, V2 and V3 are noted. The voltages V1: V2 gives the turn ratio. If the volt meter V3 reads V1−V2 then assumed dot locations are correct (for the connection shown).

The beginning and end of the primary and secondary may then be marked by A1 −A2 and a1 −a2 respectively. If the voltage rises from A1 to A2 in the primary, at any instant it does so from a1 to a2 in the secondary. If more secondary terminals are present due to taps taken from the windings they can be labelled as a3, a4, a5, a6.

It is the voltage rising from smaller number towards larger ones in each winding. The same thing Fig. 2 shows the D.C. method of testing the polarity. When the switch S is closed if the secondary voltage shows a positive reading, with a moving coil meter, the assumed polarity is correct. If the meter kicks back the assumed polarity is wrong.

Parallel Operation of Transformer:

The reason that necessitates parallel operation as follows: -

1. Non-availability of a single-phase transformer to meet the load requirement.
2. The power demand might have increased over a time necessitating augmentation of the capacity. More transformers connected in parallel will then be pressed into service.
3. To ensure improved reliability. Even, if one of the transformers gets into fault or is taken out for maintenance/repair the load can be continued to service.
4. When transportation problems limit installation of large transformers at site, it may be easier to transport smaller ones to site and work them in parallel.

When the load outgrows the capacity of an existing transformer, it may be economical to install another one in parallel with it rather than replacing it with a single larger unit. Also, sometimes in a new installation, two units in parallel, though more expensive, may be preferred over a single unit for reason of reliability half the load can be supplied with one unit out.

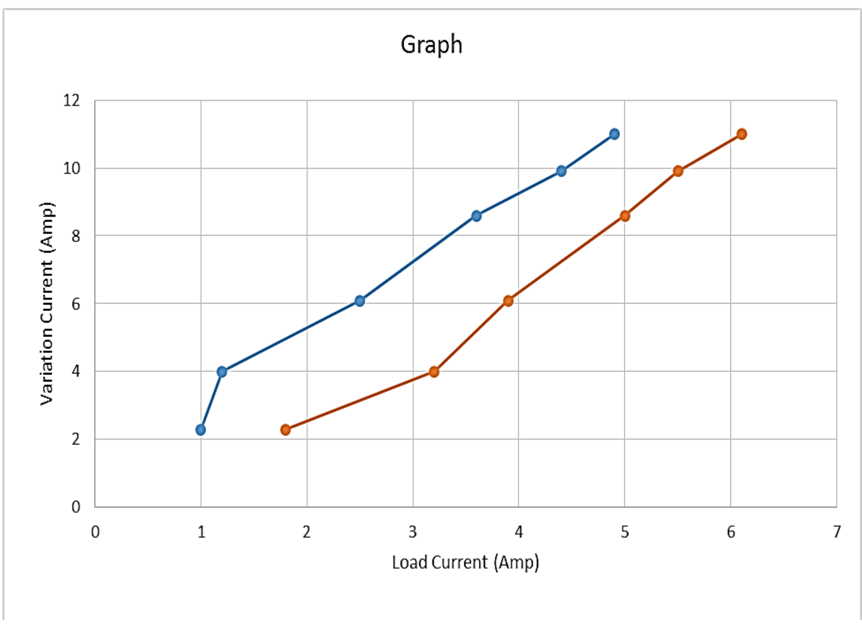


Fig.1: Graph of variation of transformer currents vs load current

4. Equipment required

S.No.	Name	Range	Remark	Qty.
1	Voltmeter	0-300V	AC	2
2	Voltmeter	0-600V	AC	1
3	Ammeter	0-10	AC	3
4	Transformer 1	230V/230V	-	1
5	Transformer 2	230V/115V	-	1
6	Variac	230 V	AC	1

5. Methodology for Measurements

Polarity Test:

1. Connections are made as per the circuit diagram.
2. Apply primary voltage of approximately 50-100 V.
3. Measure voltage across the secondary terminals.
4. If voltage across VA-a is equal to V1+V2 then it is Additive polarity.
5. If voltage across VA-a is equal to V1-V2 then it is Subtractive polarity.
6. Mark the terminals (Dot convention) after the polarity test.

Parallel Operation:

Connections are made as per the circuit diagram shown in figure 1.

1. Switch on the power supply.
2. Slowly increase the voltage up to its rated value of transformer primaries.
3. Gradually increase the load in steps and note the values of A2, V2, A1 & A.
4. Tabulate the readings as shown.
5. Decrease the load and switch off the mains supply.
6. Plot the graph of variation of current shared by each transformer vs load current.

6. Measurements

The figure below shows the connection diagrams for polarity test:

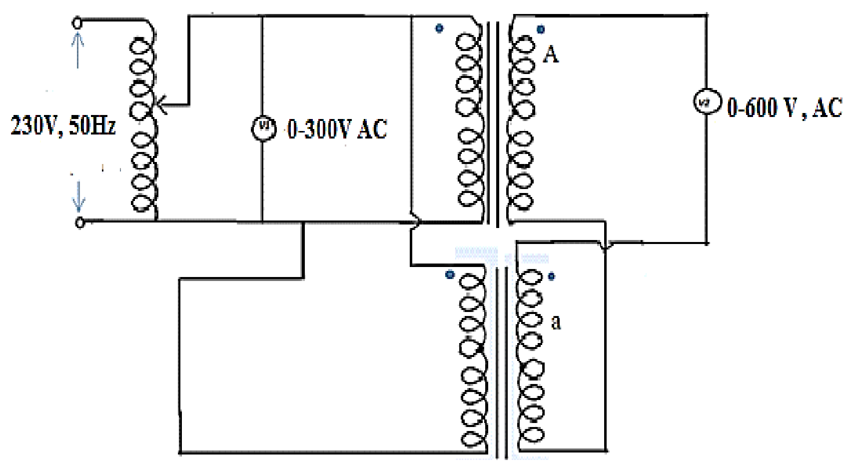


Fig.2: Connection diagram for polarity Test

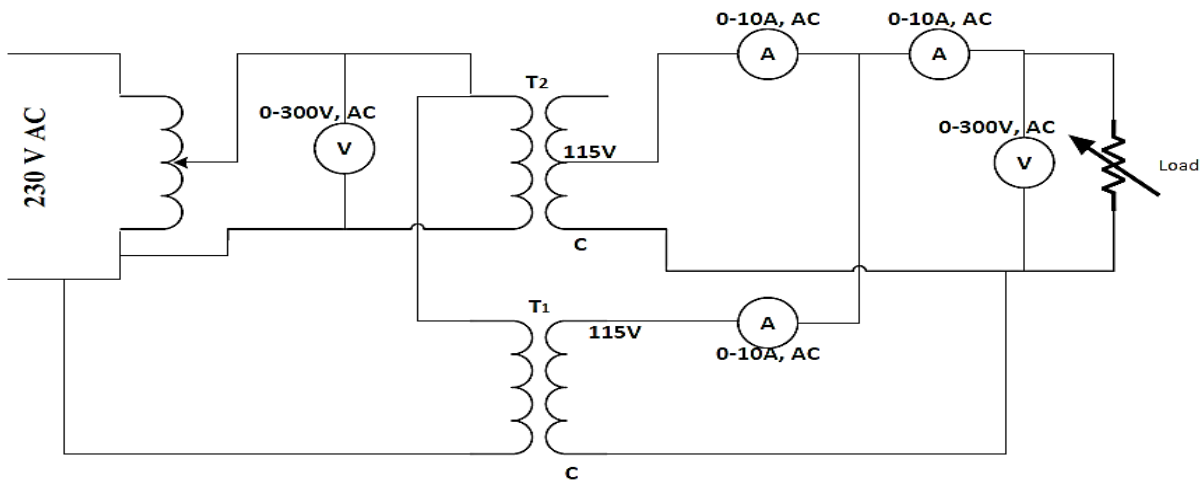


Fig.3: Connection diagram for parallel operation

Transformers specifications: -

Transformer 1	Transformer 2
KVA = 2 LV Voltage =115v HV Voltage =230v Frequency =50Hz	KVA = 1 LV Voltage = 230v HV Voltage = 230v Frequency = 50Hz

Using the above set up note down your observations in the following Table:

Table: Table to be used for recording the measurements:

S. No.	V1(volt)	I_1 Amps	I_2 Amps	I Amps
1.				
2.				
3.				
4.				

Calculations:

For a given load current IL at an angle ϕ the current and power supply by each transformer can be found out by the following formula:

$$I_1 = (I_L) * \{(Z_2) / (Z_1+Z_2)\}; \quad I_2 = (I_L) * \{(Z_1) / (Z_1+Z_2)\}; (I_L) = I_1 + I_2$$

Check the result obtained with the Theoretical calculations.

Precautions:

1. Circuit connections should not be made while power is ON.
2. Ensure variac position is zero before starting the experiment.
3. Ensure the correct connections of the transformer
4. Check the KVA ratings of the transformers.
5. All connections should be tight and loose connections are to be avoided.
6. Do polarity test before proceeding to parallel operation.
7. Readings of meters must be taken without parallax error.
8.

7. Results and Discussion

Based on your measurements, let us now discuss the results that you obtained. Please provide responses to following points:

A. What is parallel operation of transformer?

....
....

B. What is the advantage of parallel operation of transformer?

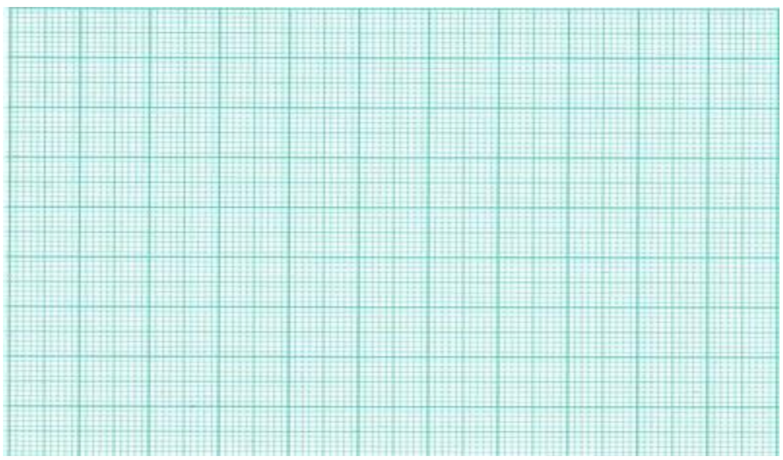
....
…………………………………………………………………………………………………

C. What are the conditions for parallel operation in transformer?

....
....
……
………………………………………………………………………………………………………
.

D. Plot the graph of variation of current shared by each transformer *vs* load current.

Variation of current shared by each transformer



Load current

E. What will happen if two transformers are connected in parallel with wrong polarity?

....
....

8. Conclusions

Write in your own words the conclusion of performing this experiment. Write about what you learned from this experiment, what you can tell about the parallel operation of two single phase transformer that you did in experiment.

....
....
....
....
....

Experiment No: …3

Sumpner's test on two identical single phase Transformers

Contents

1. Objectives

To conduct Sumpner's test on two identical single phase transformer and determine their efficiency at various loads.

2. **Expected outcome of experiment**

On successful completion of experiment the students will be able to:

1. Find out the efficiency of each transformer at various load conditions.

2. Have clear idea about the copper and core losses in transformer.

3. Know why we are conducting the sumpner test on two transformers instead of conducting the separate O.C and S.C test on two identical transformers.

3. Theory

Introduction

Sumpner's test or back to back test on transformer is another method for determining transformer efficiency, voltage regulation and heating under loaded conditions.

Short circuit and open circuit tests on transformer can give us parameters of equivalent circuit of transformer, but they cannot help us in finding the heating information. Unlike O.C. and S.C. tests, actual loading is simulated in Sumpner's test. Thus the Sumpner's test gives more accurate results of regulation and efficiency than that of O.C test and S.C test.

Sumpner's test or back to back test can be employed only when two identical transformers are available.

Both transformers are connected to supply such that one transformer is loaded on another. Primaries of the two identical transformers are connected in parallel across a supply. Secondary are connected in series such that emf's of them are opposite to each other such that the resultant voltage between two terminals of the two secondary's must be zero.

If the secondary windings of the two transformers are not in the series opposition, then there exists the some voltage difference between the two secondary terminals, it leads to the additional copper losses in the transformer.

Hence efficiency of the transformer is reduces.in order to avoid these additional copper losses; we need to connect the two secondary windings of the two transformers in series opposition. This series opposition connection can be checked by conducting the polarity test on two transformers.

Polarity Test

This is needed for identifying the primary and secondary phasor polarities. It is a must for poly phase connections. Both a.c. and d.c. methods can be used for detecting the polarities of the induced emfs.

Let us consider

V1 is voltmeter connected across the primary side of the transformer.

V2 is voltmeter connected across the secondary side of the transformer.

V3 is voltmeter connected between the two secondary's terminals of the two transformers.

Whenever the transformer is connected to an a.c source such that a supply voltage V is supplied to the primary and readings of voltmeter V1, V2 and V3 are noted. The voltages V1: V2 gives the turn ratio. If the voltmeter V3 reads less than V1 the connections are correct such a polarity is termed as subtractive polarity because it reduces the voltage stress between adjacent loads. In case V3>V1, the emf induced in primary and secondary have additive relation and transformer is said to have additive polarity.

Losses in Transformer:

Loss in any machine is broadly defined as difference between input power and output power. When input power is supplied to the primary of transformer, some portion of that power is used to compensate core losses in transformer i.e. Hysteresis loss in transformer and Eddy current loss in transformer core and some portion of the input power is lost as I2R loss and dissipated as heat in the primary and secondary windings, because these windings have some internal resistance in them. The first one is called core loss or iron loss in transformer and the latter is known as ohmic loss or copper loss in transformer

Copper losses in transformer:

Copper loss is I^2R loss, in primary side it is $I_1^2R_1$ and in secondary side it is $I_2^2R_2$ loss, where I_1 and I_2 are primary and secondary current of transformer and R_1 and R_2 are resistances of primary and secondary winding. As the both primary & secondary currents depend upon load of transformer, copper loss in transformer vary with load.

The copper losses in transformer $=I_L^2 R_{21}$ + Stray loss

Here IL is the load current and R_{21} is the total resistance of the transformer w.r.t secondary.

Core losses in transformer:

The core losses in the transformer are the independent to the load, so these losses are also constant. There are two types of core losses in the transformer i.e. Hysteresis Losses and Eddy Current losses.

Sumpner Test

This test facilitates the collection of data or open circuit and short circuit test simultaneously. Two identical transformers are needed. Primary winding of both the transformers are connected in phase opposition. On the secondary side, a low voltage just sufficient to flow the full load current is connected. Once the transformer is connected in such a manner, rated iron losses occur in core and copper losses occur in windings. We can justify that the current is just twice the no load current.

The iron loss of one transformer = 1/2W_o

The copper loss of one transformer = 1/2Wc

The Total losses of one transformer = 1/2W_o+1/2Wc

$$\text{Efficiency} = \frac{\text{Power Output}}{\text{Power Input}} \text{X}(100)$$

$$\text{Efficiency} = \frac{\text{Power Output}}{\text{Power Output} + (\text{Copper Loss}) + (\text{Core Loss})} \text{X100}$$

$$\text{Efficiency at x of FL} = \frac{(x * \text{VI} * PF)}{(x * \text{VI} * \text{PF}) + ((x^2) * \text{Copper Loss}) + (\text{Core Loss})} \text{X100}$$

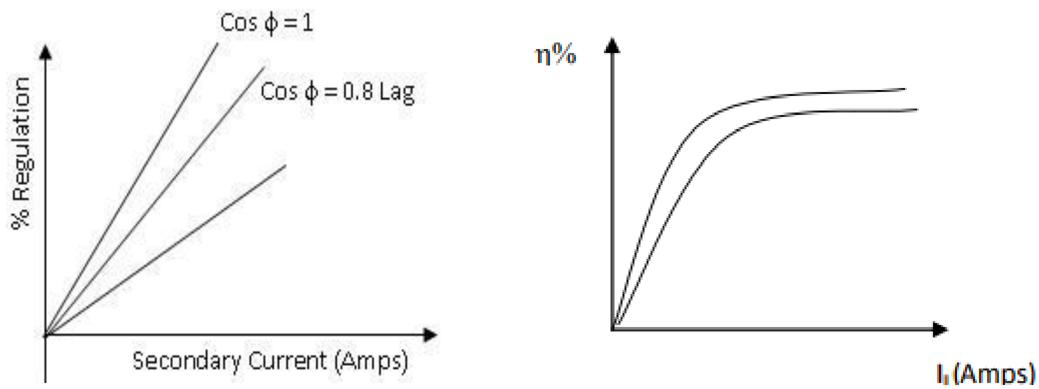


Fig.1: Graph of % regulation and efficiency at different power factor

Advantages of Sumpner test:

1. The power required to conduct the test is small.
2. The transformers are tested at the full load conditions.
3. As the test results gives the value of core and copper losses occurring simultaneously so heat run test can be conducted on two transformers.
4. The secondary current (I2) can be varied to any value using the regulating transformer. Hence we can determine the copper losses at full load condition or at any load.

Disadvantages:

1. Only limitation is that two identical transformers are required.
2. In practice exact identical transformers are not available.as two transformers are required; the test is not economical.

4. Equipment required:

Following equipment will be required to conduct this experiment.

S.No.	Name	Range	Remark	Qty.
1	Voltmeter	0-300V 0-150V 0-600V	AC	3
2	Ammeter	0-15A	AC	2
3	Transformer	230/230V	-	2
4	Wattmeter	0-300W	AC	2
5	Variac	230V	AC	2

5. Methodology for Measurements

Polarity Test:

1. Connections are made as per the circuit diagram.
2. Apply primary voltage of approximately 50-100 V.
3. Measure voltage across the secondary terminals.
4. If voltage across (A-a) is equal to V1+V2 then it is Additive polarity.
5. If voltage across (A-a) is equal to V1-V2 then it is Subtractive polarity.
6. Mark the terminals (Dot convention) after the polarity test.

Sumpner's Test:

1. Connect the circuit as shown in the diagram.
2. Apply 230V A.C. supply to primary side.
3. Note down the readings of W_o , X_o , V_o
4. Apply voltage on sec side in such a manner to provide Full rated current to secondary side.
5. Note down the readings of Wsc ,Isc , Vsc
6. Calculate total losses and efficiency using formula.

6. Measurements:

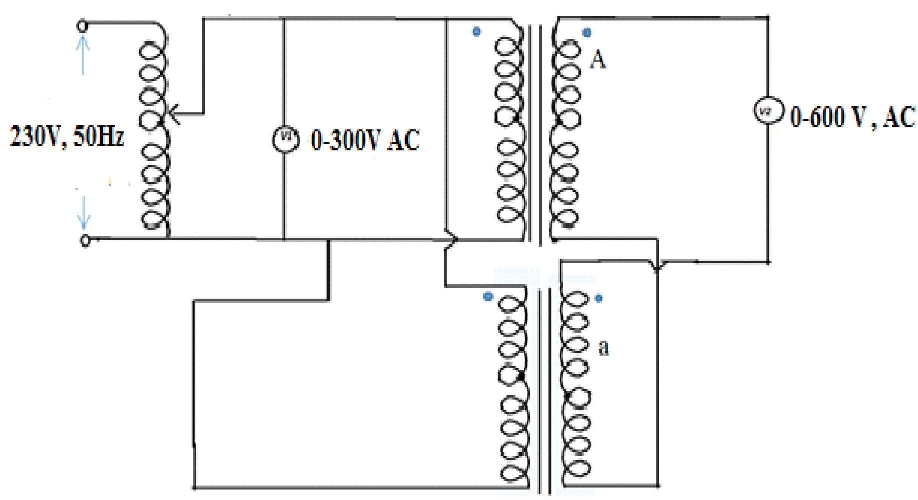


Fig.2: Connection diagram for polarity Test

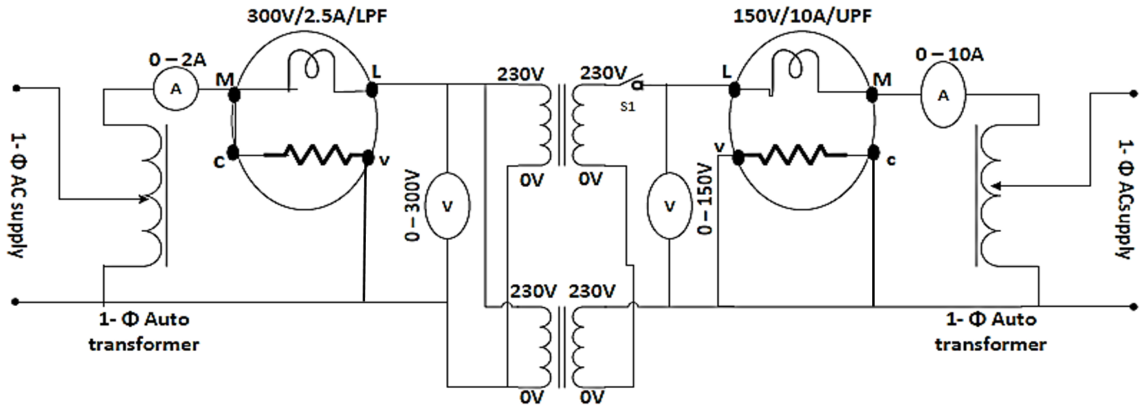


Fig.3: Connection diagram for Sumpner Test

Transformers specifications: -

Transformer
Rating =2KVA Frequency=50Hz LV Voltage =230V HV Voltage =230V

Using the above set up note down your observations in the following Table:

Table: Table to be used for recording the measurements:

S. No.	**V_o(volt)**	**I_o (Amps)**	**W_o (Watts)**	**V_{sc} (volts)**	**I_{sc} (Amp)**	**W_{sc} (Watts)**
1.						
2.						
3.						
4.						

Calculations:
Let readings obtained are:

O.C. TEST: V_1 = 220 V, I1 = 0.86 A W_1= 94.3 W

SC TEST: V_2 =50 V I_2= 4.65 A W_2 = 185 W

Then,
Core loss for each transformer Wo= W1 / 2 = = = 47.15 W

Full load copper loss for each transformer = W2 / 2 = 92.5 W

I0 = I1/2= 0.43A

Then,

No load P.F. = $\cos\varphi_o$= Wo / V 1 *I1= 94.3/ (220*0.86) = 0.498

Iw = I0 Cosϕ = 0.43 x 0.498 = 0.214A
Iμ = I0 Sinϕ = 0.43 x 0.866 = 0.372A

Now,
Calculate $R_o = V_o$ / Iw and $X_o= V_o$ / Iμ referred to L.V side

Now we have:

I_{sc} = short circuit current of each transformer = I_2 = 4.65 A

V_{sc} = short circuit voltage of each transformer = V_2 /2 = 25 V

W_{sc} = Full load copper losses of each transformer = W_2 /2= 92.5

$W_{sc} = I^2_{sc} * R_{HV}$ from this we get

$R_{o2}= R_{HV}$ = Wsc/(Isc) ^{2} = 92.5/(4.65^2)=4.277 ohms

also, $Z_{HV} = Z_{o2} = V_{sc}/ I_{sc}$= 25/4.65= 5.376 ohms

Now we can find $X_{HV} = (Z_{HV}^2 - R_{HV}^2)^{1/2} = (5.376^2-4.277^2)^{1/2}$ = 3.257 ohms

Now we have K = turns ratio = 415/230=1.8

Now we will calculate above parametrs refeered to LV winding side:

$Z_{o1}= Z_{LV}= Z_{HV} / K^2 = 5.376/(1.8)^2$ = 1.659 ohms

R_{o1}= R_{LV}= R_{HV} / K^2 = 4.277/$(1.8)^2$ = 1.32 ohms

X_{o1}= X_{LV}= X_{HV} / K^2 = 3.257/$(1.8)^2$ = 1.0052 ohms

Also, Total Losses= Wi + Wcu = Wo +W_2= 47.15+92.5 = 139.65 W
Output Power = 2 KVA

Calculate %Regulation= (I_1*R_{o1}*Cosϕ ± = I_1*X_{o1}*Sinϕ)/ V_{HV} where + is for lagging , - is for leading loads.
Efficiency at full load 0.8 pf lagging:

$$\text{Efficiency at x of FL} = \frac{(x * \text{VI} * PF)}{(x * \text{VI} * \text{PF}) + ((x^2) * \text{Copper Loss}) + (\text{Core Loss})} \text{X100}$$

For full load x=1, above formula becomes:

$$\text{Efficiency} = \frac{\text{Power Output}}{\text{Power Output} + (\text{Copper Loss}) + (\text{Core Loss})} \text{X100}$$

Putting values, Power output = 2000*0.8= 1600

Efficiency in % = (1600/ (1600+92.5+47.15)) * 100 = 0.91980 *100 = 91.98 %

Precautions:

Circuit connections should not be made while power is ON.

1. Ensure variac position is zero before starting the experiment.

2. Ensure the correct connections of the transformer

3. Readings of the meters must be taken without parallax error.

7. Results and Discussion

Based on your measurements, let us now discuss the results that you obtained. Please provide responses to following points:

A. How can you determine the efficiency of transformer?
....
....
....

B. How much voltage is applied on primary side while conducting the Sumpner’s test?
....
....
.

8. Conclusions

Write in your own words the conclusion of performing this experiment. Write about what you learned from this experiment, what you can tell about Sumpner Test that you did in experiment.

....
....
..

Experiment No: …4

To perform direct load test on Dc shunt motor and plot variation of input current, speed, torque and efficiency against output power.

Contents

1. Objectives

To perform direct load test on a DC shunt motor and plot the variation of

(a) input current vs output power

(b) speed vs output power

(c) torque vs output power

(d) efficiency output power

2. Expected Outcomes of Experiments

On successful completion of experiment, the students will be able to:

(a) Know about the direct load test.

(b) Identify the characteristics curve of Dc motor under loading conditions.

(c) Identify the efficiency of dc motor.

(d) Know about the effects of load on the performance of Dc motor.

3. Theory

Introduction:

This is a direct method of testing a dc machine. It is a simple method of measuring motor output, speed and efficiency etc., at different load conditions. A rope is wound round the pulley and its two ends are attached to two spring balances S1 and S2. The tensions provided by the spring balances S1 and S2 are T1 and T2. The tension of the rope 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 in Kg - force. A counter emf or back emf (E_b) is induced in the armature conductors while the armature (rotor) rotating in the magnetic field.

Equations for Dc motor:

The load test is conducted to determine the efficiency of a shunt motor by actually loading it. Motors are used to convert electrical power into mechanical power.

If the motor is loaded by a belt and pulley arrangement and if W_1 and W_2 are the tensions in kg on the two sides of the belt.

The torque is given by:

$$\boldsymbol{\tau} = (\boldsymbol{W1} - \boldsymbol{W2})\boldsymbol{r} \text{ kg m}$$

where ‘r’ is the effective radius of the pulley in meters

The mechanical output is given by:

$$\text{Output Power } = \frac{2\pi N\tau}{60 * 0.102} \text{ watts}$$

$$\text{Output Power } = \frac{2\pi N\tau}{60 * 0.102 * 746} \text{ HP}$$

where ‘N’ being the speed of motor in rpm

The power input to the motor is given by the product of the voltage applied to the motor and current drawn by it as:

$$\text{Input power} = (VI) \text{ Watts}$$

$$\text{Efficiency} = \frac{\text{output power in watts}}{VI}$$

The speed regulation of a DC motor is defined as the percentage change in the speed at rated load. When the load is reduced to zero, that is

$$\text{Speed regulation} = \frac{N(\text{noload}) - N(\text{rated load})}{N(\text{rated load})} * 100\%$$

Characteristics:

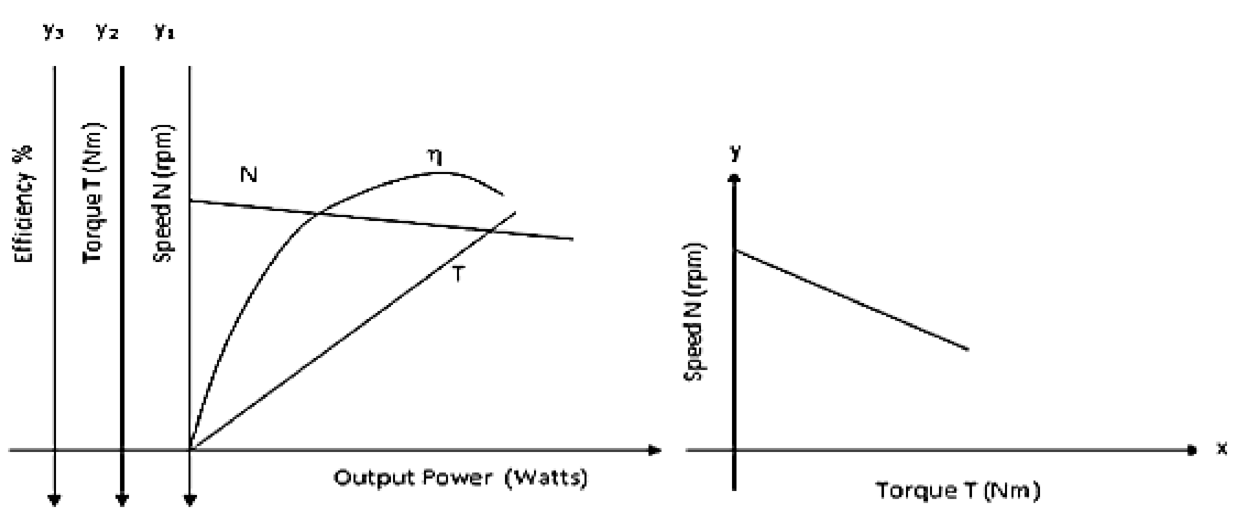


Fig.1: Sample graph of load test on dc shunt motor

4. Equipment Required

Following equipment will be required for conduct this experiment-

S.No.	Name	Range	Remark	Qty.
1	Voltmeter	0-300V	DC	1
2	Ammeter	0-15A	DC	1
3	Rheostat	355Ω/1.6A	-	1
4	Tachometer	-	-	1

5. Methodology of Measurement

For performing this experiment follow the steps as follows-

(a) Connect the circuit as shown in the circuit diagram.

(b) Keep the field control rheostat at minimum resistance position.

(c) Switch on the motor and adjust the potentiometers till the armature attains the rated voltage and increase the field rheostat till the motor attains the rated speed.

(d) Record the readings of the instruments at no-load condition.

(e) Loosen the rope on the brake drum and put some water inside the rim of the brake drum.

(f) Gradually, increase the load on the brake drum and record the readings as per the given table.

(g) Do not exceed the armature current more than its rated value.

6. Measurements

Machine specifications:

DC MOTOR
Power=3BHP Speed=1450 rpm Voltage=220V RATED current=12.5 A

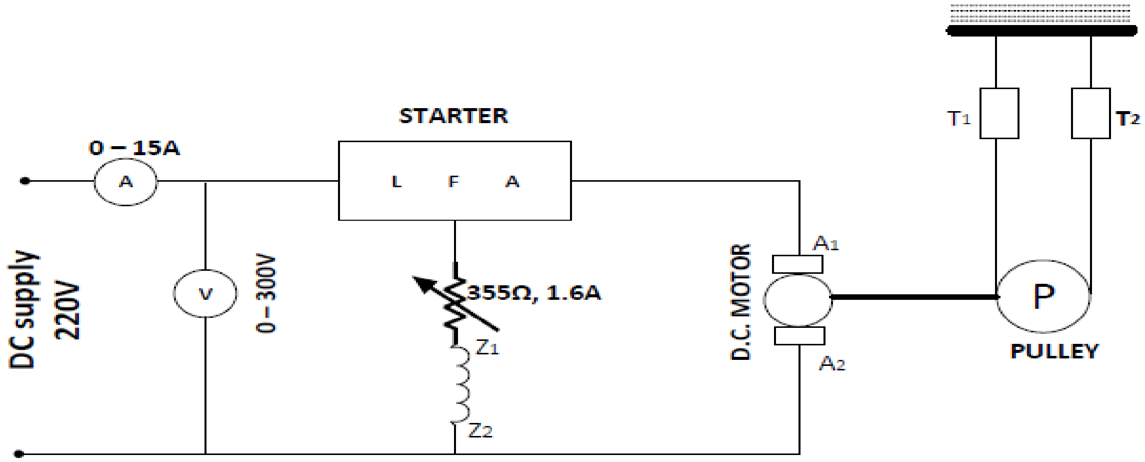


Fig.2: Connection Diagram for direct load test on DC shunt motor

Using the above set up note down your observations in the following Table:

Table: Table to be used for recording the measurements:

S.NO.	SUPPLY VOLTAGE (V)	INPUT CURRENT (A)	SPEED (rpm)	T1 (kg)	T2 (kg)	T1-T2 (kg)	TORQUE (kg m)	OUTPUT POWER (W)	INPUT POWER (W)	Ŋ (%)
1.										
2.										
3.										

<u>Calculations</u>

Circumference=2πR=0.59 m, R=.059/2π =0.093

T = (T1-T2) ×R×9.81 N-m, ω =2πN/60 and Pout =T*ω

Efficiency: η = Pout/ Pin

7. Results and Discussion

Based on your measurements, let us now discuss the results that you obtained. Please provide responses to following points:

A. What is the condition for maximum torque of a D.C. shunt motor??

....
.

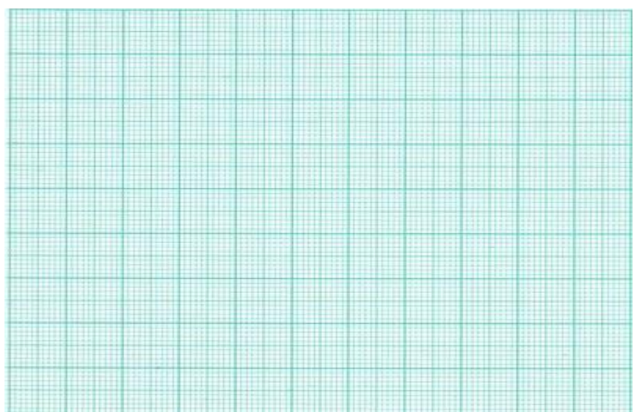
…………………………………………………………………………………………………

B. Why is the starter necessary?

....
....
....

C. Plot the graphs between:

a) Efficiency Vs Output power, b) Speed Vs Output power c) Torque Vs Output Power
d) Speed vs Torque.



8. Conclusions

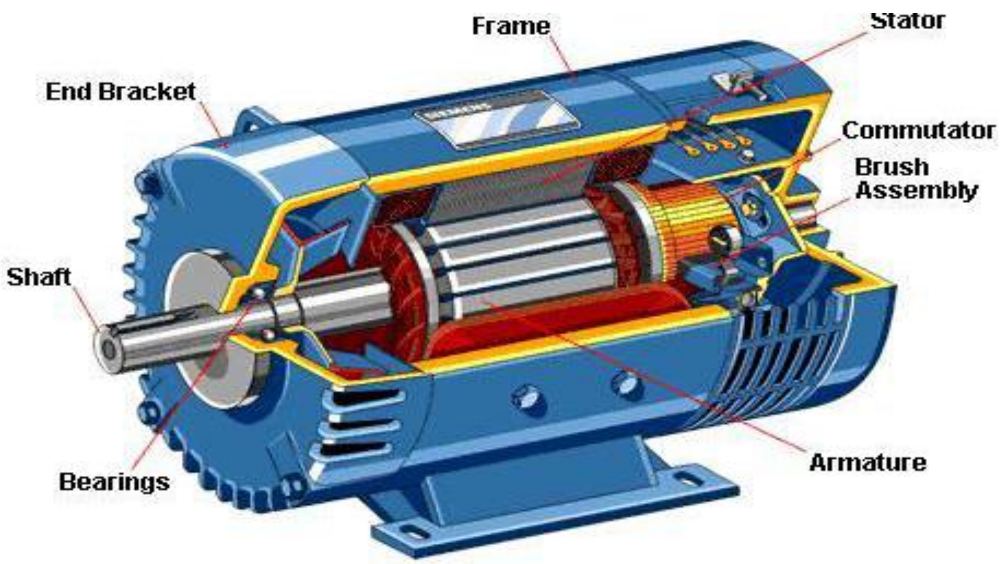
Write in your own words the conclusion of performing this experiment. Write about what you learned from this experiment, what you can tell about the direct load test on DC shunt motor that you did in experiment.

....
....

Experiment No: …5

Magnetization characteristics of a DC Machine

Contents



1. Objectives

To obtain magnetization characteristics of a DC machine. Estimate field circuit resistance of a DC shunt generator at rated speed. Measure field winding and armature winding resistance. Plot the external characteristics of DC shunt generator.

2. Expected outcome of experiment

On successful completion of experiment, the students will be able to:

1. Know about dc machine and its working
2. Study the magnetization characteristic dc machine
3. Observe the variation of no load EMF with respect to field current

3. Theory

Introduction

Dc generator principle is whenever a conductor is placed in magnetic field and there is a flux linkage then an EMF is introduced in the conductor according to faraday law of electromagnetic induction direction of induced emf is faraday right hand rule.

Principle of dc motor is whenever a current carrying conductor is placed in magnetic field than its fell a force direction of force is given by faraday right hand rule.

D.C generators may be classified as

(i) Separately excited generator,

(ii) Shunt generator, and

(iii) Series generator and

(iv) Compound generator.

In a separately excited generator field winding is energised from a separate voltage source in order to produce flux in the machine. So long the machine operates in unsaturated condition the flux produced will be proportional to the field current.

Series winding is meant to be connected in series with the armature and naturally to be designed for rated armature current. Obviously there will be practically no voltage or very small voltage due to residual field under no load condition (Ia = 0). However, field gets strengthened as load will develop rated voltage across the armature with reverse polarity, is connected and terminal voltage increases.

A compound generator has two separate field coils wound over the field poles. The coil having large number of turns and thinner cross sectional area is called the shunt field coil and the other coil having few number of turns and large cross sectional area is called the series field coil. Series coil is generally connected in series with the armature while the shunt field coil is connected in parallel with the armature. If series coil is left alone without any connection, then it becomes a shunt machine with the other coil connected in parallel.

Magnetization characteristics:

It is the relationship between the field current and the air gap flux. If the speed of the generator is maintained constant, the voltage available at the terminals of the armature at no load would be proportional to the air gap only. It is also known as no load or open circuit characteristic sometimes saturation curve. Except for permanent magnet generators, a generator produces output voltage proportional to the magnetic field, which is proportional to the excitation current; if there is no excitation current there is zero voltage.

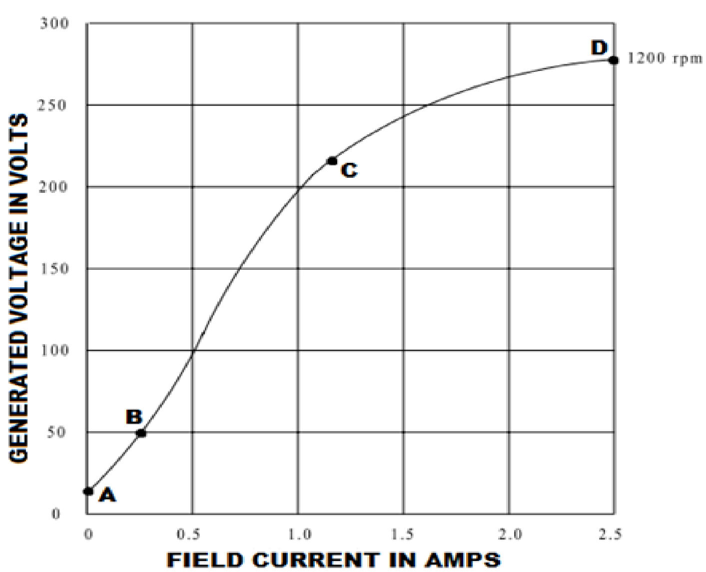


Fig.1: Magnetisation characteristics of DC generator

Magnetization curve of a DC generator has a great importance because it represents the saturation of the magnetic circuit. For this reason, this curve is also called saturation curve. According to the molecular theory of magnetism the molecules of a magnetic material, which is not magnetized, are not arranged or aligned in definite order.

When current passed through the magnetic material then its molecules are arranged in definite order. Up to a certain value of field current the maximum molecules are arranged. In this stage the flux established in the pole increased directly with the field current and the generated voltage is also increased. Here, in this curve, point B to point C is showing this phenomenon and this portion of the magnetization curve is almost a straight line. Point C is also known as the knee of the magnetization curve.

A small increase in magnetism requires very large field current above the saturation point. That is why upper portion of the curve (point C to point D) is bend as shown in figure.

Magnetization curve of a DC generator does not start from zero initially. It starts from a value of generated voltage due to residual magnetism

Critical field resistance and speed:

The critical field resistance is defined as the maximum field circuit resistance (for a given speed) with which the shunt generator would excite. ... It is a Tangent to the Open Circuit Characteristics of the Generator (at a given speed). If we fix the value of field resistance (not at critical value) and go on decreasing the speed of DC generator then we see that for a fix value speed the resistance line of the fix resistance is parallel to magnetisation characteristics, this value of speed is called critical speed of DC generator.

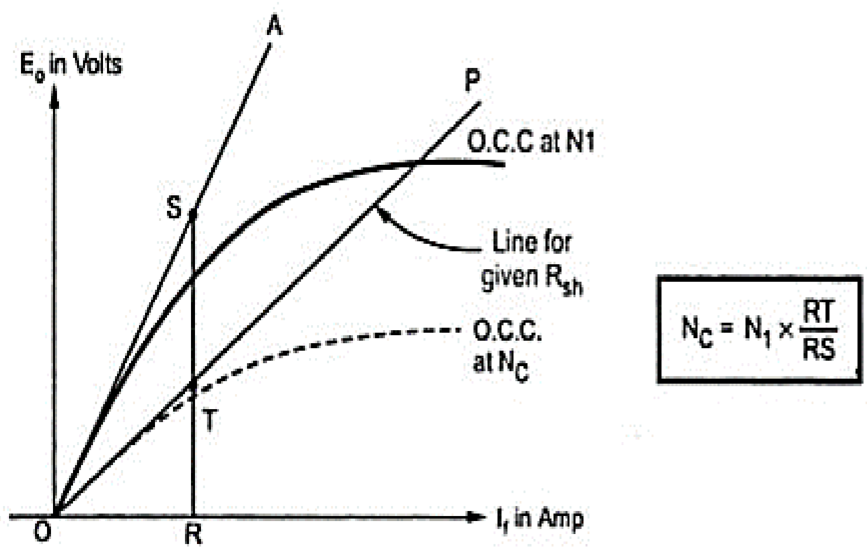


Fig.2: Critical speed and critical resistance plot

4. Equipment required

Following equipment will be required to conduct this experiment.

S.No.	Name	Range	Remark	Qty.
1	Voltmeter	0-300V	DC	2
2	Ammeter	0-2.5, 0-5A	DC	2
3	Rheostat	355Ω/1.6A, 350 Ω /1.4A	-	2

5. Methodology for Measurements

Magnetization characteristics

1. Make the connections as shown in the circuit diagram. Switch on the DC supply.
2. Start the motor and bring it to the speed at which magnetization curve is to be taken, here its 1500rpm.
3. Change the current and note the respective voltage readings.
4. Take readings in reverse order of current.

Armature winding and Field winding resistance

1. Make the connections as given in circuit diagram.
2. For armature winding resistance connections are made with A1 and A2, and field resistance with Z1 and Z2.
3. In case of armature winding resistance, ammeter and voltmeter used be should have 0-5 A and 0-10V respectively.
4. In case of Field winding resistance, ammeter and voltmeter used be should have 0-2.5A and 300V respectively.
5. Switch on the AC supply.
6. Change the voltage and note the respective current readings
7. Use the machine specifications and nature of tests to determine the range of instruments.

6. Measurements

The figure below shows the connection diagram for field circuit of DC Machine:

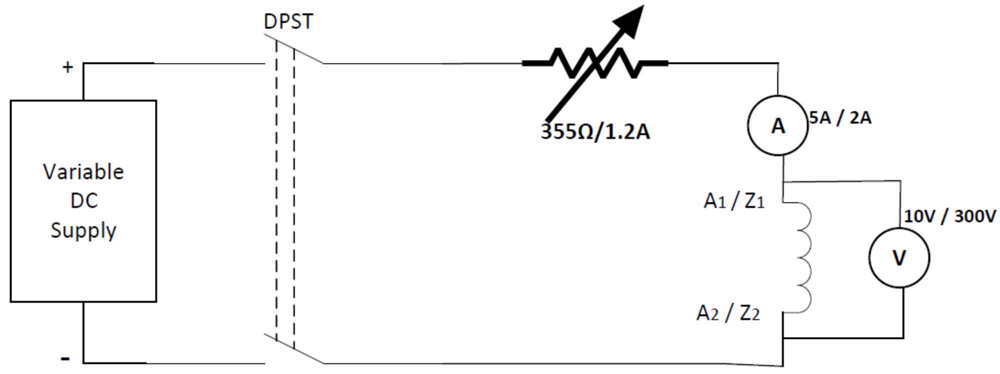


Fig.3: Connection diagram for field circuit of DC Machine

The figure below shows the connection diagram for dc generator and dc motor:

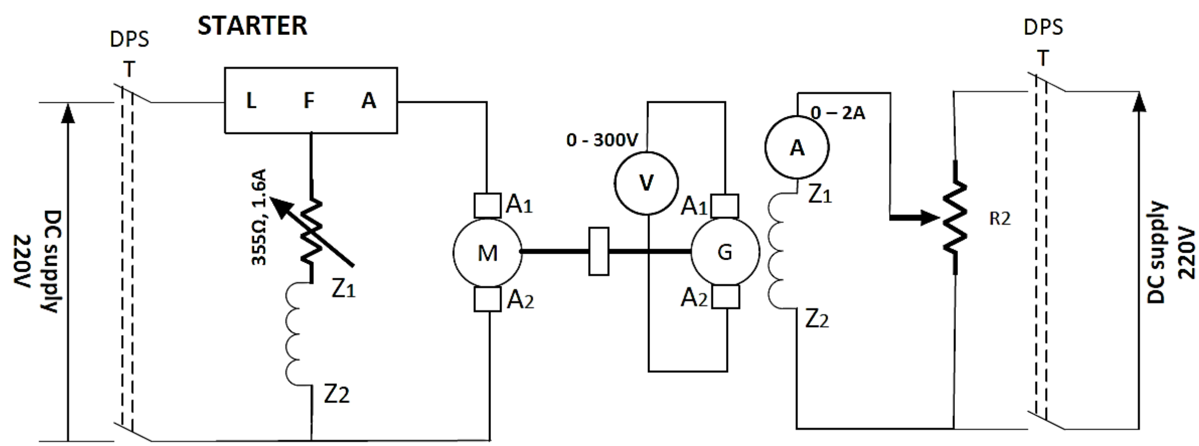


Fig.4: Connection diagram for DC generator and dc motor

DC Generator Specifications: -

DC GENERATOR
Speed=1500rpm Voltage=230V Current=13 amp Power=3 HP

Using the above set up note down your observations in the following Tables:

Table1: To determine magnetization characteristics:

At Constant Speed of Rotation =1500 RPM

S. No.	E(volts)	I(Amps)
1.		
2.		
3.		
4.		

Table2: To determine armature resistance:

S. No.	E(volts)	I(Amps)	Ra=V/I ohms
1.			
2.			
3.			
4.			

Table3: To determine field winding resistance:

S. No.	E(volts)	I(Amps)	R_f =V/I ohms
1.			
2.			
3.			
4.			

<u>Precautions</u>:

1. The speed of generator during the experiment should be kept be constant.
2. It is desirable to run the motor for sufficient time.

7. Results and Discussion

Based on your measurements, let us now discuss the results that you obtained. Please provide responses to following points:

A. When DC Generator fails to build up the voltage, what are the reasons?

....
....

B. Why starter is used to start the DC machine?
....
....

C. Plot the graph of magnetisation characteristics.

Generated Voltage (Volts)

Field Current I_f (Amperes)

8. Conclusions

Write in your own words the conclusion of performing this experiment. Write about what you learned from this experiment, what you can tell about magnetisation characteristics of DC machine that you did in experiment.

....
....
....

Experiment No: …6

Scott connection of Two Single Phase Transformers

Contents

1. **Objectives**

To make Scott connection of two single phase transformer and to verify the current relation by drawing phasor diagram for balanced and unbalanced resistive load condition.

2. **Expected outcome ofexperiment**

On successful completion of experiment the students will be able to:

- Know how to practically perform the Scott Connection.
- Practically do the three phase to two phase conversion.
- Observe the balanced and unbalanced load effect on the current.

3. Theory

Introduction

We can convert Three-Phase to two phase and using two transformers. We can show two-phase voltages between lines 1 and 2, and lines 3 and 4, we will get balanced three phase voltages between R, Y and B.

Star-Star Connection: -

This test is most economical for small high voltage transformer because the no of turns per phase and the amount of insulation required is minimum. The ratio of line voltages on the primary and secondary sides is same as the transformation ratio of each transformer. Angular displacement between primary and secondary voltages is zero. By stabilizing primary neutral, we can avoid distortion in the secondary phase voltages. This connection works satisfactorily only if the load is balanced.

Delta-Delta connection: -

This connection is economical for large, low-voltage transformer in which insulation problem is not so urgent, because it increases the number of turns/phase. The ratio of transformation between primary and secondary line voltage is exactly the same as that of each transformer. No difficulty is experienced from unbalanced load as the case of Y-Y connection. The three phase voltages remain practically constant regard less of load imbalance. An advantage of this connection is that one transformer becomes disabled the system can continue to operate in open-delta or in V-V although with reduced available capacity. The reduced capacity is 58% and not 66.7% of the normal value.

Star-Delta Connection: -

The main use of this connection is the sub-stationed of the transmission line where the voltage is star connected with grounded neutral. The ratio between the secondary and primary line voltage is 1/3 times the, transformation ratio of each transformer.

Delta - Star connection: -

This connection is generally employed where it is necessary to step up the voltages. The neutral of the secondary is grounded for providing 3-phase 4-wire service. In recent years, this connection has gained considerable popularity because it can be used to serve both the 3-phase power equipment and single phase lightening circuits.

4. Equipmentrequired

Followingequipmentwillbe requiredto conductthisexperiment.

S.No.	Name	Range	Remark	Qty.
1	Voltmeter	0-300V	AC	3
2	Ammeter	0-10A	AC	5
3	Rheostat	9Ω,9A	-	2

5. Methodology of measurements

1. Connect the connection as shown in the figure.
2. Give 3 phase supply of 230 volts/phase.
3. Take the reading for balanced load (I4=I5).
4. Take the reading for unbalanced load (I4=I5).

6. Measurements

The figure below shows theconnection diagramfortheexperiment:

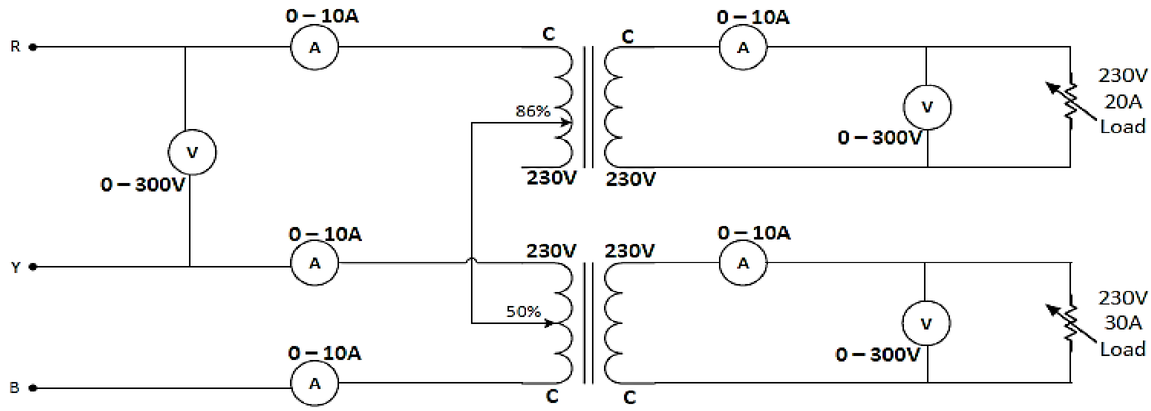


Figure6: Connectiondiagramto findcore losses ofsingle phase transformer

Usingthe above setup notedown yourobservationsinthefollowingTable:

Table 1: Table to be usedfor recordingthe measurementfor Balanced Load

S.NO.	V	V4	V5	I1	I2	I3	I4	I5

Table 2: Table to be used for recording the measurement for Unbalanced Load

S.NO.	V	V4	V5	I1	I2	I3	I4	I5

Precautions:

1. Circuit connections should not be made while power is on.
2. Ensure variac position is zero before starting the experiment.
3. Ensure the correct connection of the transformer.
4. Check the KVA rating of the transformers.

7. Results and Discussion

Based on yourmeasurements,letus now discusstheresults thatyou obtained.

Please provideresponses to followingpoints:

A. Is it possible to obtain a 3- phase a.c. supply from 2 – phase a.c. supply by using Scott-connection?

....
……………………………………………………………………………………………..

B. Where does the Scott-connection find its use?

....
……………………………………………………………………………………………..

C. Are the two transformers connected for Scott-connection coupled magnetically?

…………………………………………………………………………………………….
…………………………………………………………………………………………….

8. Conclusions

Writein yourown wordsthe conclusion ofperformingthis experiment. Write aboutwhatyoulearned fromthisexperiment, whatyou can tellaboutthe Scott Connection test thatyou didin experiment.

....
....
....

Experiment No: …7

To conduct open and short circuit test on three-phase transformer and determine the equivalent circuit parameters in per unit.

Contents

1. Objectives

To conduct open circuit and short circuit tests on a three phase three winding transformer and to determine the equivalent circuit parameters in per unit.

2. Expected Outcomes of Experiments

On successful completion of experiment, the students will be able to:

- Perform the OC test for obtaining the core losses
- Practically obtain copper losses using S.C. Test.
- Obtain the parameters of equivalent circuit practically

3. Theory

Introduction:

A transformer is a static device which transfers the electrical energy from one circuit to another circuitThe 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. The equivalent circuit is shown below:

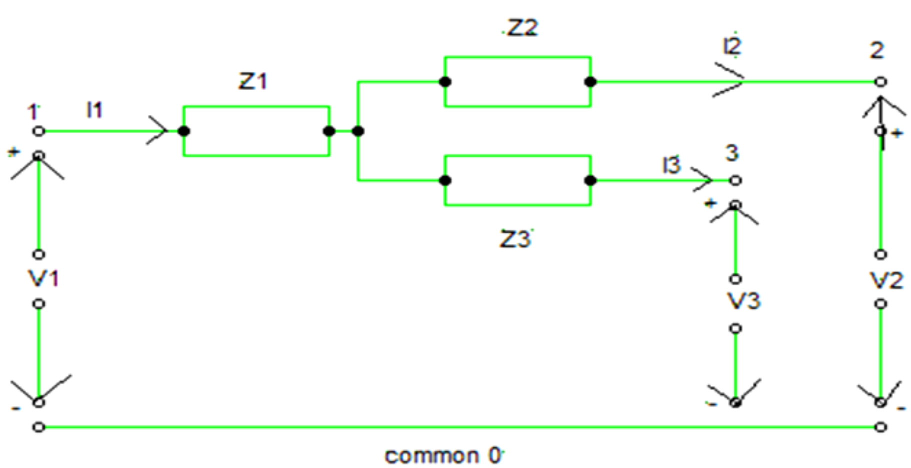


Fig. 1: Equivalent circuit of the three winding transformer

Open Circuit Test:

In open circuit test, usually HV side is kept open and meters are connected on LV side as shown in the fig.1. When rated voltage is applied to the LV side, the ammeter reads the no-load current Io and wattmeter reads the power input. The no load current INL is 2 to 5% of full load current. Hence, the copper losses at no-load are negligible.

We represent the iron or core losses. Iron losses are the sum of hysteresis and eddy current losses. The core loss at no load is given by:

$$\mathbf{Wo = V_{LV}\ I_O\ Cos_{\phi 0}}(1)$$

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 an auto-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.

i). When HV side kept open voltmeter gives reading equal to rated voltage of the LV side. Ammeter gives no load current i.e. approximately 2-3% of rated current.

Here we expect to get the Shunt Branch impedance $\mathbf{Z_m}$.

$$\mathbf{Z_m = V_1/I_1}$$

$$\mathbf{P_c = V_1/R_{m2}}$$

(ii). When LV side short circuited. The ammeter reading gives the primary equivalents of full load current IL.

Here we expect to get the transformer equivalent **(Ze).**

$$\mathbf{Ze = Vsc/IL}$$

$$\mathbf{Pcu = Re*IL2}$$

4. Equipment Required

Following equipment will be required for conduct this experiment-

SNO	NAME	RANGE	REMARKS	QTY
1	Voltmeter	0-150 V 0-600V	AC	2
2	Ammeter	0-2.5A,0-6A	AC	2
3	Wattmeter	0-150W 0-600W	AC	2
4	3-φ Transformer	400V	AC	1
5	3 Winding Autotransformer	230V	-	1

5. Methodology of Measurement

1) Open Circuit Test:-

a) Connect the 3 Φ mains supply to the auto-transformer (The connections to the auto-transformer have been described in detail in the prelude to the manual)

b) Output of the Auto-transformer is fed to the TPST. (Choose appropriate fuse value based on the maximum current that will flow amongst the three pairs of winding under test i.e. Primary-Secondary, Secondary-Tertiary and Primary-Tertiary)

c) The connections of the 3 Φ-3 winding transformer are elaborately mentioned on the Transformer's front panel. They should be strictly adhered to. Open the connections if already connected and reconnect in accordance with the directions on the panel. Connect primary and secondary in Y and Tertiary in Δ.

d) The Secondary and tertiary should be left open (i.e. The tertiary should be left as it is and the secondary should be left open).

e) The Ammeter and the wattmeter should be connected as shown in Fig.2. The Voltmeter should be kept floating. Take care to use a low power factor wattmeter for open-circuit test.

f) Increase the autotransformer voltage till the voltmeter reads the rated primary side voltage.

g) Once this voltage is reached note down the readings of the Voltmeter, wattmeter and ammeter. Do not forget to note down the multiplication factor of the wattmeter.

h) Slowly decrease the voltage of the autotransformer to 0 volts. Switch off the mains power supply and throw open the TPST.

2). Short-Circuit test:-

a) Follow the steps 1,2and 3 of (A).

b) Make the connections as shown in figure 3. Three-phase supply is given to primary through auto-transformer, the secondary will be short circuited and the tertiary will be open-circuited.

c) Determine the rated current which would flow in the primary and secondary depending on the rated KVA.

d) Close the TPST switch and gradually increase the Autotransformer voltage till either A1 or A2, whichever reaches the rated current first.

e) Note down the readings of V, A1 and W1. Note down the multiplication factor of the Wattmeter and proceed to calculate the short circuit parameters i.e., Z12.

f) Repeat the above procedure with supply given to primary, and tertiary short-circuited to get Z13. (Refer Figure 4).

g. Repeat the above procedure with supply given to secondary, and tertiary short-circuited to get Z23.

6. Measurements

The figure below shows the connection diagram for the experiment:

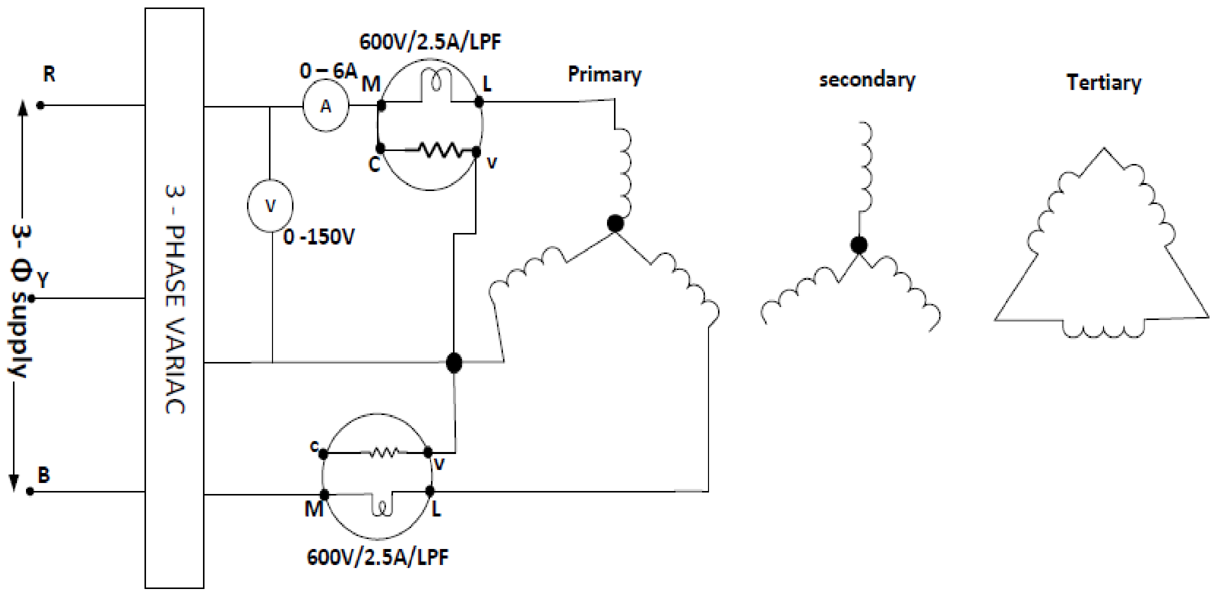


Fig.2 Circuit diagram for Open Circuit Test

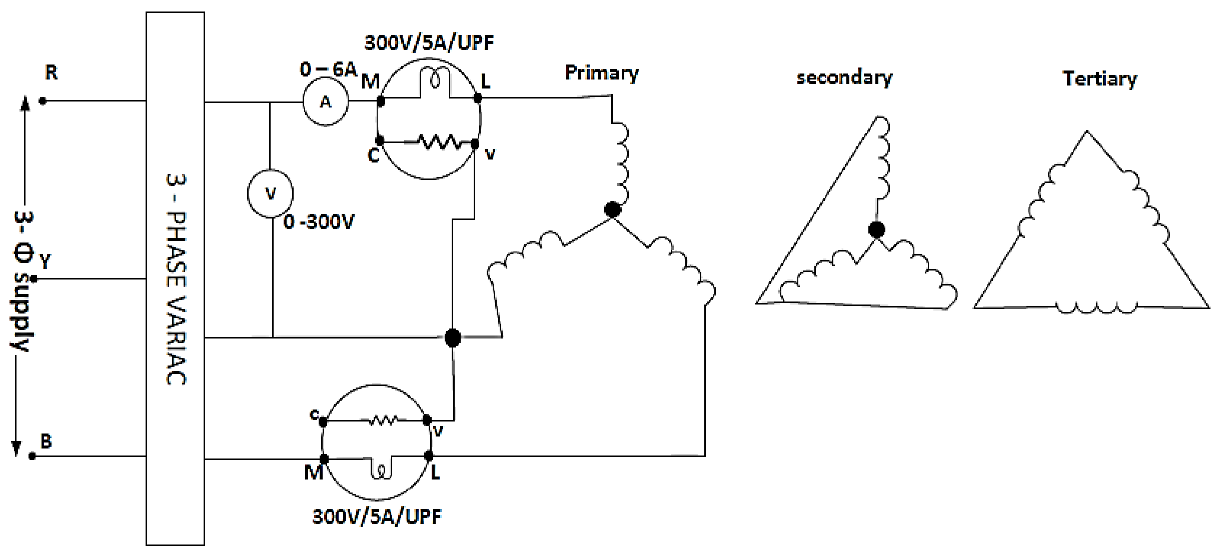


Fig.3: Circuit diagram for Short Circuit Test

<u>Machine specifications</u>:

Three Phase Transformer
Rated current=12.5 A Primary voltage =400V Secondary voltage=230/115V Primary current=4.33 amp KVA=3

Using the above set up note down your observations in the following Table:

Table: Table to be used for recording the measurements:

S.NO	V	I	W1	W2	Sequence	Pri.	Sec.	Tec.
1					1	En	O	O
2					2	En	S	O
3					3	En	O	S
4					4	O	O	S

<u>Calculations:</u>

Rated current = KVA/√3×rated voltage = 3000/√3×400 = 4.33 A

(1) Ze=Vsc/Isc

Z12=Vsc1/Isc1

= 18/4.3=4.186

Z23=Vsc2/Isc2

Z23=30/4.3=6.976

Z13=Vsc3/Isc3

=15/4.3=3.488

(2) $R=Psc(W1)/Isc^2$ (3) $X=(Z2-X2)1/2$

Where Vsc=short circuit voltage, Isc= short circuit current, Psc= power input, Z= lumped impedence, R=lumped resistance and X=lumped reactance. Also Z=R+jX

Frome the three short circuit test we obtain three lumped impedence namely Z12, Z23, & Z13

$Z1=(Z12+Z13-Z23)/2$

$=(4.186+3.488-6.976)/2=0.349$

$Z2=(Z23+Z12-Z13)/2$

$=(6.976+4.186-3.488)/2=3.837$

$Z3=(Z13+Z23-Z12)/2$

$=(3.488+6.976-4.186)/2=3.139$

For open circuit test we have

$Y=I/V$

$=.92/400=2.3*10^{-3}$

$P0=V^2Gi$

$Gi=56/400^2=3.5*10^{-4}$

$Bm=\sqrt{Y^2-G^2}$

$=\sqrt{(2.3*10^{-3})^2-(3.5*10^{-4})^2}$

$=2.273*10^{-3}$

Where Yo=Gi-jBm is the equivalent admittance of the shunting branch in the open circuit.

Precautions:

a. Circuit connections should not be made while power is on.

b. Ensure variac position is zero before starting the experiment.

c. Ensure the correct connection of the transformer.

d. Check the KVA rating of the transformers.

7. Results and Discussion

Based on your measurements, let us now discuss the results that you obtained. Please provide responses to following points:

A. Why H.V. winding is kept open during O.C. test and 1.v. winding is shorted during S.C. test in case of large transformers?

....
....

B. What will happen if dc supply instead of ac supply is applied to a transformer?
....
..…………………………………………………………………………………………

C. “The wattmeter reading during O.C. test is considered as core loss while wattmeter reading during S.C. test is considered as copper loss” Justify?
....
....

D. In O.C. test, a voltmeter is connected across secondary winding and still it is called as O.C. test. Why?
....
....

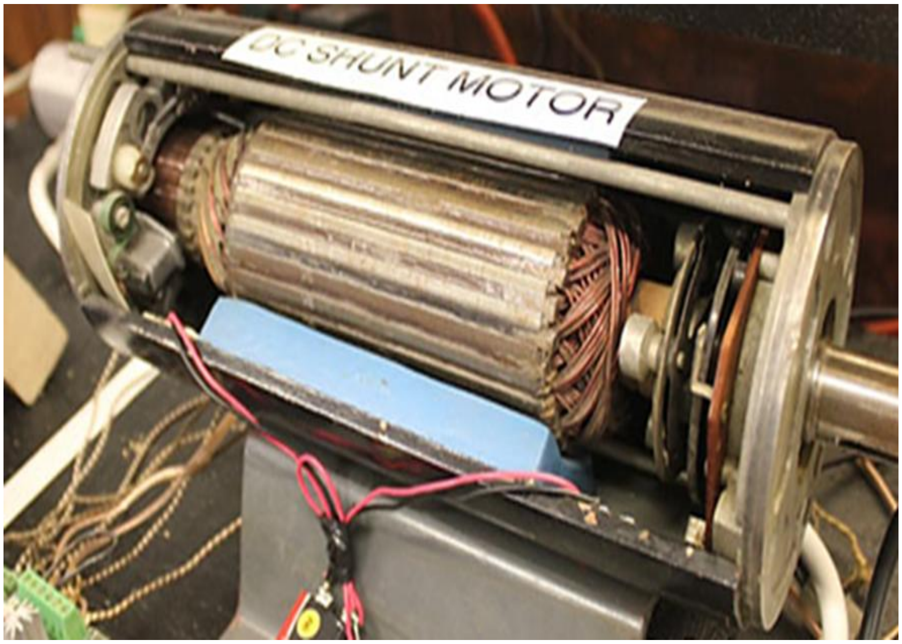
8. Conclusions

Write in your own words the conclusion of performing this experiment. Write about what you learned from this experiment, what you can tell about O.C and S.C test that you did in this experiment.
....
....
....

Experiment No: …8

Swinburne's test on a DC Shunt motor

Contents



1. Objectives

To conduct Swinburne's test on a dc shunt motor and to find out the efficiency of dc shunt motor. Compute and plot the efficiency at various loads.

2. Expected outcome of experiment

On successful completion of experiment the students will be able to:

- Find out the core loss present in the dc shunt motor and hence we can predetermine the efficiency of the dc shunt motor.
- Get clear idea about the losses present in the dc shunt motor.
- Know why Swinburne test is useful to find out the efficiency of large rating machine.

3. Theory

Introduction

For a d.c shunt motor change of speed from no load to full load is quite small. Therefore, mechanical loss can be assumed to remain same from no load to full load. Also if field current is held constant during loading, the core loss too can be assumed to remain same.

Losses in DC Shunt Motor:

For a dc motor, input power is in the form of electrical and output power is in the form of mechanical. In a practical machine, whole of the input power cannot be converted into output power as some power is lost in the process. This causes the efficiency of the machine to be reduced. Efficiency is the ratio of output power to the input power. Thus, in order to design rotating dc machines with higher efficiency, it is important to study the losses occurring in them. Various losses present in the dc shunt motor are given below.

1. <u>Copper losses:</u>

- Armature Cu loss
- Field Cu loss
- Loss due to brush contact resistance

2. <u>Iron Losses:</u>

- Hysteresis loss
- Eddy current loss

3. Mechanical losses:

- Friction loss
- Windage loss

The above three categorizes various types of losses that occur in a dc generator or a dc motor. Each of these is explained in details below.

Copper Losses:

These losses occur in armature and field copper windings, whenever the current flowing through these windings. Copper losses consist of Armature copper loss, Field copper loss and loss due to brush contact resistance.

Armature copper loss = $I_a^2R_a$

Where,

I_a =Armature current

R_a =Armature resistance

this loss contributes about 30 to 40% to full load losses. The armature copper loss is variable and depends upon the amount of loading of the machine.

Field copper loss = $I_f^2R_f$

Where,

I_f = field current

R_f = field resistance

In the case of a shunt wounded field, field copper loss is practically constant. It contributes about 20 to 30% to full load losses.

Brush contact resistance also contributes to the copper losses. Generally, this loss is included into armature copper loss.

Iron Losses (Core Losses):

As the armature core is made of iron and it rotates in a magnetic field, a small current gets induced in the core itself too. Due to this current, eddy current loss and hysteresis loss occur in the armature iron core. Iron losses are also called as Core losses or magnetic losses. Hysteresis loss is due to the reversal of magnetization of the armature core. When the core passes under one pair of poles, it undergoes one complete cycle of magnetic reversal.

The frequency of magnetic reversal if given by:

$$f=P.N/120 \qquad (1)$$

Where,

P = no. of poles

N = Speed in rpm

the loss depends upon the volume and grade of the iron, frequency of magnetic reversals and value of flux density.

Hysteresis loss is given by, Steinmetz formula:

$$P_h = K_h f B_{max}^n \quad (2)$$

where,

η = Steinmetz hysteresis constant

V = volume of the core in m^3

f=frequency in Hz

<u>Eddy current loss:</u>

When the armature core rotates in the magnetic field, an emf is also induced in the core (just like it induces in armature conductors), according to the Faraday's law of electromagnetic induction. Though this induced emf is small, it causes a large current to flow in the body due to the low resistance of the core. This current is known as eddy current. The power loss due to this current is known as eddy current loss.

The eddy current losses are given by

$$P_e = K_e B_m^2 t^2 f^2 V \quad \text{Watts} \qquad (3)$$

Where,

K_e = co-efficient of eddy current. Its value depends upon the nature of magnetic material like volume and resistivity of core material, thickness of laminations

B_{max} = maximum value of flux density in wb/m^2

t = Thickness of lamination in meters

f = Frequency of reversal of magnetic field in Hz

<u>Mechanical Losses:</u>

Mechanical losses consist of the losses due to friction in bearings and commutator. Air friction loss of rotating armature also contributes to these.

The mechanical losses are given by

1. Friction losses at brushes and bearings
2. Windage losses between the stator and the rotor.

These losses are about 10 to 20% of full load losses.

Stray load Losses:

In addition to the losses stated above, there may be small losses present which are called as stray load losses or miscellaneous losses. These losses are difficult to account. They are usually due to in accuracies in the designing and modeling of the machine.

Stray load losses are given by

1. Stray iron losses, these are due to the cross magnetizing effect of armature reaction.

2. Stray copper losses due to the skin effect.

Most of the times, stray losses are assumed to be 1% of the full load.

Swinburne's test:

This method is an indirect method of testing a DC machine. It is named after Sir James Swinburne. Swinburne's test is the most commonly used and simplest method of testing of shunt and compound wound DC machines which have constant flux. In this test the efficiency of the machine at any load is pre-determined. We can run the machine as a motor or as a generator. In this method of testing no load losses are measured separately and eventually we can determine the efficiency.

For a d.c shunt motor change of speed from no load to full load is quite small. Therefore, mechanical loss can be assumed to remain same from no load to full load. Also if field current is held constant during loading, the core loss too can be assumed to remain same. In this test, the motor is run at rated speed under no load condition at rated voltage. The current drawn from the supply IL0 and the field current I_F are recorded. Now we note that input power to the motor is given by:

$$\mathbf{P_{IN} = VI_{Lo}} \quad (4)$$

Cu loss in the field circuit is given by:

$$\mathbf{W_F = VI_F} \quad (5)$$

Power input to the armature = $VI_{L0} - VI_F = V\ I_{a0}$

Armature copper losses are: $W_{cu} = I_{ao}^2 R_a$

Constant losses are given by: $W_c = VI_{l0} - (I_{L0} - I_F)^2 R$

Total losses = constant losses +armature copper losses = $W_{CU} + W_C$

The efficiency of the motor is ratio of output power to the input power and is given by

$$\eta_{motor} = \frac{VI_{L0} - (W_{CU} + W_C)}{VI_{L0}} \quad (6)$$

The biggest advantage of Swinburne's test is that the shunt machine is to be run as motor under no load condition requiring little power to be drawn from the supply. Based on the no load reading, efficiency can be predicted for any load current.

However, this test is not sufficient if we want to know more about its performance (effect of armature reaction, temperature rise, commutation etc.) when it is actually loaded.

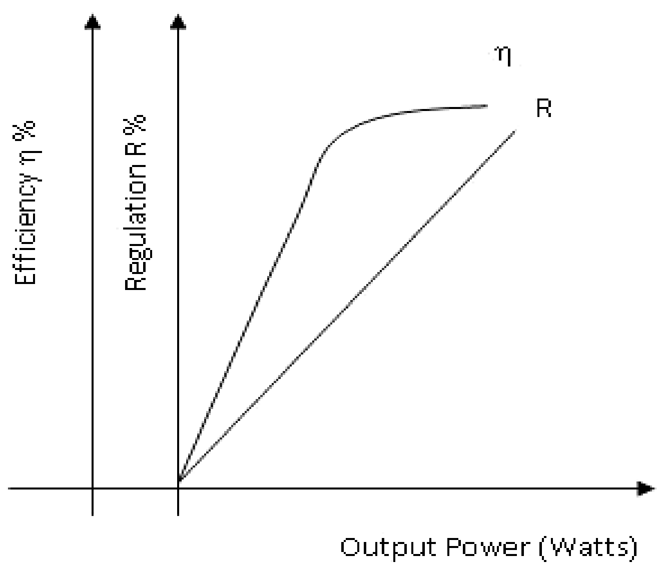


Fig.1: Sample graph of % regulation and efficiency vs output power

Advantages:

1. Power required to conduct this test is very less because of it is conducted under no load condition, it draws a power only to meet the core losses.
2. It is simple and easy to conduct.

Disadvantages:

As this test is conducted on no load condition, it does not consider the exact temperature raise and armature reaction and hence it shows the higher efficiency.

4. Equipment required

Sr. No.	Name	Range	Remarks	Quantity
1.	Voltmeter	0-300 V	DC	2
2.	Ammeter	0-5 A 0-2.5 A	DC DC	2 1
3.	Rheostat	0-80 Ω, 3.5 A 0-360Ω,1.2 A	---	1 1
4.	Tachometer	2000 rpm	----	1

5. Methodology for Measurements

1. Connect the circuit as shown in the circuit diagram.
2. Set the 80 ohms' rheostat to its max. Value and maintain the rated speed by adjusting the other rheostat.
3. Periodically start reducing the value of 80-ohm rheostat and maintain the speed by varying the other rheostat.
4. Note down the readings of machine voltage, machine current, and shunt field current.
5. Plot a graph between efficiency and output power.

6. Measurements

<u>DC Motor Specifications:</u>

DC MOTOR
Current rating -13.0A Voltage-220 V Speed -1450rpm

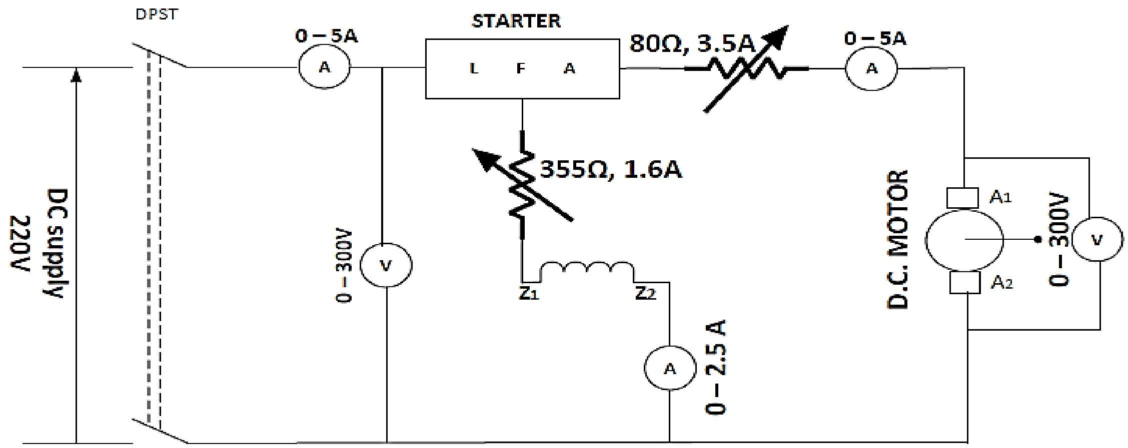


Fig.4: Connection diagram for Swinburne's Test

Using the above set up note down your observations in the following Table:

Table: Table to be used for recording the measurements

Sr. No.	Vs (input voltage) V	I (input current) A	Ish (shunt field current) A	Ia (Armature current) A	Va (armature voltage) V	Pin (input power) Watts	Po(output power) Watts	Efficiency %
1.								
2.								
3.								
4.								

Precautions:

1. Circuit connections should not be made while power is ON.
2. The armature resistance must be keep at maximum position at the time starting.
3. All connections should be tight and loose connections are to be avoided.
4. There should be no load at the time of starting the DC shunt motor.
5. Readings of the meters must be taken without parallax error.

7. Results and Discussion

Based on your measurements, let us now discuss the results that you obtained. Please provide responses to following points:

1. What is Swinburne Test? Why is it needed?

....

....

2. Why is it advised to operate the DC Machine at no load at the beginning of the expt.?

....

....

8. Conclusions

Write in your own words the conclusion of performing this experiment. Write about what you learned from this experiment, what you can tell about Swinburne's' Test that you did in experiment.

....

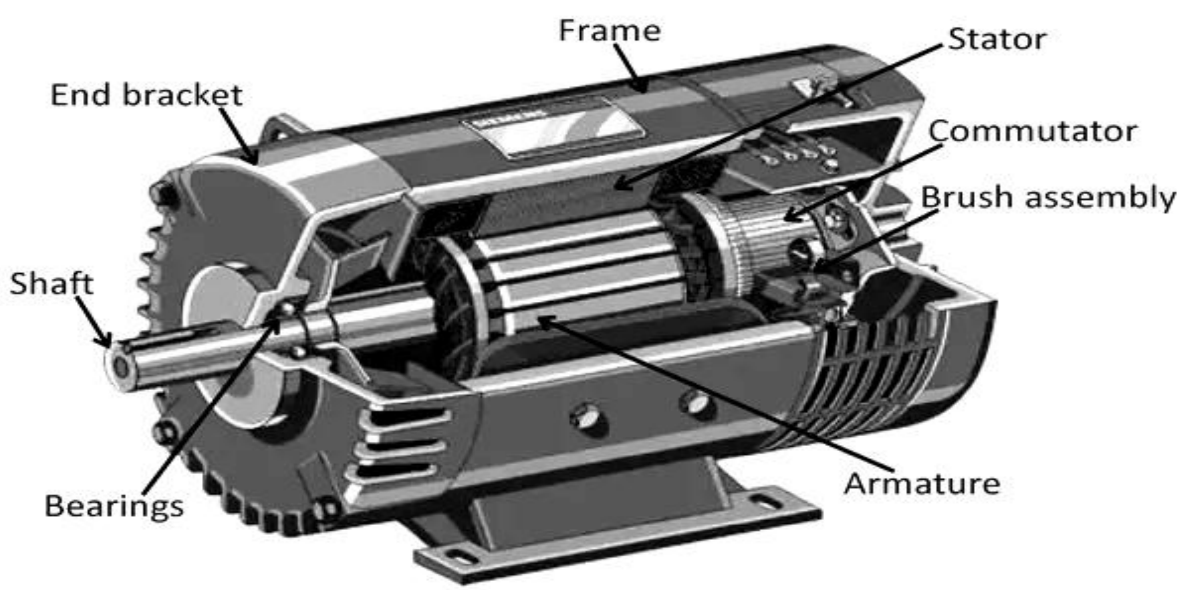
....

....

Experiment No: …9

Direct load test on DC Compound generator.

Contents



1. Objectives

To conduct direct load test on DC Compound generator with

(a) Shunt field alone

(b) Cumulative and differential compounding for short shunt Connections.

2. Expected outcome of experiment

On successful completion of experiment the students will be able to:

- Know practically about the series field and shunt field winding.
- Differentiate practically between differential and cumulative type dc generator.
- Observe the effect of field excitation of on armature voltage.

3. Theory

Introduction

A Compound generator consists of a series field winding and a shunt Field winding.

Compounded Generator is categorized as

(a) Level Compounded

(b) Over Compounded

(c) Under Compounded

Based on the EMF generated from No load to rated-load, it is further categorized into:

(a) Cumulatively compound generator.

(b) Differentially Compounded generator.

Differentially Compounded Generator:

In this generator, the flux produced by both Field windings opposes each other. Hence, the net flux in the air gaps decreases and the generated EMF decreases with the increase in the load.

Cumulatively Compound generator:

In this generator, the flux produced by both field Windings adds up together. Hence, the net flux will be increased as the load on the Generator increases. The EMF generated and hence, the terminal voltage increases with load till the series field is saturated. The terminal voltage decreases further Increase in the load current due to the armature reaction.

4. Equipment required

Following equipment will be required to conduct this experiment.

S.No	Name	Range	Remarks	Quantity
1	Voltmeter	0-300 V	DC	1
2	Ammeter	0-10 A	DC	1
3	Rheostat	0-355 Ω, 1.6 A	-	1
4	Tachometer	2000 rpm	-	1

5. Methodology for Measurements

1. Note down the ratings of the dc shunt motor and dc compound generator.
2. Set the dc drive potentiometers at zero positions.
3. Keep field rheostat of the generator at maximum resistance position.
4. Keep all the load switches in OFF position.
5. Connect the circuit as per the circuit diagram.
6. Push the START button and adjust the dc drive potentiometers until armature winding of the motor attains the rated voltage.
7. Now adjust the field rheostat of the generator to bring the terminal voltage of the generator to its rated value.
8. Gradually increase the load. (i.e. switch on the electrical load).
9. Record the readings of the measuring instruments at different load conditions.
10. Do not exceed the rated values of the armature current in the motor and in the generator.
11. Gradually decrease the loads and switch OFF the supply.
12. Maintain the motor (prime mover) speed at a constant value throughout the experiment.
13. Conduct the experiment (a) As a cumulatively compounded (b) As a Differential compounded.

6. Measurements

The figure below shows the connection diagrams for polarity test:

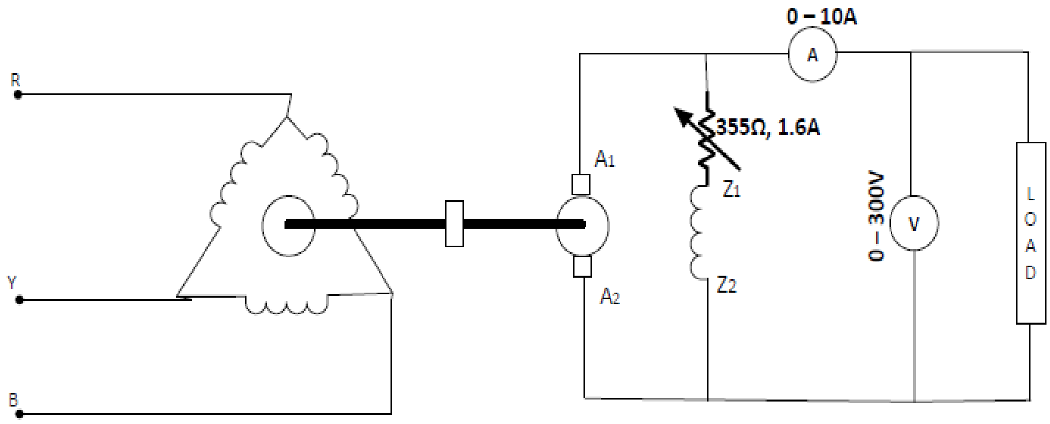


Fig.1: Connection diagram for shunt field

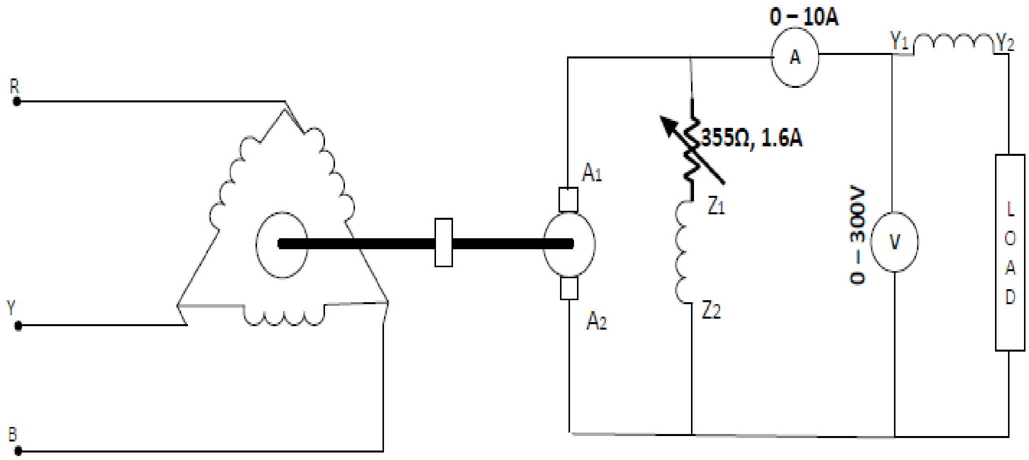


Fig.2: Connection diagram for cumulative compound and differential

Machine specifications: -

DC MOTOR
Voltage- 220V Current- 8.6 A Speed- 1440 rpm Kw/HP- 2.2

Using the above set up note down your observations in the following Table:

Table: Table to be used for recording the measurements:

Shunt Field:

S.No.	**V(Volts)**	**I(amp)**

Cumulative Compound:

S. No.	**V(Volts)**	**I(amp)**

Differential Compound:

S.No	**V(Volts)**	**I(amp)**

Precautions:

1. Circuit connections should not be made while power is on.
2. Ensure variac position is zero before starting the experiment.
3. Ensure the correct connection of the motor.

7. Results and Discussion

Based on your measurements, let us now discuss the results that you obtained. Please provide responses to following points:

A. Which types of generators are used for parallel operation?

....
....

B. Where series generators used?

....
....

8. **Conclusions:**

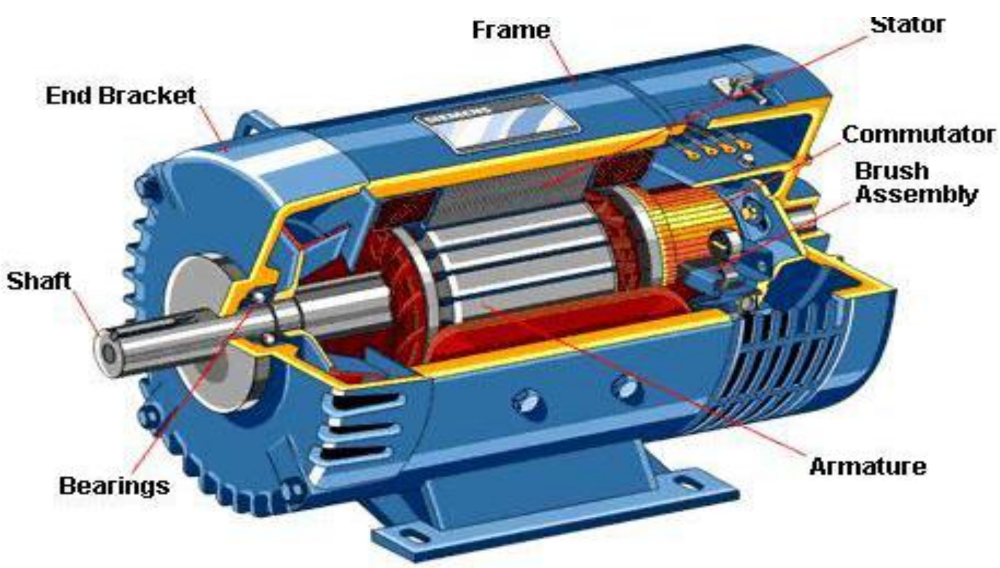
Write in your own words the conclusion of performing this experiment. Write about what you learned from this experiment, what you can tell about direct load test on DC compound generator that you did in experiment.

....
....

Experiment No: …10

Speed control of DC shunt motor using armature and field control

Contents



1. Objectives

To study the three-point starter for DC machine speed control of DC shunt motor using armature and field control plot the variation of speed with added resistance.

2. Expected outcome of experiment

On successful completion of experiment the students will be able to:

1. Practically do the dc machine speed control
2. Study the armature resistance effect on speed
3. Practically observe the field winding resistance effect on speed

3. Theory

Introduction

We know, back emfEb of a DC motor is the induced emf in the armature conductors due to the rotation of armature in magnetic field. Thus, magnitude of the Eb can be given by the EMF equation of a DC generator.

$$E_b = P\O NZ/60A \qquad (1)$$

(where, P = no. of poles, Ø = flux/pole, N = speed in rpm, Z = no. of armature conductors, A = parallel paths)

Eb can also be given as,

$$E_b = V - I_a R_a \qquad (2)$$

thus, from the above equations

$$N = E_b\, 60A/P\O Z \qquad (3)$$

but, for a DC motor A, P and Z are constants

Therefore,

$$N \propto K\, E_b/\O \quad \text{(where, K=constant)}$$

This shows the speed of a dc motor is directly proportional to the back emf and inversely proportional to the flux per pole.

Armature Resistance Control:

Speed of a dc motor is directly proportional to the back emfEb. andEb = V - IaRa. That means, when the supply voltage V and the armature resistance Ra are kept constant, speed is directly proportional to the armature current Ia.

Thus, if we add a resistance in series with the armature, Ia decreases and, hence, the speed also decreases. Greater the resistance in series with the armature, greater the decrease in speed.

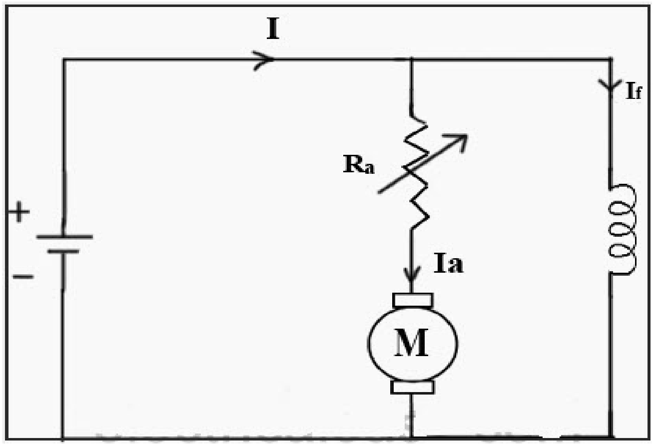


Fig.1: Circuit of controlling speed using Armature control

Field Resistance Control:

It is already explained above that the speed of a dc motor is inversely proportional to the flux per pole. Thus by decreasing the flux, speed can be increased and vice versa.To control the flux, a rheostat is added in series with the field winding, as shown in the Fig. 2. Adding more resistance in series with the field winding will increase the speed as it decreases the flux.

In shunt motors, as field current is relatively very small, Ish^2*R loss is small and, hence, this method is quite efficient.

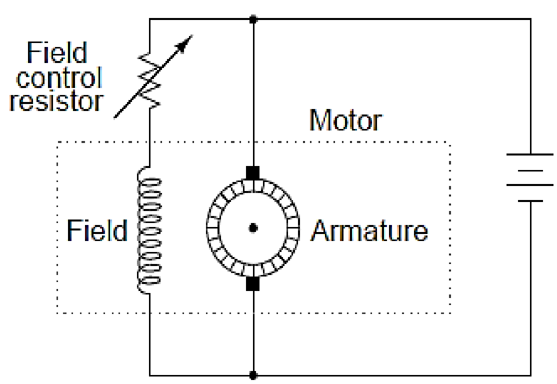


Fig. 2: Circuit of controlling speed using field resistance control

4. Equipment required

Following equipment will be required to conduct this experiment.

S.No.	Name	Range	Remark	Qty.
1	Voltmeter	0-300V	DC	2
2	Ammeter	0-2.5A,0-5A	DC	2
3	Rheostat	355Ω/2A,100Ω/5A	-	2
4	Tachometer	-	-	1

5. Methodology for Measurements

1. Make the connections as shown in the circuit diagram.
2. Close the main switch and move the starter slowly.

Field resistance control method

1. Since the rated rpm is 1450 so max speed limit is 1700 rpm.
2. Make the armature resistance equals to zero.
3. Increase the field resistance and note the respective speed.

Armature resistance control method:

1. Since the rated rpm is 1450 so minimum speed limit is 1200rpm.
2. Make the field resistance equals to zero.
3. Increase the armature resistance and note the respective speed.

6. Measurements

The figure below shows the connection diagram for speed control of DC Motor:

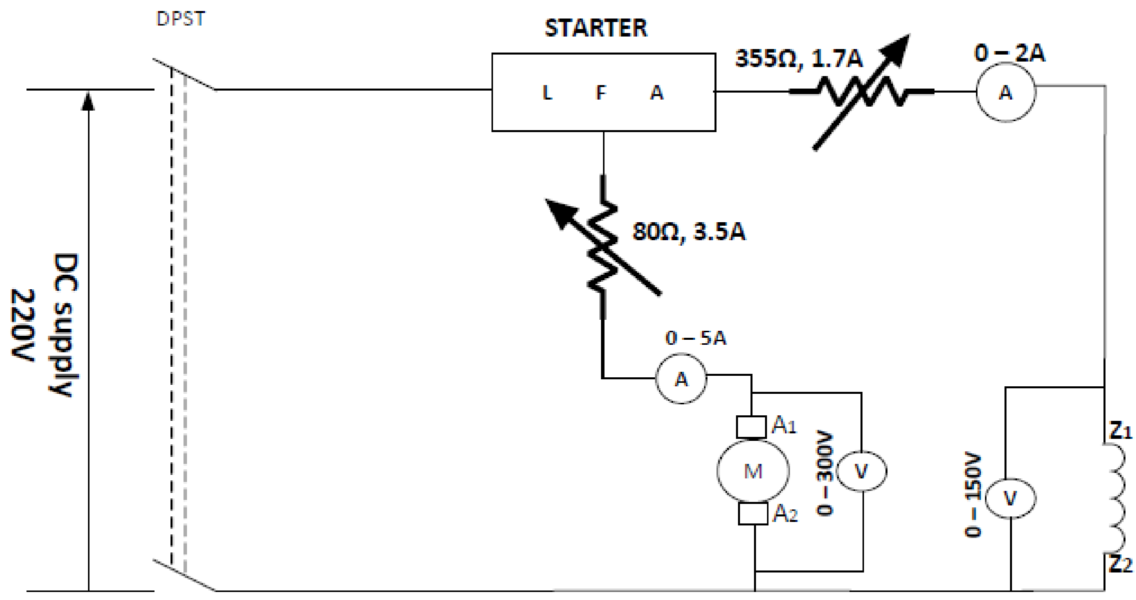


Fig.3: Connection diagram for speed control of DC motor

<u>DC Motor Specifications:</u>

DC MOTOR
Current rating -13.0A Voltage-220 V Speed -1450rpm

Using the above set up note down your observations in the following Table:

Table: Table to be used for recording the measurements:

Field Control Method:

S.no.	Speed(rpm)	Voltage(V)	Current(A)	Added Resistance R=V/A

Armature Control Method:

S.no.	Speed(N)	Voltage(V)	Ampere(A)	Added Resistance R=V/A

<u>Precautions</u>:

1. Speed limit should be noted carefully.
2. Parallax error should be removed.
3. Readings should be taken carefully.

7. Results and Discussion

Based on your measurements, let us now discuss the results that you obtained. Please provide response to following points:

A. What will happen to the speed if armature current is increased?
....
....

B. What will happen to the speed if flux is decreased?
……………………………………………………………………………………………
……………………………………………………………………………………………

C. Why three-point starter is necessary to start the DC Motor?
……………………………………………………………………………………………
……………………………………………………………………………………………

8. **Conclusions**

Write in your own words the conclusion of performing this experiment. Write about what you learned from this experiment, what you can tell about speed control of DC motor that you did in this experiment.

....
....
....