

e-Lab Sheet for

ELECTRICAL MACHINE & CONTROL

Polytechnic Edition



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e-Lab Sheet for ELECTRICAL MACHINE & CONTROL

POLYTECHNIC EDITION

JABATAN KEJURUTERAAN PETROKIMIA
POLITEKNIK TUN SYED NASIR SYED ISMAIL

e-LAB SHEET FOR ELECTRICAL MACHINE & CONTROL POLYTECHNIC EDITION

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PREFACE

e-Lab Sheet for Electrical Machine & Control student edition is a compilation lab sheet for the Diploma of Electrical and Instrumentation at the Department of Petrochemical Engineering at Tun Syed Nasir Syed Ismail Polytechnic and undergraduate students who are new in the field of electrical, especially in the engineering disciplines such as electrical engineering, electronics engineering, mechatronics engineering and instrumentation engineering. This book is meant to be a self-study aid, systematically organized to meet the requirements of major public and private universities in Malaysia. It presents the virtual lab and examples of exercises or question with review question. It is suitable for beginner learners in basic electrical machine fundamentals.

This e-Lab Sheet is divided into five-set lab exercise covering major topics in electrical machine fundamentals as prescribed by the Ministry of Higher Education. Each set of the lab in this e-Lab Sheet is presented by the explanation of step-by-step procedures. Students will be doing the virtual simulation for each lab at the link provided and record or print the result after the simulation process is done. It will help students to understand the theoretical, the process, the result, or the wiring concepts in the simulation process. Students should be able to relate the hands-on lab and the simulation lab by referring to the lab result and conclude the findings.

While this e-Lab Sheet is intended for diploma and undergraduate students, it is also envisioned to be a very useful e-Lab Sheet for postgraduate students, professionals, and researchers.

We sincerely hope that this e-Lab Sheet will be beneficial and adequate for its users. Any constructive criticism and suggestions will be duly acknowledged and appreciated

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PRACTICAL WORK 1:**To Study the Load Characteristics of DC Shunt Generator****1. COURSE LEARNING OUTCOME**

At the end of this experiment, students should be able to perform the controlling methods for DC and AC machines and demonstrate the ability to work in a team to complete assigned tasks.

2. OBJECTIVES

At the end of this experiment, students should be able to:

- i. study the load characteristics of DC Shunt Generator.
- ii. draw the internal characteristics and external characteristics under different loading conditions.

3. THEORY**Introduction**

In a shunt generator, the field winding is connected in parallel with the armature winding so that the terminal voltage of the generator is applied across it. The shunt field winding has many turns of fine wire having high resistance. Therefore, only a part of the armature current flows through shunt field winding and the rest flows through the load. The Figure shows the connections of a shunt wound generator. The armature current I_a splits up into two parts; a small fraction I_{sh} is flowing through shunt field winding while the major part I_L goes to the external load.

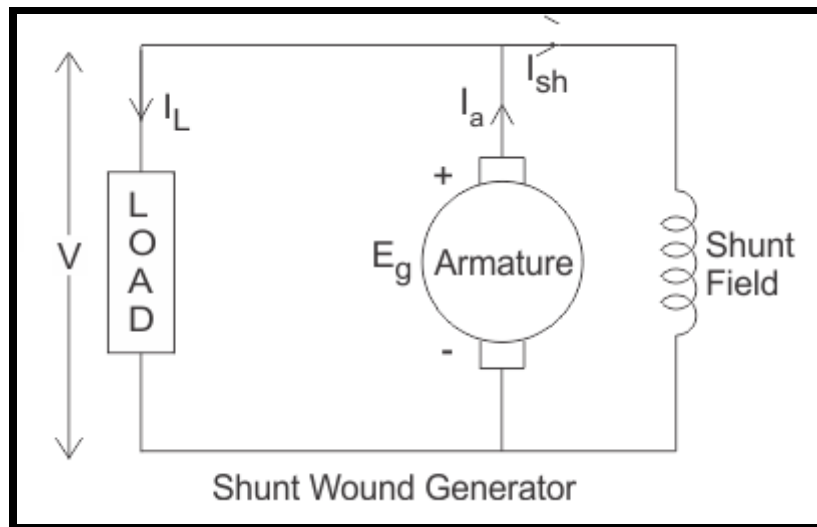


Figure 1: Equivalent circuit of DC shunt generator for load characteristics.

Internal Characteristics

The internal characteristic curve represents the relation between the generated voltage E_g and the load current I_L . When the generator is loaded then the generated voltage is decreased due to the armature reaction. So, the generated voltage will be lower than the emf generated at no load. Here in the figure below AD curve is showing the no-load voltage curve and AB is the internal characteristic curve.

External or Load Characteristics

AC curve is showing the external characteristic of the shunt wound DC generators. It is showing the variation of terminal voltage with the load current. Ohmic drop due to armature resistance gives lesser terminal voltage the generated voltage. That is why the curve lies below the internal characteristic curve.

$$V = (E_g - I_a R_a) = E_g - (I_L + I_{sh}) R_a$$

The terminal voltage can always be maintained constant by adjusting the load terminal. External characteristics of shunt dc generator. When the load resistance of a shunt-wound DC generator is decreased, then the load current of the generator increased as shown in the above figure. However the load current can be increased to a certain limit with (up to point C) the decrease of load resistance. Beyond this point, it shows a reversal in the characteristics.

Any decrease of load resistance results in the current reduction and consequently, the external characteristics curve turns back as shown in the dotted line, and ultimately the terminal voltage becomes zero. Though there is some voltage due to residual magnetism. We know, Terminal voltage Now, when I_L increased, then terminal voltage decreased. After a certain limit, due to heavy load current and increased ohmic drop, the terminal voltage is reduced drastically. This drastic reduction of terminal voltage across the load results from the drop in the load current although at that time load is high or load resistance is low. That is the reason the load resistance of the machine must be maintained properly. The point in which the machine gives maximum current output is called breakdown point (point C in the picture).

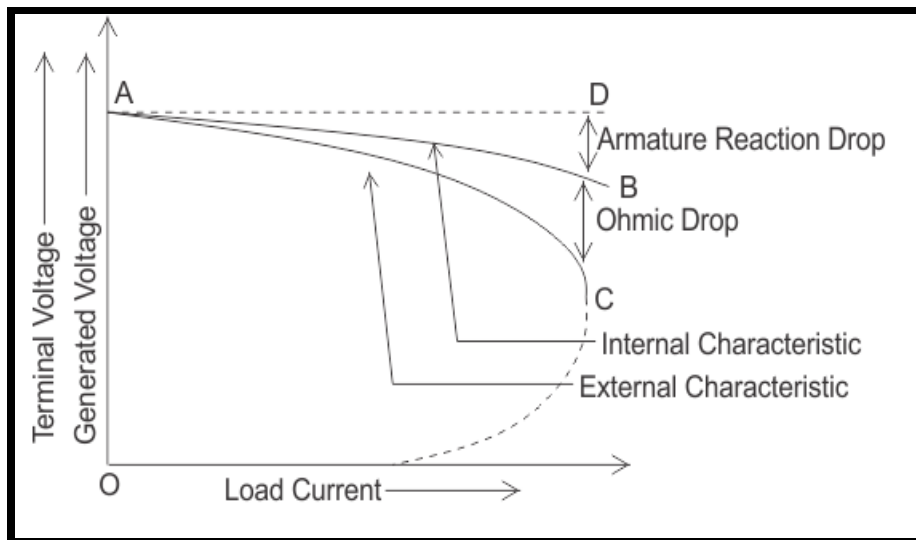


Figure 2: Load characteristics of DC shunt generator.

Note: It may be seen from the external characteristics that the change in terminal voltage from no-load to full load is small. The terminal voltage can always be maintained constant by adjusting the field rheostat R automatically.

4. EQUIPMENT / TOOLS

- 4.1 Click this link <https://ems-iitr.vlabs.ac.in/exp/load-characteristics-dc-shunt/> or scan the QR code below.



- 4.2 Then, click item **Simulation**.
- 4.3 After that, click here to go to the simulation page.
- 4.4 Start the simulation procedure.

5. SIMULATION PROCEDURE

Step 5.1: Make all the correct connections. Refer to the steps below and **draw the wiring diagram in Figure 3**.

1. Connect the **positive (+)** terminal of MCB to a **positive (+)** terminal of A Meter-1.
2. Connect the **positive (+)** terminal of MCB to a **positive (+)** terminal of V Meter-2.
3. Connect the **negative (-)** terminal of MCB to a **negative (-)** terminal of V Meter-1.
4. Connect the **negative (-)** terminal of MCB to a **A2** of DC Motor.
5. Connect the **A2** (DC Motor) to a **Z2** (DC Motor).
6. Connect the **A2** (DC Generator) to a **Z2** (DC Generator).
7. Connect the **L** (Starter) to a **negative (-)** terminal of A Meter-1.
8. Connect the **F** (Starter) to a **Z1** (DC Motor).
9. Connect the **A** (Starter) to a **A1** (DC Motor).
10. Connect the **L2** (Lamp Load) to a **A2** of DC Generator.
11. Connect the **Z2** of DC Generator to a **negative (-)** terminal of V Meter-2.
12. Connect the **negative (-)** terminal of A Meter-2 to a **positive (+)** terminal of V Meter-2.
13. Connect the **L1** (Lamp Load) to a **positive (+)** terminal of V Meter-2.
14. Connect the **positive (+)** terminal of A Meter-2 to a **A1** of DC Generator.
15. Connect the **positive (+)** terminal of A Meter-2 to a **Z1** of DC Generator.

Step 5.2: Click on "Check" Button.

Step 5.3: If your wiring is right, the starter lamp will turn ON (green light) and the rotor of DC Generator will be rotating. If your wiring is wrong, you must **repeat Step 5.1** and **5.2**.

Step 5.4: The circuit will be turned **ON**, we must select the no. of "Bulbs" from the lamp load.

Step 5.5: We must choose one by one bulbs to take a readings from Voltmeter and Ammeters. There are **10** bulbs to turn ON.

Step 5.6: Jot down the readings of the voltmeters and ammeters in **Table 1**.

Step 5.7: Click "Add" Button to Add the values to the Observation Table.

Step 5.8: Add different values to the Table.

Step 5.9: Click on "Graph" Button to generate a graph.

Step 5.10 Plot the graph.

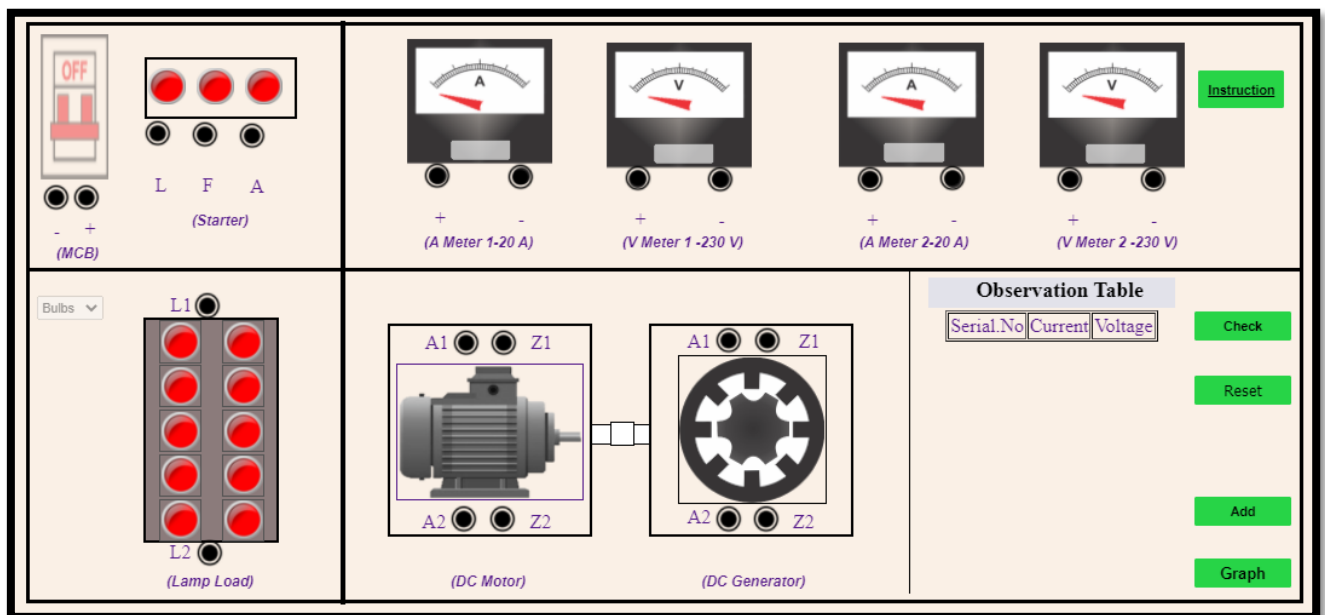


Figure 3: Draw the wiring diagram for this figure.

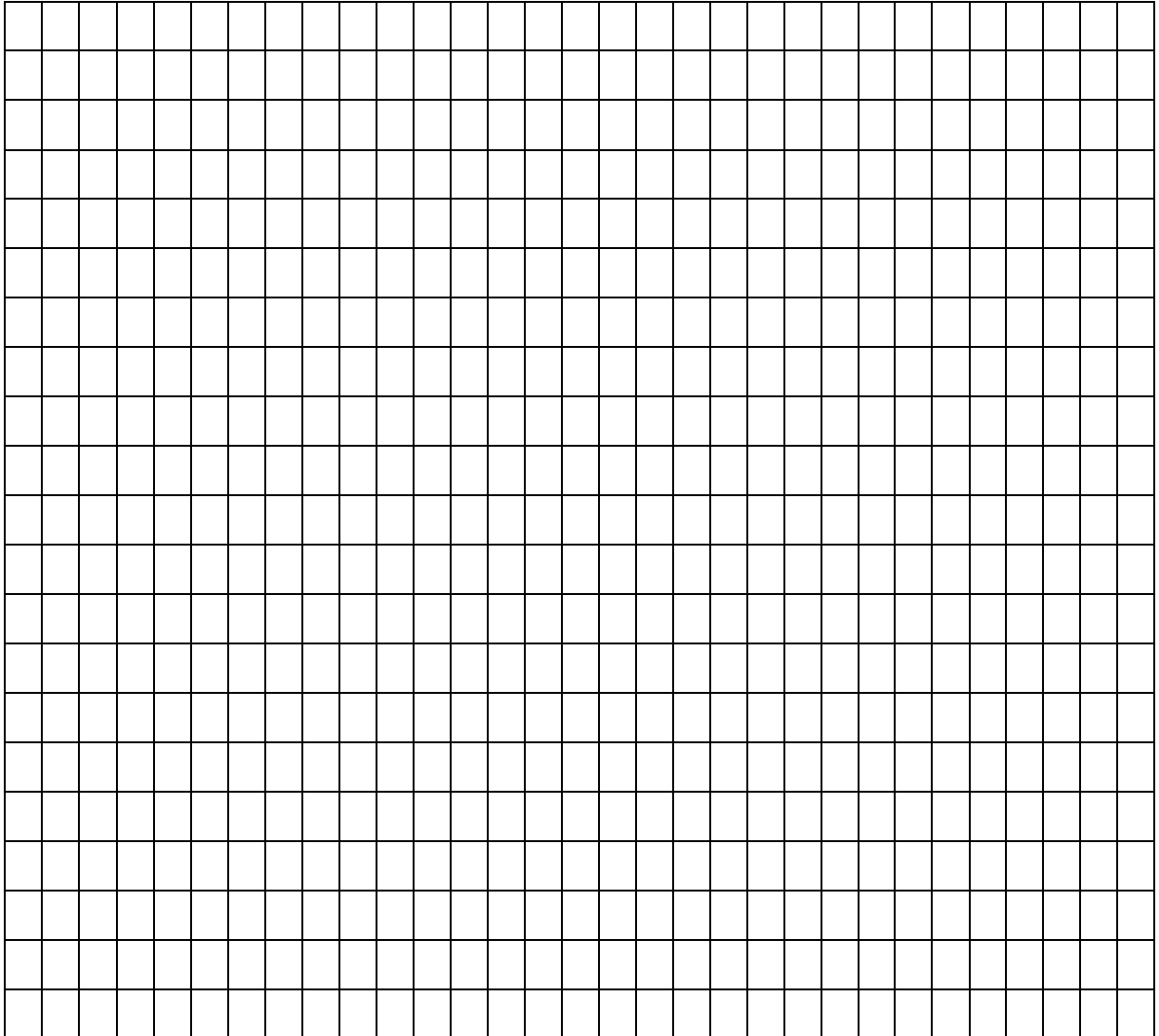
6. RESULT

- 6.1 Read the reading shown by voltmeter (2-230 V) and ammeter (2-20 A) then write the results in **Table 1**.

Table 1: The Results

Bulb (ON)	Voltmeter (2-230 V)	Ammeter (2-20 A)
Bulb 1		
Bulb 2		
Bulb 3		
Bulb 4		
Bulb 5		
Bulb 6		
Bulb 7		
Bulb 8		
Bulb 9		
Bulb 10		

- 6.2 draw the graph volt Vs current. The data for this graph is referred from to the output shown in **Table 1**.



7. QUESTION

- 7.1 Why a dc shunt generator is used for battery charging?

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- 7.2 Explain why external characteristics of a dc shunt generator is more drooping than that of a separately excited generator. Discuss their applications.

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8. DISCUSSION

Based on the data in Table 1, explain your result by relating the theory and the practical.

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9. CONCLUSION

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**PRACTICAL
WORK 2:****To Study the Speed Control of DC Motor by Field
Resistance Control****1. COURSE LEARNING OUTCOME**

At the end of this experiment, students should be able to perform the controlling methods for DC and AC machines and demonstrate the ability to work in a team to complete assigned tasks.

2. OBJECTIVES

At the end of this experiment, students should be able to:

- i. study the speed control of DC Motor by field resistance control
- ii. draw a graph between the armature current and motor speed by varying the field resistance.

3. THEORY**Introduction.**

We know that the speed of the shunt motor is given by: $N = (V - I_a R_a) / k\Phi$ in which, V_a is the voltage applied across the armature and ϕ is the flux per pole and is proportional to the field current I_f . As explained earlier, the armature current I_a is decided by the mechanical load present on the shaft. Therefore, by varying V_a and I_f we can vary N . For fixed supply voltage and the motor connected as shunt, we can vary V_a by controlling an external resistance connected in series with the armature. I_f can surely be varied by controlling external field resistance R_f connected with the field circuit. Thus, for shunt motor, we have essentially two methods for controlling speed, namely by a varying armature resistance and varying field resistance.

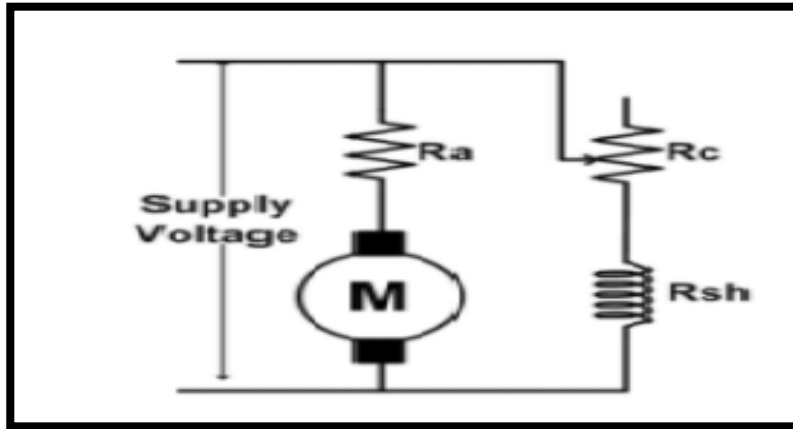


Figure 1: Equivalent circuit for field control of DC motor

Speed control by varying field current:

In this method, field circuit resistance is varied to control the speed of a d.c shunt motor. Let us rewrite the basic equation to understand the method. $N = (V - I_a R_a) / k\Phi$

If we vary I_f , flux ϕ will change, hence speed will vary. To change I_f , an external resistance is connected in series with the field windings. The resistance is called the shunt field regulator. the field coil produces rated flux when no external resistance is connected, and rated voltage is applied across field coil. We can only decrease flux from its rated value by adding external resistance. Thus, the speed of the motor will rise as we decrease the field current and speed control above the base speed will be achieved. Speed versus armature current characteristics is shown.

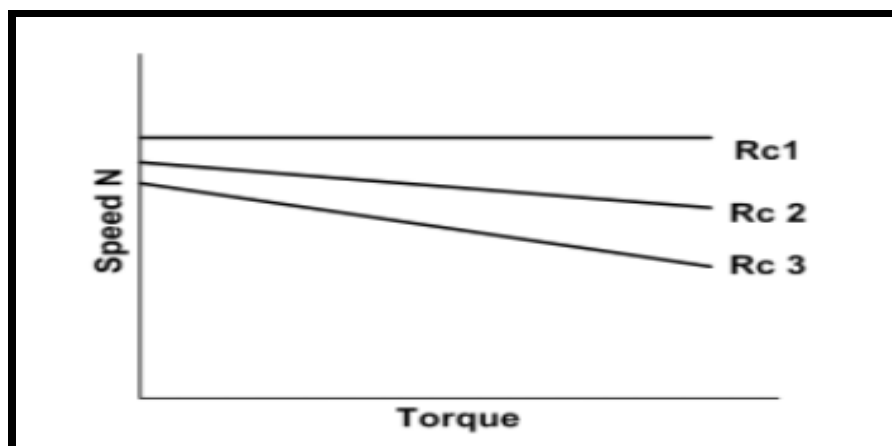


Figure 2: Torque speed characteristics of DC motors

4. EQUIPMENT / TOOLS

4.1 Click this link <https://ems-iitr.vlabs.ac.in/exp/dcmotor-field-resistance-control/> or scan the QR code below.



- 4.2 Then, click item Simulation.
- 4.3 After that, click here to go to the simulation page.
- 4.4 Start the simulation procedure.

5. SIMULATION PROCEDURE

Step 5.1: Make all the Correct Connections. Refer to the steps below and **draw the wiring diagram in Figure 3**. Connect all dots in the following manner:

1. Connect the wiring from point **A** positive (+) terminal to point **K** (DC Motor).
2. Connect the wiring from point **A** positive (+) terminal to point **Y** (DC Motor).
3. Connect the wiring from point **A** positive (+) terminal to point **J** negative (-) terminal Voltmeter.
4. Connect the wiring from point **B** negative (-) terminal to point **P**.
5. Connect the wiring from point **E** (Field Resistance) positive (+) terminal to point **M** negative (-) terminal Ammeter.
6. Connect the wiring from point **F** (Field Resistance) negative (-) terminal to point **D** (DC Motor).
7. Connect the wiring from point **G** (Armature Resistance) positive (+) terminal to point **R**.
8. Connect the wiring from point **H** (Armature Resistance) negative (-) terminal to point **I** positive (+) terminal Voltmeter.

9. Connect the wiring from point **I** positive (+) terminal to point **C** (DC Motor).
10. Connect the wiring from point **C** (DC Motor) to point **H** negative (-) terminal Armature Resistance.
11. Connect the wiring from point **L** positive (+) terminal Ammeter to **Q**.

Step 5.2 : check the connections by clicking on Check Button. If your wiring is right, check the pop-up view of the correct statement of the connection then proceed to take readings.

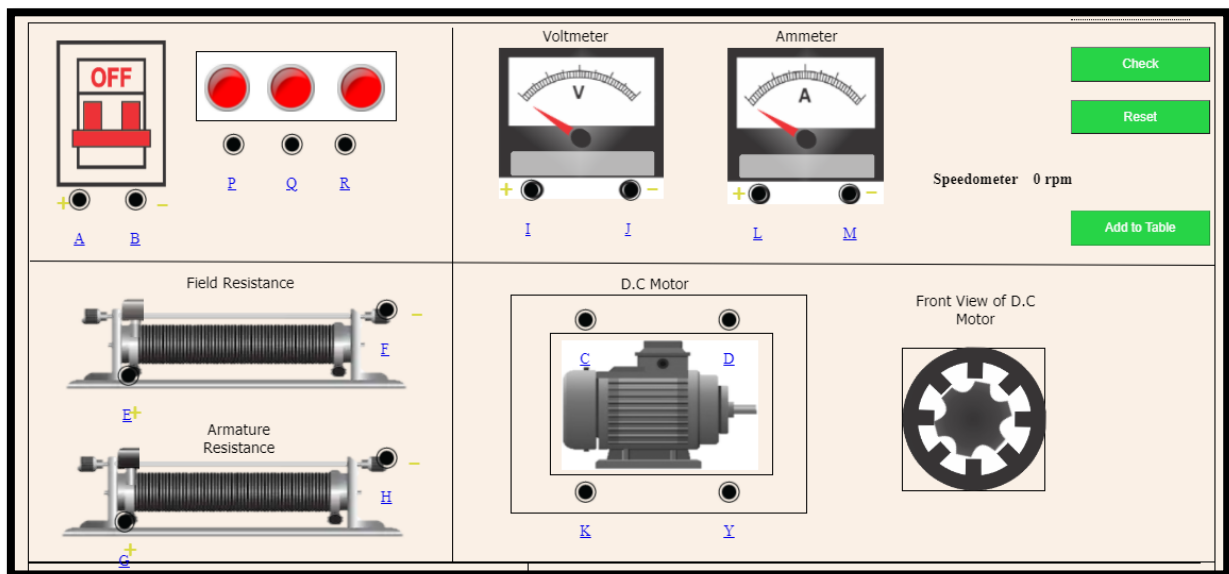


Figure 3: Draw the wiring diagram for this figure.

Step 5.3 : If it shows alert "Incorrect Corrections" ? then press reset button and make the connection again. Do Step 5.1 and 5.2.

Step 5.4 : If it shows alert "Correct Connections" then Turn On the MCB. The Green light will turn ON.

Step 5.5 : Then set the Voltmeter first with the help of the second slider.

Step 5.6 : Now, move the first slider to get corresponding values of Ammeter and Speedometer.

Step 5.7 : Press the "Add to table" button to insert the values in table.

Step 5.8 : After inserting values on table click on "Plot graph" to get your required graph.

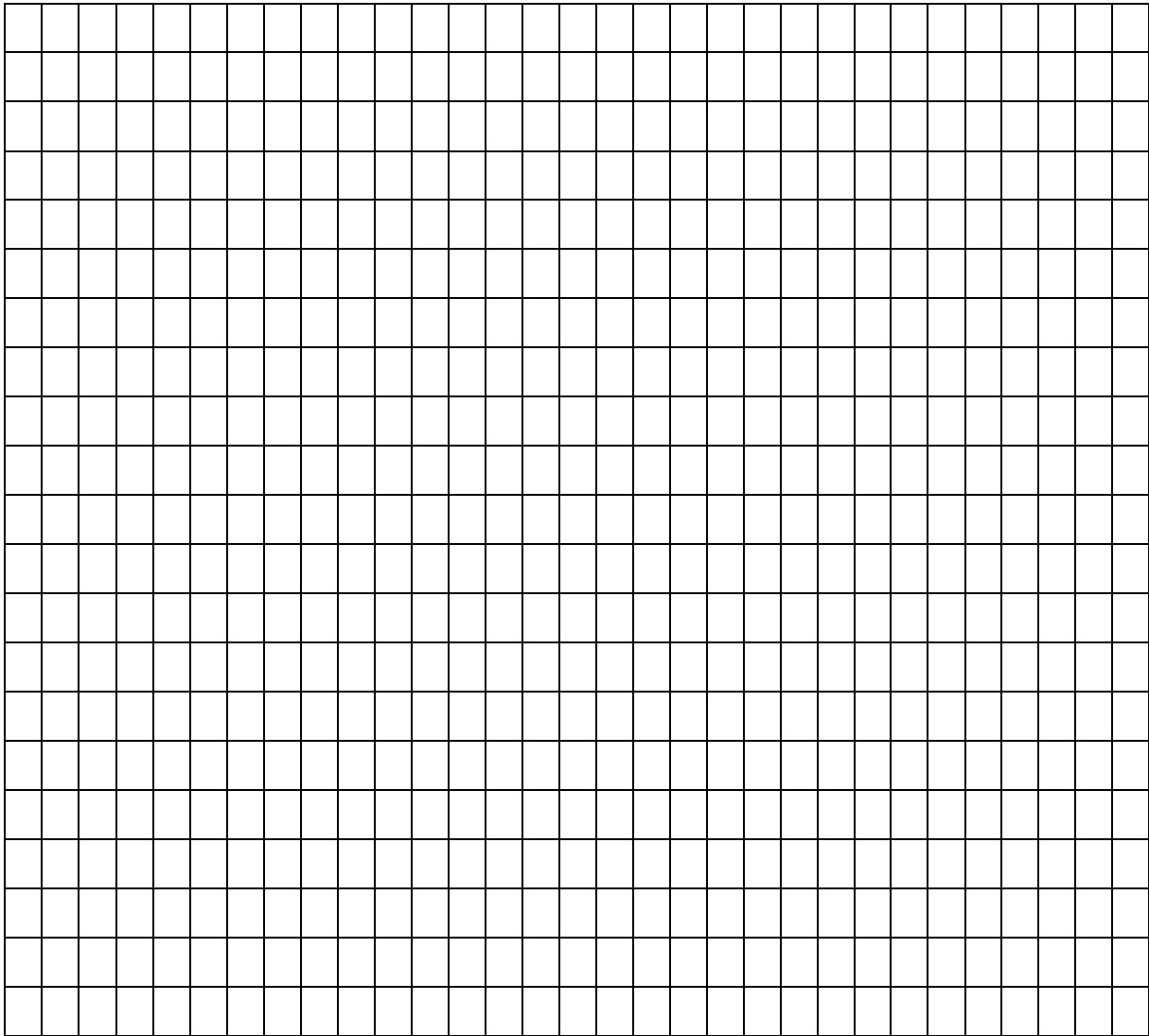
6. RESULT

6.1 Read the readings shown by ammeter and speedometer then write the results in **Table 1**.

Table 1: The Results

Field Resistance(Ω)	Current(A)	Speed(rpm)
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

6.2 Draw the graph Speed Vs Current by referring to the output shown in **Table 1**.



7. QUESTIONS

7.1 What are the different methods of speed control in dc motor? Discuss in detail.

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7.2 Define the term speed regulation?

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8. DISCUSSION

From the data in Table 1, explain your results by relating the theory and the practical.

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9. CONCLUSION

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PRACTICAL WORK 3:	Perform Speed Control of DC Motor by Using Ward-Leonard Method of Speed Control
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1. COURSE LEARNING OUTCOME

At the end of this experiment, students should be able to perform the controlling methods for DC and AC machines and demonstrate the ability to work in a team to complete assigned tasks.

2. OBJECTIVE

At the end of this experiment, students should be able to:

- i. study the generation of rotating magnetic field produced due to three coils using AC current.

3. THEORY

Introduction

In the Ward-Leonard method the speed control of D.C. motor can be obtained by varying the applied voltage to the armature. In this method, M is the main D.C. motor whose speed is to be controlled, and G is a separately excited D.C. generator which is driven by a 3-phase induction motor. The combination of ac driving motor and the dc generator is called the motor-generator set.

Speed control by varying armature resistance

The speed of a D.C. motor is directly proportional to the back e.m.f and inversely to the net flux per pole Φ , If brush contact drop is neglected i.e

$$N = (V - I_a R_a) / k\Phi$$

In which,

N = Speed in rpm

V = voltage applied across armature circuits

R_a = armature resistance, this includes the series field and interpole winding resistance if in circuit.

I_a = armature current,

K = a constant

Thus, the speed of a D.C motor may be varied by any of the following adjustments:

1. Changing the flux per pole Φ , by varying the field current,
2. Changing external resistance in the armature circuit,
3. Changing the applied voltage V (Ward-Leonard speed control method)

Ward-Leonard System:

This system is used for the unusually wide and very sensitive speed control as required for colliery winders, electric excavators, elevators and the main drives in steel mills and blooming and paper mills. M1 is the main motor whose speed control is required. The field of this motor is permanently connected across the dc supply lines. A dc or an ac motor M2 is directly coupled to generator G. The motor M2 runs at an approximately constant speed. The output voltage of G is directly fed to the main motor M1.

In this method, the variable voltage that is to be applied to the motor armature is obtained from an additional separately excited direct current generator, and the motor under control also runs as a separately excited motor. The above equation shows that, if the motor excitation is constant and the applied voltage V is varied, the speed will be almost directly proportional to the armature voltage. The system can more be adapted for forward as well as reverse operation of the motor by changing the polarity of the voltage applied to its armature. This condition can be achieved by reversing the direction of the field current of the separately excited variable voltage generator.

The variable voltage generator in the Ward-Leonard system is driven by a constant speed 3-phase induction motor. If the constant voltage direct current power for excitation is not available otherwise, the same may be obtained from a constant voltage exciter coupled with the auxiliary motor-generator set. The direction of the

field current of the variable voltage generator may be reversed by any one of the following methods:

1. by providing a reversing switch in the field circuit.
2. by connecting two potentiometer rheostats across generator field across the movable terminals.

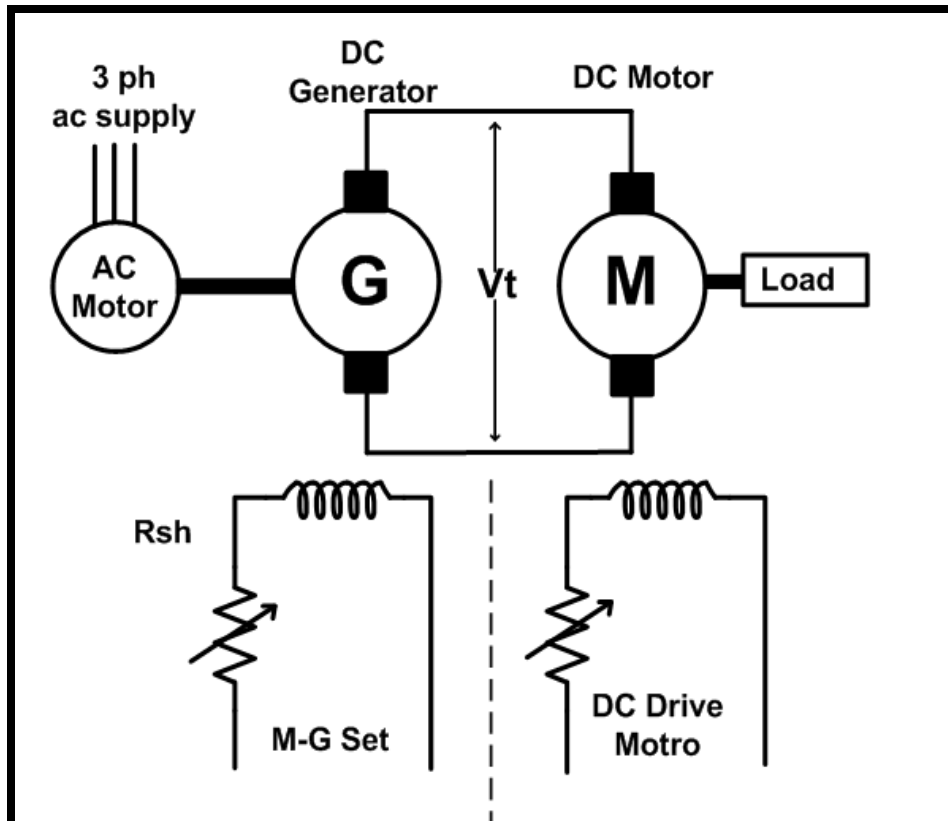


Figure 1: Equivalent circuit of Ward-Leonard method.

Graph:

In the plotted graph the speed is directly proportional to the armature voltage.

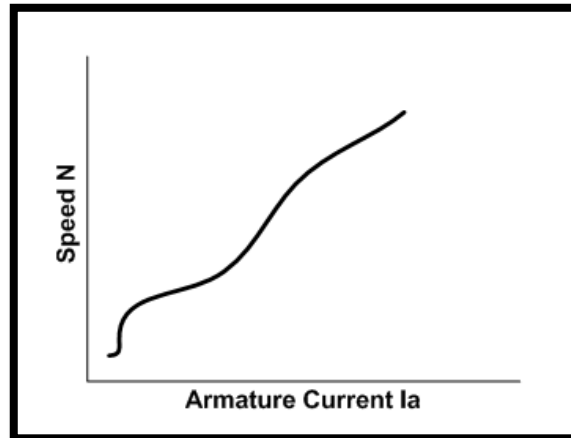


Figure 2: Armature voltage speed characteristics

Advantages of using the Ward-Leonard method

1. A very large range of speed variation is possible.
2. The direction of rotation may be easily reversed by reversing the generator field current.
3. The control is affected through the generator field circuit, which is a current circuit.
4. The speed regulation is good.
5. Overall efficiency, though poor, is still much higher than that obtained in the armature voltage control using series resistance.

Drawbacks of Ward-Leonard method

1. Higher initial cost due to the use of two additional machines of the same rating as the main dc motor.
2. Larger size and weight.
3. Requires more floor area and costly foundation.
4. Frequent maintenance is needed.
5. Lower efficiency due to higher losses.
6. The drive produces noise.

4. EQUIPMENT / TOOLS

- 4.1 Click this link <https://ems-iitr.vlabs.ac.in/exp/dcmotor-ward-leonard/simulation.html> or scan the QR code below.



- 4.2 Start the simulation procedure.

5. SIMULATION PROCEDURE

Step 5.1: Make all the Correct Connections. Refer to the steps below and **draw the wiring diagram in Figure 3.**

1. Connect points A1, B1, C1 of MCB Switch to input points A2, B2, C2 of Autotransformer respectively.
2. Connect output points E1, F1, G1 of Autotransformer to points E2, F2, G2 of Induction Motor respectively.
3. Connect point D1 of DC Supply with point D2 of Starter.
4. Connect point K1 of DC Supply with points M1, K2 of DC Generator and point L1 of DC Motor.
5. Connect point H1 of Starter with point H2 of DC Generator Field Resistance and I1 of DC Motor.
6. Connect point J1 of Starter with point J2 of Voltmeter and with point I2 of DC Generator.
7. Connect point I2 of DC generator with point M2 of DC motor.
8. Connect point M1 of DC generator with point N1 of DC motor.
9. Connect point N2 of DC generator with point O1 of DC Generator Field Resistance.
10. Connect point L1 of DC Motor with point L2 of Voltmeter.
11. Connect point L2 of Voltmeter with point M1 of DC generator.

Step 5.2: Click on “Check Connection” button to check the correctness of the connections.

Step 5.3: If the connections are incorrect, you can click on “Reset” button to make the connections again.

Step 5.4: If the connections are correct, then Turn “ON” the MCB Switch.

Step 5.5: Double click on the Autotransformer. The DC Generator Field Resistance, Voltmeter, DC Motor will be turn ON.

Step 5.6: Now, slide the Knob of the Rheostat. The readings of Voltmeter and RPM Meter will be shown in the box below.

Step 5.7: To create a table, click on “Add Values” button. Live Graph will be created when values are added in the table. You can print the page by clicking on the button “Print this Page”.

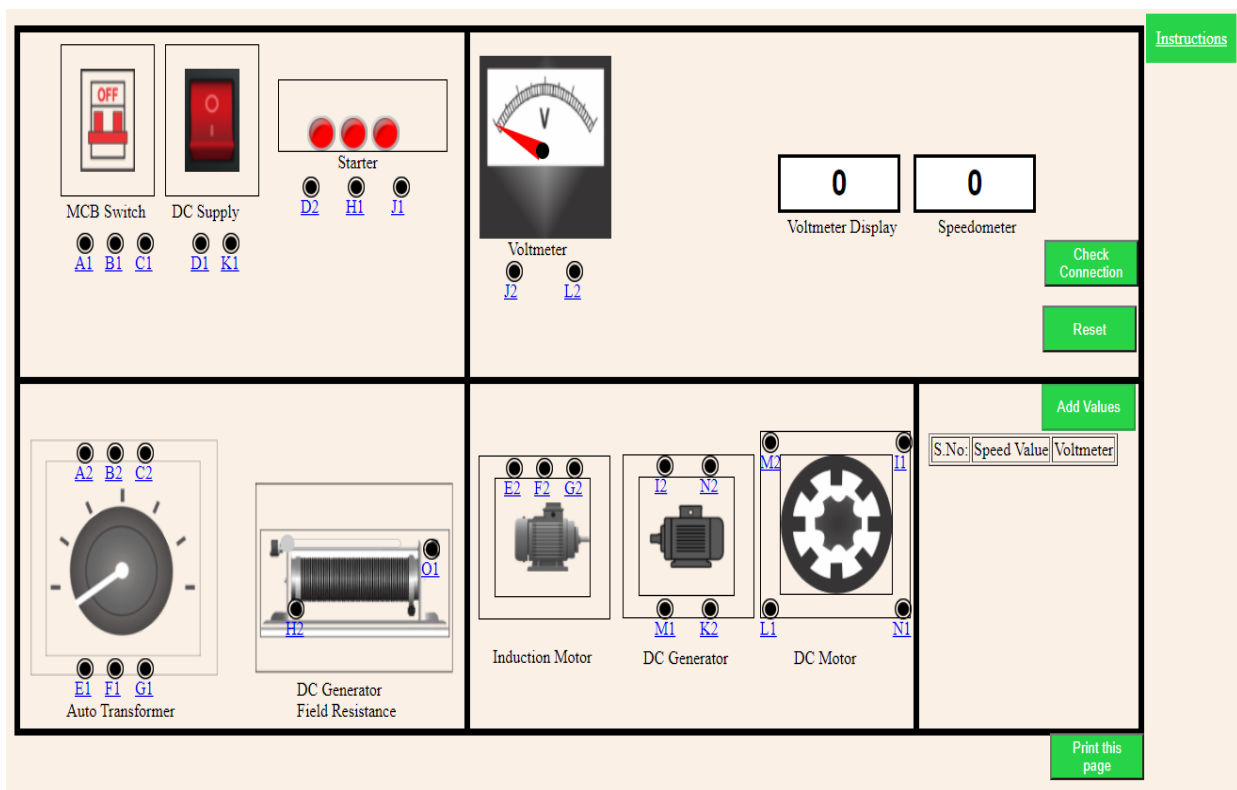


Figure 3: Draw the wiring diagram for this figure.

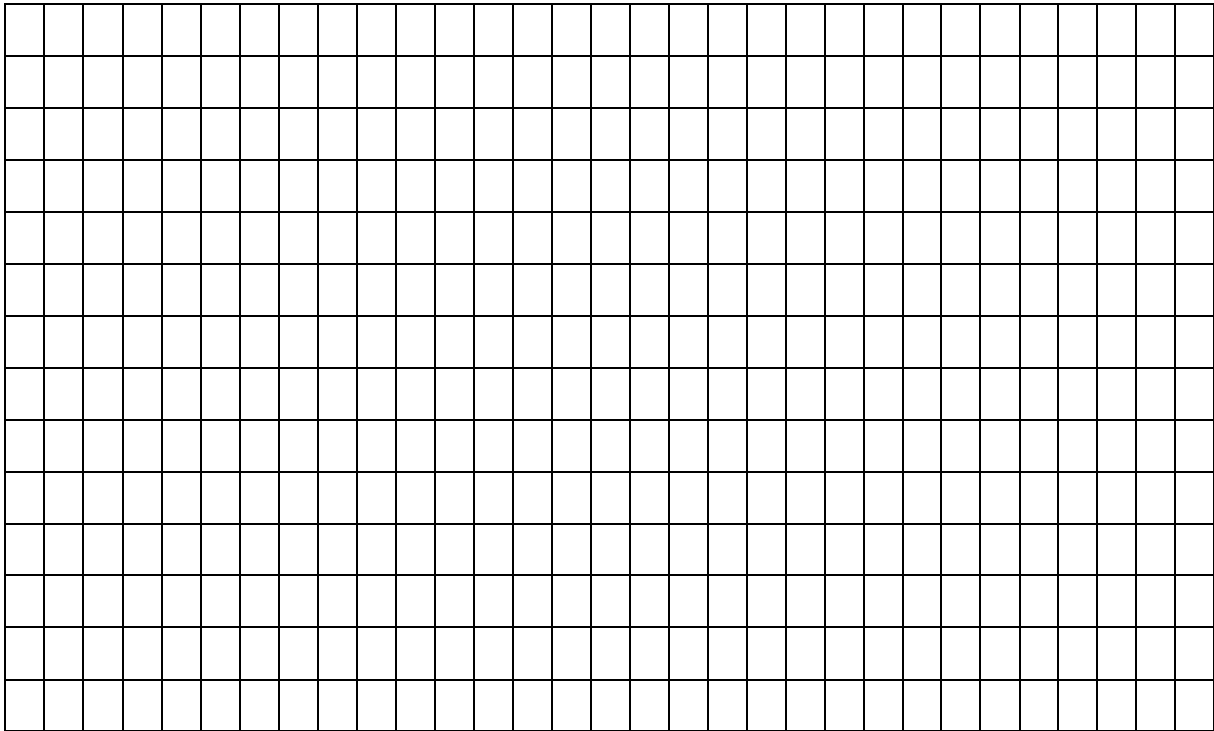
6. RESULT

- 6.1 Read the readings shown by Voltmeter (V) and Speed (rpm) from the output.
- 6.2 Write the results in Table 1.

Table 1: The Results

Times	Voltmeter (V)	Speed (rpm)
1		
2		
3		
4		
5		
6		
7		

- 6.3 Draw the graph Voltage Vs Speed by referring to the output shown in Table 1.



7. QUESTION

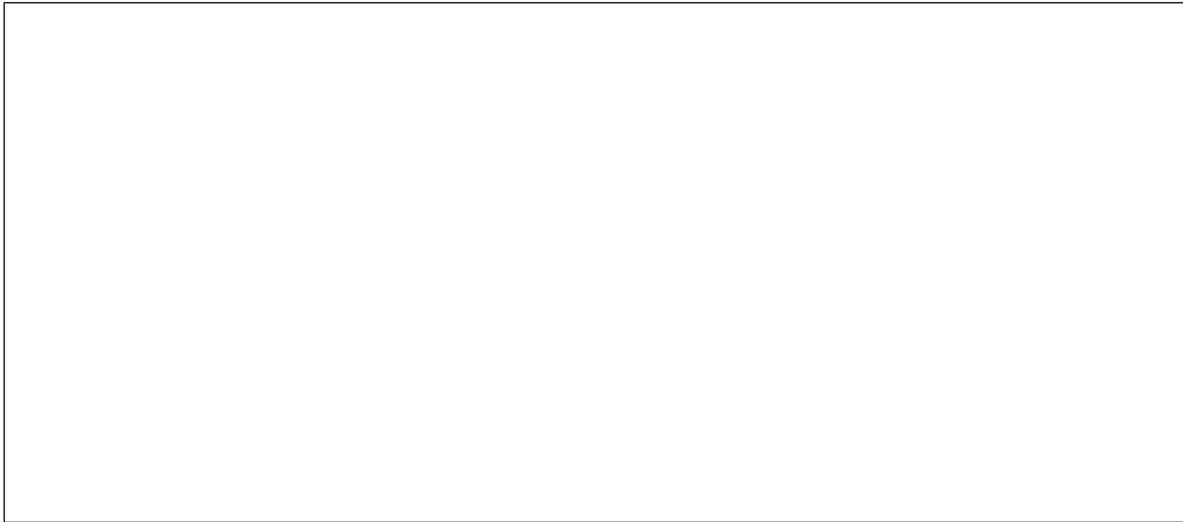
7.1 List the **THREE (3)** of the following adjustments in the speed of a D.C motor.

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7.2 Draw and label the equivalent circuit of Ward-Leonard method.



8. DISCUSSION

Based on the data in Table 1, explain your results by relating the theory and the practical.

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9. CONCLUSION

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**PRACTICAL
WORK 4:****Speed Control of Slipring Induction Motor****1. COURSE LEARNING OUTCOME**

At the end of this experiment, students should be able to perform the controlling methods for DC and AC machines and demonstrate the ability to work in a team to complete assigned tasks.

2. OBJECTIVES

At the end of this experiment, students should be able to:

- i. perform the speed control test on slip ring induction motor by rotor resistance control method.
- ii. plot the motor speed characteristics at different values of applied resistance in slip ring of induction motor.

3. THEORY**Introduction**

A wound rotor induction motor or slip ring induction motor has a stator like a squirrel cage induction motor, meanwhile a rotor with insulated windings is brought out via slip rings and brushes. However, no power is applied to the slip rings. Their sole purpose is to allow resistance to be placed in series with the rotor windings while starting.

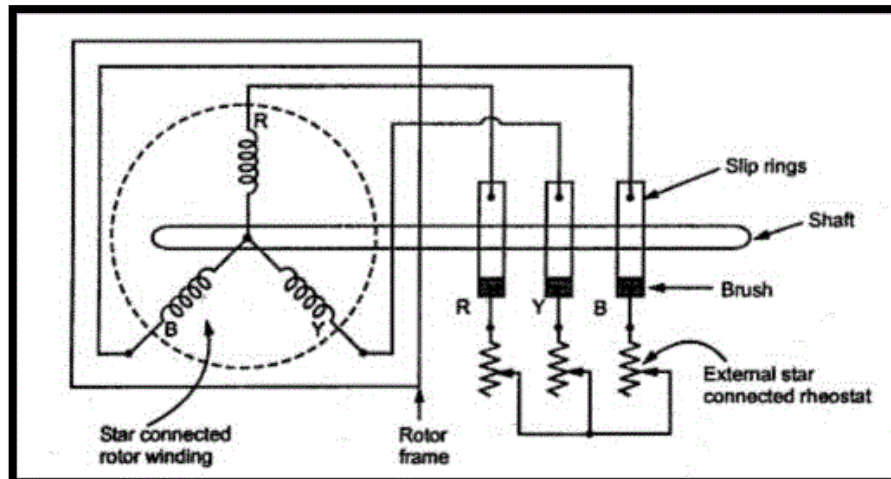


Figure 1 : Equivalent circuit of slip ring induction motor.

Slip Ring Characteristics

A slip ring motor or a phase wound motor is an induction motor that can be started with a full line voltage, applied across its stator terminals. The rotor winding terminals of a wound rotor motor are connected to three slip-rings mounted on, but insulated from the shaft. The leads, from the three brushes pressing on these slip-rings, are taken to external resistances. At the time of start, the value of starting current is adjusted by adding up external resistance to its rotor circuit. As the rotor speeds up, the external resistance is decreased in steps so that motor torque tends to remain maximum during the accelerating period.

Finally, under normal operation, the external resistance is fully cut off and the slip-rings are short-circuited so that the motor now develops full load torque at low value of slip-rings. The point to be noted is the “slip necessary to generate maximum torque is directly proportional to the rotor resistance.” So it is evident that the slip increases with an increase in external resistance. With the above statements, let us discuss the different methods of speed control of slip ring induction motors:

1. Rotor Rheostat Control
2. Cascade Control

Speed Control by Rotor Rheostat Control

The external rheostat that is used for the starting purpose of these slip ring motors can also be used for its speed control. Nevertheless, the point to look into is the starting rheostat must be rated for “continuous” operation. With the same rheostat added to the rotor circuit, it is possible to regulate the speed of slip ring motors. The resistance is engaged to the maximum during starting and slowly cuts-off to increase the speed of the motor. When running at full speed, if the need arises to reduce the speed, the resistance is slowly added up and thus the speed reduces. To understand the speed control, let us look into the torque-slip relation given below.

$$\text{Torque } T = \frac{S}{R}$$

In which,

S – is the slip of the motor,

R – is the rotor resistance.

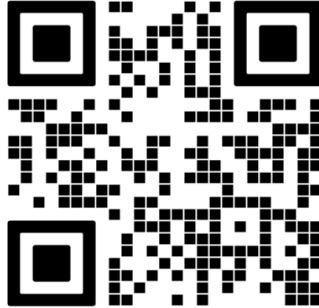
It is evident from the above relation that as the rotor resistance increases, the torque decreases. However, for a given load demand, the motor and thus the rotor have to supply the same torque without any decrease. So, in order to maintain the torque constant, as the rotor resistance increases the slip also increases. This increase in slip is nothing but a decrease in motor speed.

Disadvantages:

There are some disadvantages in this Rotor Rheostat Control. As the rotor resistance is increased, the “ $I^2 \cdot R$ ” losses also increases which in turn decreases the operating efficiency of the motor. It can be interpreted as the loss is directly proportional to the reduction in speed. As the losses are significant, this method of speed reduction is used for short period only.

4. EQUIPMENT / TOOLS

- 4.1 Click this link <https://ems-iitr.vlabs.ac.in/exp/speed-control-slip-ring/> or scan the QR code below.



- 4.2 Then, click "Simulation".
- 4.3 After that, "click here to go to the simulation page".
- 4.4 Start the "simulation procedure".

5. SIMULATION PROCEDURE

Step 5.1: Make all the correct connections. Refer to the steps below and draw the wiring diagram in Figure 2.

Step 5.2 : Make the proper connections by clicking the node as instructed below. If the wire is misplaced, connect all dots in the following manner:

1. Connect the wiring from point **1** (MCB) to point **21** (Autotransformer).
2. Connect the wiring from point **2** (MCB) to point **22** (Autotransformer).
3. Connect the wiring from point **3** (MCB) to point **23** (Autotransformer).
4. Connect the wiring from point **4** (Voltmeter) to point **12** (Autotransformer).
5. Connect the wiring from point **5** (Voltmeter) to point **13** (Autotransformer).
6. Connect the wiring from point **6** (Ammeter) to point **12** (Autotransformer).
7. Connect the wiring from point **7** (Ammeter) to point **8** (Wattmeter)
8. Connect the wiring from point **9** (Wattmeter) to point **15** (3 ϕ Induction Motor).
9. Connect the wiring from point **10** (Wattmeter) to point **12** (Autotransformer).
10. Connect the wiring from point **11** (Wattmeter) to point **17** (3 ϕ Induction Motor).
11. Connect the wiring from point **16** (3 ϕ Induction Motor) to point **13** (Autotransformer).

12. Connect the wiring from point **17** (3 ϕ Induction Motor) to point **14** (Autotransformer).
13. Connect the wiring from point **18** (Resistance Box) to point **24** (3 ϕ Induction Motor).
14. Connect the wiring from point **19** (Resistance Box) to point **25** (3 ϕ Induction Motor).
15. Connect the wiring from point **20** (Resistance Box) to point **26** (3 ϕ Induction Motor).

Step 5.3 : Click "Check" button.

1. If the connection is correct, an alert appears. Click ok. Now, go to Step 5.4.
2. If the connection is wrong, an alert appears. Click ok. Now, go to Step 5.2. Check the connection and either re-attach the incorrect wire connection or Click on reset button and start again step by step.

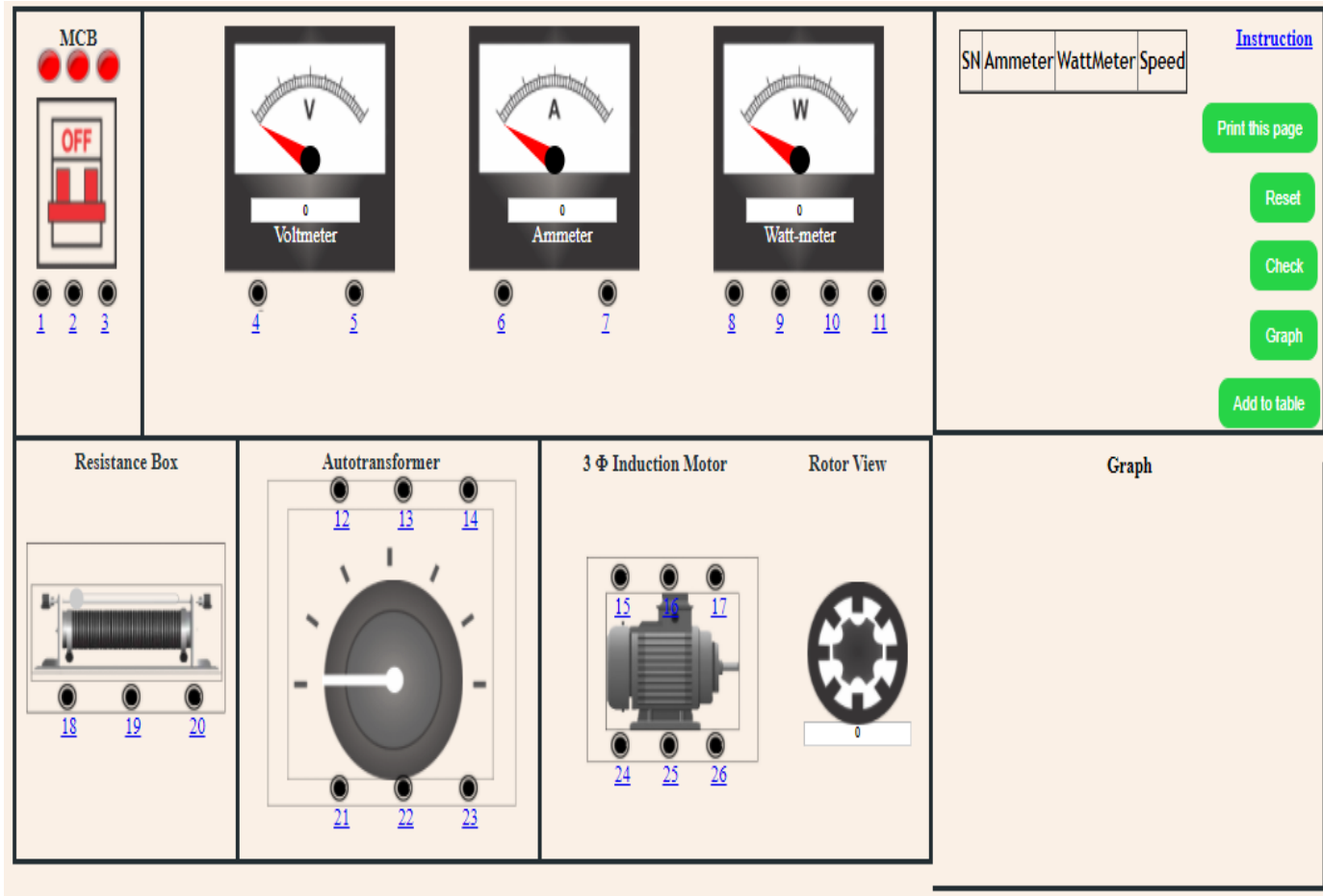


Figure 2: Draw the wiring diagram for this figure.

Step 5.4 : Switch on the MCB.

Step 5.5 : Click anywhere on the autotransformer.

Step 5.6: Slide the knob of the Rheostat to change the resistance.

Step 5.7 : Take readings from Rotor, Voltmeter, Ammeter and Watt-meter.

Step 5.8 : Click "Add to table" button to insert values in the table.

Step 5.9 : Follow the procedure from Step 6 to Step 8, till you have six readings on the table.

Step 5.10: After taking a minimum of six readings, click the "Graph" button.

Step 5.11: Click "Print" button, to print the full connections with graph and table.

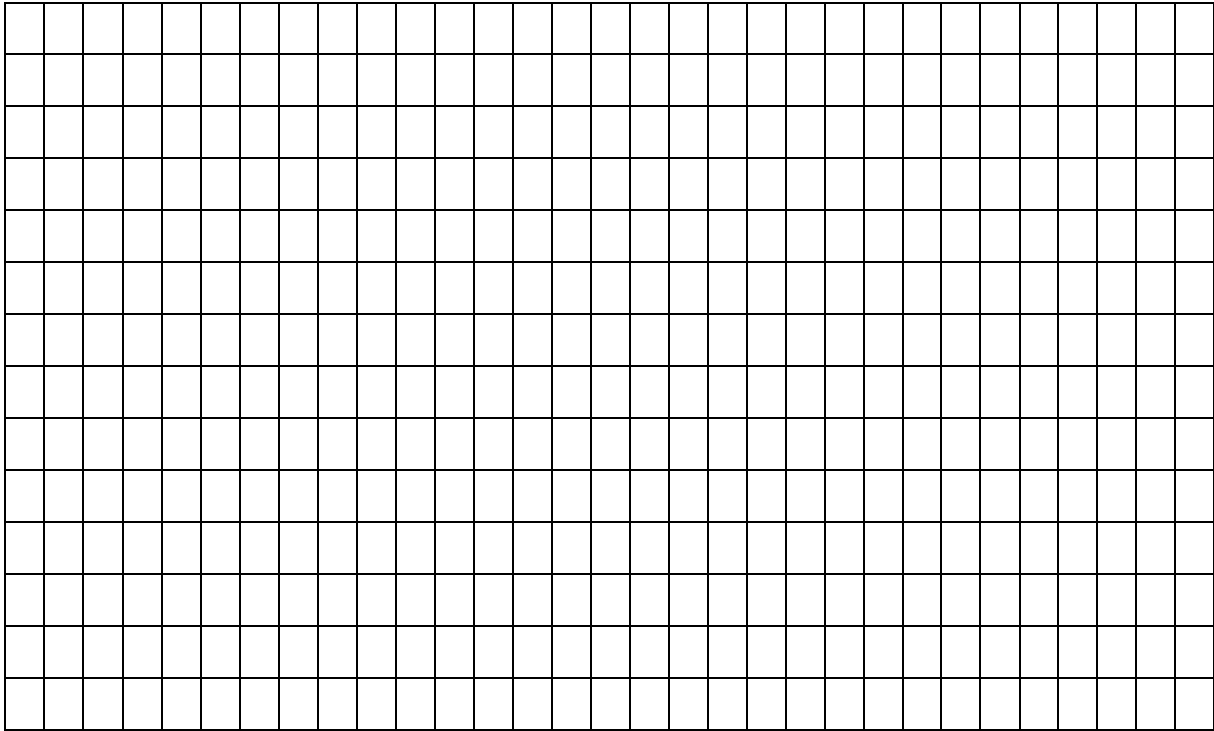
6. RESULT

- 6.1 Read the readings shown by Voltmeter (V), Wattmeter (W) and Speed (rpm) by referring to the value of Ammeter (A).
- 6.2 Write the results in Table 1.

Table 1: The Results

Ammeter (A)	Voltmeter (V)	Wattmeter (W)	Speed (rpm)
0			
2.6			
2.9			
4.8			
5.5			
6.1			
6.4			
6.9			
7.5			
8.0			

- 6.3 Draw the graph of Speed Vs Current by referring to the output shown in Table 1.



7. QUESTIONS

7.1 Why do we use slip rings in motors?

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7.2 What is the difference between a slip ring and a split ring?

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8. DISCUSSION

Based on the data in Table 1, explain your results by relating the theory and the practical.

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9. CONCLUSION

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PRACTICAL WORK 5:	Determination of Transformer Equivalent Circuit from Open Circuit and Short Circuit Test
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1. COURSE LEARNING OUTCOME

At the end of this experiment, the students should be able to perform the controlling methods for DC and AC machines and demonstrate the ability to work in a team to complete assigned tasks.

2. OBJECTIVES

At the end of this experiment, students should be able to:

- determination the of transformer equivalent circuit from an open circuit and a short circuit test.
- determining the parameter of the transformer such as efficiency, voltage regulation and circuit constant.

3. THEORY

Introduction

The open circuit and short circuit tests are performed to determine the parameter of the transformer like the efficiency, voltage regulation, circuit constant, etc. These tests are performed without the actual loading and because of this reason, very little power is required for the test. The open circuit and the short circuit tests give very accurate results as compared to the full load test.

Open Circuit Test

The purpose of the open-circuit test is to determine the no-load current and the losses of the transformer because of which their no-load parameter is determined. This test is performed on the primary winding of the transformer. The wattmeter, ammeter, and voltage are connected to their primary winding. The nominal rated voltage is supplied to their primary

winding with the help of the ac source.

The secondary winding of the transformer is kept open and the voltmeter is connected to their terminal. This voltmeter measures the secondary induced voltage. As the secondary of the transformer is open, the no-load current flows through the primary winding. The value of the no-load current is very small as compared to the full rated current. The copper loss occurs only on the primary winding of the transformer when the secondary winding is open. The reading of the wattmeter only represents the core and iron losses. The core loss of the transformer is the same for all types of loads.

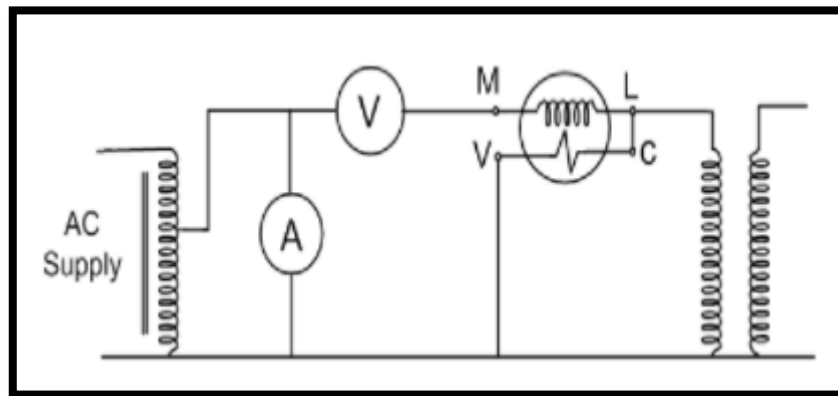


Figure 1: Equivalent circuit diagram for open circuit test on a transformer.

Calculation of open circuit test

Let,

W_0	—	wattmeter	reading
V_1	—	voltmeter	reading
I_0	—	ammeter	reading

Then the iron loss of the transformer $P_i = W_0$ and

$$W_0 = (V_1)(I_0)\cos\Phi \quad \dots\dots\dots \text{eq (1)}$$

The no-load power factor is

$$\cos\Phi = W_0/V_1I_0$$

Working component I_w is

$$I_w = W_0/V_1 \quad \dots\dots\dots \text{eq (2)}$$

Putting the value of W_0 from the equation (1) and equation (2) you will get the value of working component as

$$I_w = I_0\cos\Phi$$

Magnetizing component is

$$I_m = [I_0^2 - I_w^2]^{(1/2)}$$

No-load parameters are given below :

Equivalent exciting resistance is

$$R_0 = V_1/I_w$$

Equivalent exciting reactance is

$$X_0 = V_1/I_m$$

Short Circuit Test

The short circuit test is performed to determine the below mentioned parameter of the transformer.

1. It determines the copper loss that occurs on the full load. The copper loss is used for finding the efficiency of the transformer.
2. The equivalent resistance, impedance, and leakage reactance are known by the short circuit test.

The short circuit test is performed on the secondary or high voltage winding of the transformer. The measuring instrument like wattmeter, voltmeter, and ammeter is connected to the high voltage winding of the transformer. Their primary winding is shortcircuited by the help of a thick strip or ammeter which is connected to their terminal. The low voltage source is connected across the secondary winding because of which the full load current flows from both of the secondary and the primary winding of the transformer. The full load current is measured by the ammeter connected across their secondary winding. The low voltage source is applied across the secondary winding which is approximately 5% to 10% of the normal rated voltage. The flux is set up in the core of the transformer. The magnitude of the flux is small compared to the normal flux. The iron loss of the transformer depends on the flux. It occurs less in the short circuit test because of the low value of flux. The reading of the wattmeter only determines the copper loss that occur on their windings. The voltmeter measures the voltage applied to their high voltage winding. The secondary current induced in the transformer is due to the applied voltage.

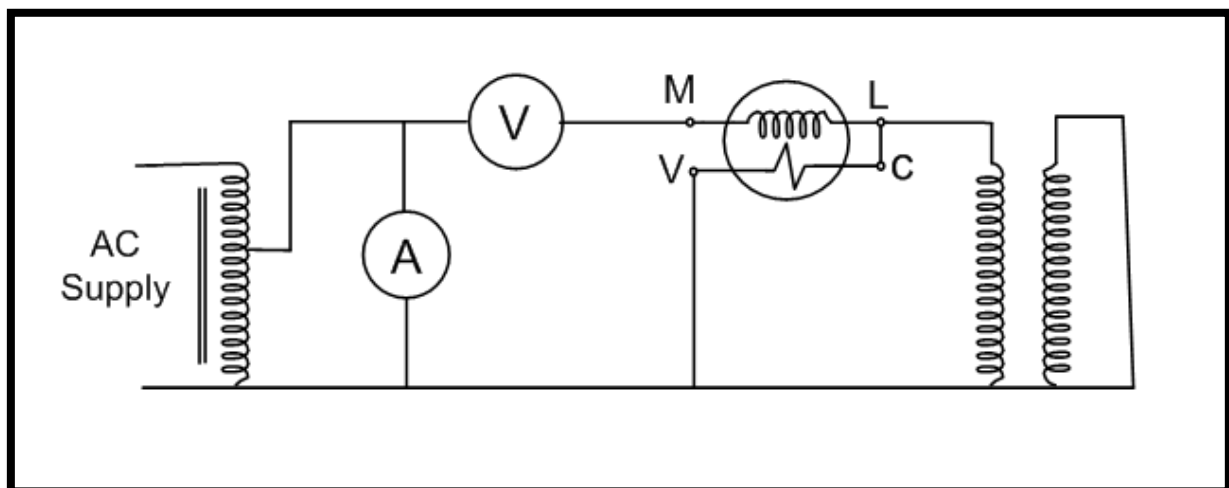


Figure 2: Equivalent circuit diagram for short circuit test on transformer.

Calculation of short circuit test

Let,

W_c	—	wattmeter	reading
V_{sc}	—	voltmeter	reading
I_{sc}	—	ammeter	reading

Then the full load copper loss of the transformer is given by

$$P_c = [I_{fl}/I_{sc}]^2 \cdot W_c$$

$$I_{sc}^2 R_s = W_c$$

Equivalent resistance referred to secondary side is

$$R_s = W_c / (I_{sc}^2)$$

Equivalent impedance referred to the secondary side is given by

$$Z_s = V_{sc} / I_{sc}$$

The equivalent reactance referred to the secondary side is given by

$$X_s = [(Z_s)^2 - (R_s)^2]^{1/2}$$

4. EQUIPMENT / TOOLS

- 4.1 Click this link or <https://ems-iitr.vlabs.ac.in/exp/circuit-parameters-oc-test/simulation.html> scan the QR code below.



- 4.2 Then, click item Simulation.
4.3 After that, click here to go to the simulation page.
4.4 Start the simulation procedure.

5. SIMULATION PROCEDURE

Step 5.1: Make all the correct connections. Refer to the steps below and **draw the wiring diagram of an open circuit transformer test in Figure 3.**

1. Connect negative node MCB to negative node autotransformer.
2. Connect positive node MCB to positive node autotransformer.
3. Connect negative node voltmeter 1 to negative node autotransformer.
4. Connect positive node voltmeter 1 to positive node autotransformer.
5. Connect negative node ammeter to M node wattmeter.
6. Connect positive node ammeter to positive node autotransformer.
7. Connect C node wattmeter to L node wattmeter.
8. Connect L node wattmeter to P1 node at transformer.
9. Connect V node wattmeter to P2 node at transformer.
10. Connect P2 node at transformer to negative node autotransformer.
11. Connect S1 node at transformer to positive node at voltmeter 2.
12. Connect S2 node at transformer to negative node at voltmeter 2.

Step 5.2 : Then check the connections by clicking on “Check Connection”.

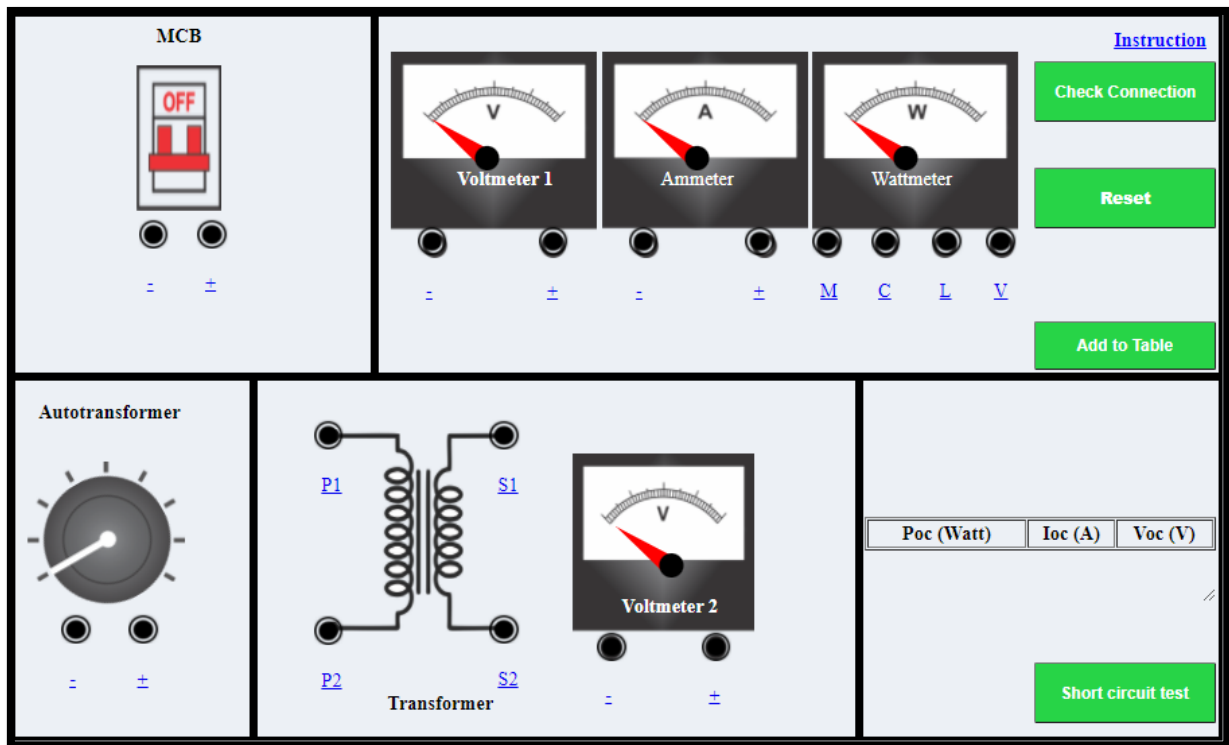


Figure 3: Draw the wiring diagram of an open circuit transformer test for this figure.

Step 5.3 : If the connection is wrong, follow the error message displayed and correct the connection.

Step 5.4 : Then turn ON MCB by clicking the MCB.

Step 5.5 : Then click autotransformer to get the change in all meter.

Step 5.6 : Then click “Add to table” button to get the reading of over open circuit transformer.

Step 5.7 : Then we have done the open circuit transformer test. Click short button for short circuit transformer test.

Step 5.8: Make all the correct connections. Refer to the steps below and **draw the wiring diagram of a short circuit transformer test in Figure 4.**

1. Connect negative node MCB to negative node autotransformer.
2. Connect positive node MCB to positive node autotransformer.

3. Connect negative node voltmeter to negative node autotransformer.
4. Connect positive node voltmeter to positive node autotransformer.
5. Connect negative node ammeter to M node wattmeter.
6. Connect positive node ammeter to positive node autotransformer.
7. Connect C node wattmeter to L node wattmeter.
8. Connect L node wattmeter to P1 node at transformer.
9. Connect V node wattmeter to P2 node at transformer.
10. Connect P2 node at transformer to negative node autotransformer.
11. Connect S1 node at transformer to S2 node transformer.

Step 5.9 : Then check the connections by clicking on Check Connection.

Step 5.10 : If the connection is wrong, follow the error message displayed and correct the connection.

Step 5.11 : Then turn ON MCB by clicking the MCB.

Step 5.12 : Then click autotransformer to get the change in all meter.

Step 5.13 : Then click “Add to table” button to get the reading of over short circuit transformer.

Step 5.14 : we have done short circuit transformer test. Then click submit button to get the results.

Step 5.15 : Then we have the results in a diagram.

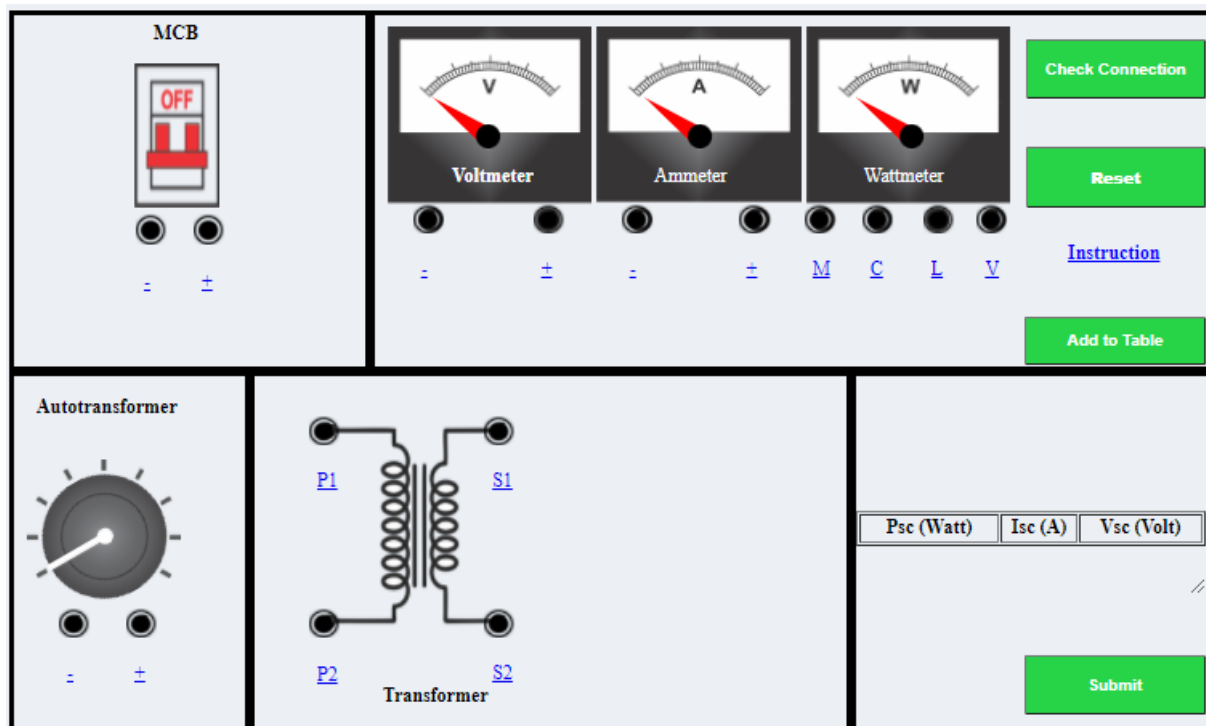


Figure 4: Draw the wiring diagram of a short circuit transformer test for this figure.

6. RESULT

6.1 Insert the results of the open circuit transformer test in **Table 1**.

Table 1: Open circuit results

Poc (Watt)	Ioc(A)	Voc (V)

6.2 Insert the results of the short circuit transformer test in **Table 2**.

Table 2: Short circuit results

Psc (Watt)	Isc(A)	Vsc (V)

6.3 Draw the equivalent circuit diagram for transformer in **Table 3**.

7. QUESTIONS

7.1 Explain the working principle of autotransformer. What are the advantages, disadvantages and applications?

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7.2 The efficiency of a 20 KVA, 2000/200 V, single phase transformer at unity pf is 98%. Calculate the total loss at this condition.

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8. DISCUSSION

Based on the data in Table 1, explain your results by relating the theory and the practical.

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9. CONCLUSION

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e-Lab Sheet for Electrical Machine and Control

is an invaluable and comprehensive e-Lab Sheet written for students studying Electrical Machine and Control in Polytechnics and other students who want to get by to the heart of this subject. It is based on the latest syllabus endorsed by the Curriculum Development and Evaluation Division in the Department of Polytechnic Education. This e-Lab Sheet aims to stimulate student's interest and to help them to understand the principles electrical machine and control.

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