



NED University of Engineering & Technology
Department of Electrical Engineering

LAB MANUAL
For the course

ELECTRICAL MACHINES I
(EE-346) For T.E.(EE)

Instructor name: _____

Student name: _____

Roll no: _____ **Batch:** _____

Semester: _____ **Year:** _____

To be filled by lab technician

Attendance: Present out of ____ Lab sessions

Attendance Percentage _____

To be filled by Lab Instructor

Lab Score Sheet

Roll No.	Rubric based Lab I	Rubric based Lab II	Rubric based Lab III	Rubric based Lab IV	Rubric based Lab V	Rubric based Lab VI	OEL/PBL Rubric Score A	Final LAB Rubric Score B	Attendance Percentage C	Final weighted Score for MIS System [10(A)+10(B)+5(C)]/25 Round to next higher multiple of 5

Rubrics based labs for EE-346 EM-I: 1 to 6

Note: All Rubric Scores must be in the next higher multiple of 5 for correct entry in MIS system.

LAB MANUAL

For the course

ELECTRICAL MACHINES I **(EE-346) For T.E.(EE)**

Content Revision Team:

Dr. Raja Masood Larik, Dr. Abdul Ghani Abro, Ms. Najia Naveed,

Last Revision Date:

Approved By

The Board of Studies of Department of Electrical Engineering

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4		Speed control of a DC shunt motor by flux control method.		
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11		Open Ended Lab To Perform the parallel operation of two DC generators and shift the load of one on another		

EXPERIMENT # 1

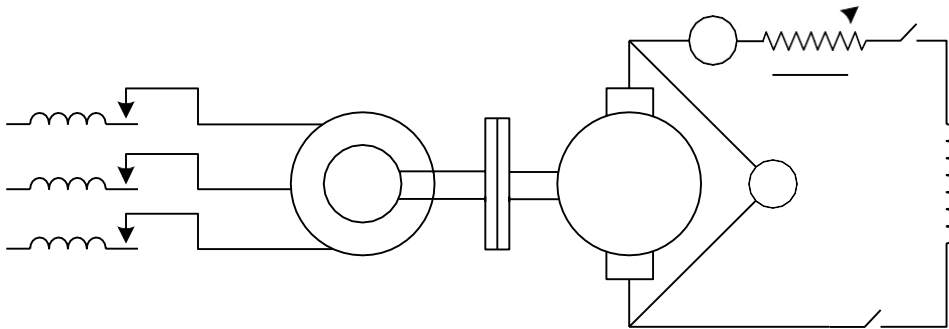
OBJECT :-

To draw the magnetization curve of self excited DC shunt generator (open circuit characteristics curve O.C.C).

APPARATUS :-

1. Bench 10-ES/EV or Bench 14-ES/EV
2. DC multi-range ammeter
3. Voltmeter

CIRCUIT DIAGRAM



THEORY :-

The magnetization characteristics also known as “No load” or “Open circuit” characteristics is the relation between emf generated and field current at a given speed.

Due to residual magnetism in the poles, some emf is generated even when field current is zero. Hence the curve starts a little way up. It is seen that the first part of the curve is practically straight. This is due to the fact that at low flux densities reluctance of iron path is being negligible, total reluctance is given by air gap reluctance which is constant. Hence the flux and consequently the generated emf is directly proportional to exciting current. However at high flux densities iron path reluctance is being appreciable and straight relation between emf and field current no longer holds good. In other words saturation of poles starts.

PROCEDURE :-

1. Connect the shunt field to armature terminal through the ammeter switch and rheostat.
2. Connect the multi-range voltmeter across the terminals of generator.

3. Check the connections carefully.
4. Press the upper yellow switch (on) to start the AC Induction Squirrel Cage Motor.
5. Supply the voltage to the motor by the help of 3- ϕ Auto Transformer .
6. Closed the field switch and note the reading of voltmeter (voltage due to residual magnet).
7. Excite the field at the low current and note the voltage again.
8. Increase the field current in steps and note the voltage each time.
9. Take at least 11-12 readings.
10. Tabulate the reading and draw the curve between armature induced e.m.f and exciting current.

OBSERVATIONS :-

S.No.	FIELD CURRENT 'I _F ' (A)	TERMINAL VOLTAGE V _T (volts)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

RESULT :-

1. The curve starts somewhat above the origin. The voltage at zero excitation is due to residual magnetism of the field, which is necessary for building up the voltage of self-excitation generator.
2. The voltage increases rapidly at first and then changes a little in value at higher excitations indicating the effect of the poles saturation.

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Remarks					
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EXPERIMENT # 2

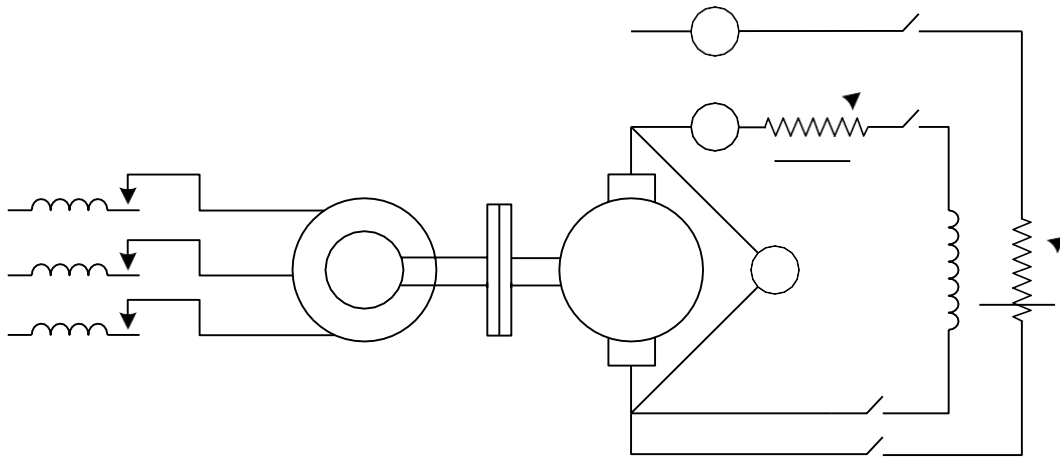
OBJECT :-

To draw the load characteristics of self excited D.C Shunt Generator.

APPARATUS :-

1. Bench 10-ES/EV or Bench 14-ES/EV
2. DC multi-range ammeter
3. Voltmeter

CIRCUIT DIAGRAM



THEORY :-

After building up of voltage, if a shunt generator is loaded then terminal voltage drops with increase in load current. There are three main reasons for the drop of terminal voltage for a shunt generator under load.

I. ARMATURE REACTION :-

Armature reaction is the effect of magnetic field set up by the armature current on the distribution of flux under main poles of a generator. Due to demagnetizing effect of armature reaction, pole flux is weakened and so induced e.m.f in the armature is decreased.

II. ARMATURE RESISTANCE :-

As the load current increases, more voltage is consumed in ohmic resistance of armature circuit. Hence the terminal voltage ($V_t = E - I_a R_a$) is decreased where “E” is the e.m.f induced in armature under load condition.

III. DROP IN TERMINAL VOLTAGE :-

The drop in terminal voltage (V_t) due to armature resistance and armature reaction results in decreased field current, which further reduces e.m.f induced.

For a shunt generator

$$I_a = I_L + I_f$$

$$E = V_t + I_a R_a$$

PROCEDURE :-

1. Connect meters as shown in diagram.
2. Press yellow switch “on” and increase AC voltage of induction motor (prime mover) by the help of 3-phase autotransformer until it reaches at normal speed.
3. When motor reaches rated speed, switch on excitation of shunt field.
4. Now increase excitation by moving black wheel (field rheostat) to right until terminal voltage reaches 220 volt.
5. Now keep the switch on and maintain speed constant throughout.
6. Note down the meter readings from all meters carefully.
7. Vary load and keep speed constant by autotransformer.
8. Take readings of voltmeter and ammeter at different loads.

OBSERVATIONS :-

S.No	$I_f(A)$	$I_L(A)$	$V_T(V)$	$I_a = I_f + I_L$	$V_d = I_a R_a$
1					
2					
3					
4					
5					
6					
7					
8					

RESULT :-

The terminal voltage of a D.C. Generator is maximum at no load, which decrease with increasing load.

PRECAUTIONS :-

1. Ammeters should always be connected in series.
2. Voltmeters should always be connected in parallel.
3. Always connect positive lead to positive terminal of meter and negative lead to negative terminal.

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Remarks					
Instructor's Signature with Date:					

EXPERIMENT # 3

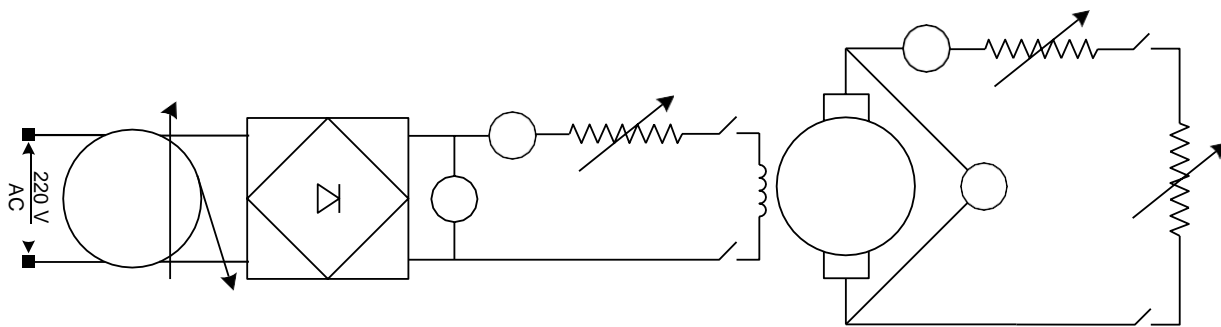
OBJECT :-

To draw the external and internal characteristics of separately excited D.C generator.

APPARATUS :-

1. Bench 10-ES/EV or Bench 14-ES/EV
2. DC multi-range ammeter
3. Voltmeter

CIRCUIT DIAGRAM



THEORY :-

The load or external characteristic of a generator is the relation between the terminal voltage and load current. The characteristic expressed the manner in which the voltage across the load varies with I , the value of load current. The internal or total characteristic of a generator is the relation between the e.m.f actually induced in the generator E_a and the armature current I_a . The internal characteristic of the generator, which is separately excited, can be obtained as below:

Let:

V_t = Terminal voltage
 I_a = Armature current
 R_a = Armature resistance

Then,

$$E_a = V_t + I_a R_a$$
$$I_a = I_L$$

Therefore if we add drop of armature ($I_a R_a$) to terminal voltage V_t we get actually induced e.m.f (E_a).

PROCEDURE :-

1. Make the connections according to the circuit diagram.
2. Run the generator at a constant speed and the exciting current.
3. Connect the load across the generator armature.
4. Increase the load current gradually by the help of load rheostat and note the readings of ammeters and voltmeter.

OBSERVATIONS :-

S.No	$I_L(A)$	$I_f(A)$	$V_T(V)$	$E_a = V_t + I_a R_a (V)$
1				
2				
3				
4				
5				
6				
7				
8				

RESULT :-

From the graph it is observed that the terminal voltage across generator decreases as the load increases.

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EXPERIMENT # 4

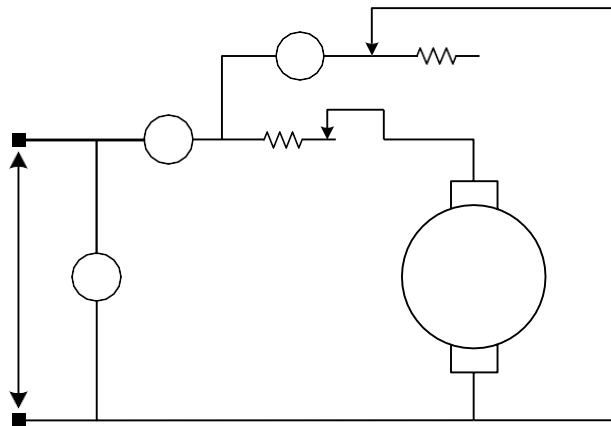
OBJECT:

Speed control of a D.C. Shunt Motor by flux control method.

APPARATUS:

1. Bench 13-ES/EV or Bench 15-ES/EV
2. DC multi-range ammeter
3. Voltmeters
4. Digital tachometer

CIRCUIT DIAGRAM



THEORY:

The flux of a dc motor can be changed by changing field current with the help of a shunt field rheostat.

A resistance is necessary to connect in series of the armature to control initial high starting current because armature has low resistance. when motor armature rotates, the armature conductors also rotate and hence cut the flux. According to the laws of electromagnetic induction, e.m.f. is induced in them whose direction according to the Fleming's Right Hand Rule, is in opposition to the applied voltage, it is referred as Back emf " E_b ". The voltage applied across the motor armature has to overcome the back emf and supply the armature ohmic drop. Hence

$$V = E_b + I_a R_a$$
$$E_b = V - I_a R_a \text{ ----- (1)}$$

The equation for back emf is:

$$E_b = (N Z P) / 60a \quad [\text{Where } N \text{ is in r.p.m}]$$

Or,

$$E_b = k \phi N \text{ where, } k = Z.P / 60a$$

Putting value of E_b in (1),

$$k \phi N = V - I_a R_a$$

Therefore,

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

It is seen from the above that $N \propto 1/\phi$. By decreasing flux the speed can be increased and vice versa. Changing field current with the help of a shunt field rheostat can change the flux. This method is used when the speed above the normal speed is required.

PROCEDURE:

1. Make connections as shown in figure.
2. Make sure that an appropriate range resistance (starting rheostat) is used in series with an armature and also make sure that resistance in the field circuit (field rheostat) is cutoff before starting motor.
3. Start the motor by pressing yellow switch "ON" without load.
4. Adjust the armature rheostat. Now decrease field current by the help of rheostat slowly, step by step and take readings of field current and speed from digital tachometer at every step. Adjust the field rheostat to give maximum speed at which it is safe to operate the motor.

OBSERVATION:

S. No	Field Current	Speed
	$I_f(A)$	N (RPM)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

RESULT:

Speed increases as the field excitation decreases.

PRECAUTIONS:

- To start with, put the whole armature control resistance in the circuit.
- While reducing the field resistance, must control the high speed of the motor.

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Remarks					
Instructor's Signature with Date:					

EXPERIMENT # 5

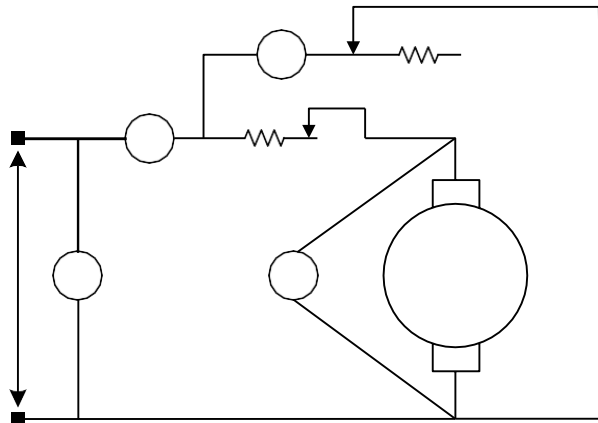
OBJECT:

Speed control of a D.C. Shunt Motor by armature or rheostatic control method.

APPARATUS:

1. Bench 13-ES/EV or Bench 15-ES/EV
2. DC multi-range ammeter
3. Voltmeters
4. Digital tachometer

CIRCUIT DIAGRAM



THEORY:

A resistance is necessary to connect in series of the armature to control initial high starting current because armature has low resistance. when motor armature rotates, the armature conductors also rotate and hence cut the flux. According to the laws of electromagnetic induction, e.m.f. is induced in them whose direction according to the Fleming's Right Hand Rule, is in opposition to the applied voltage, it is referred as Back emf " E_b ". The voltage applied across the motor armature has to overcome the back emf and supply the armature ohmic drop. Hence

$$\begin{aligned} V &= E_b + I_a R_a \\ E_b &= V - I_a R_a \text{ ----- (1)} \end{aligned}$$

The equation for back emf is:

$$E_b = (N \phi Z P) / 60a \quad [\text{Where } N \text{ is in r.p.m}]$$

Or,

$$E_b = k \phi N \text{ where, } k = Z.P / 60a$$

Putting value of E_b in (1),

$$k \phi N = V - I_a R_a$$

Therefore,

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

Above equation shows that if the voltage across the armature is varied by inserting a variable rheostat in series with the armature circuit, speed can be varied.

PROCEDURE:

4. Make connections as shown in figure.
5. Make sure that an appropriate range resistance (starting rheostat) is used in series with an armature and also make sure that resistance in the field circuit (field rheostat) is cutoff before starting motor.
6. Now cut the armature resistance slowly by the help of moving block wheel (rheostat) to right side. Take ten readings for armature voltage and speed of armature.

OBSERVATION:

S. No	Armature Voltage	Speed
	V _a (V)	N (RPM)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		

RESULT:

- Speed is very nearly proportional to the applied voltage in the case of armature control method.

PRECAUTIONS:

- To start with, put the whole armature control resistance in the circuit.

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EXPERIMENT # 6

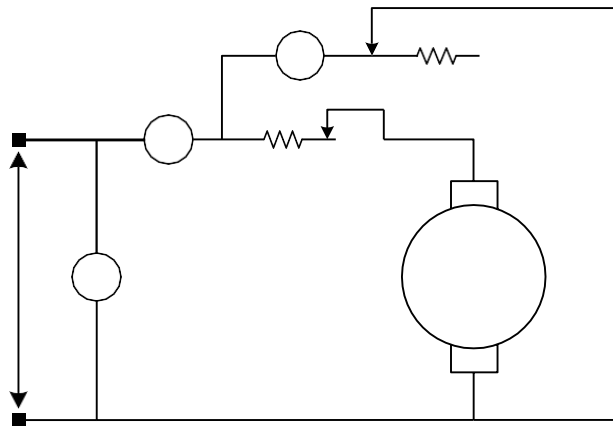
OBJECT:

To find the constant losses of the D.C shunt motor by No load test.

APPARATUS:

1. Bench 13-ES/EV or Bench 15-ES/EV
2. DC multi-range ammeter
3. Voltmeters
4. Digital tachometer

CIRCUIT DIAGRAM



THEORY:

It is simple and direct method in which losses are measured separately and efficiency at any desired load can be predetermined. However this test is applicable to those machines in which flux is practically constant i.e shunt and compound wound machines. The motor is run at its rated voltage and speed is adjusted to rated speed. The no load and shunt currents are measured

Let

- ↪ **Supply voltage = V**
- ↪ **No load input = $V I_o$**
- ↪ **Power input to armature = $V (I_o - I_{sh})$**
- ↪ **Power input to Shunt = $V I_{sh}$**

No load power input to armature supplies the iron losses in core, friction losses, windage losses and armature copper loss.

If we subtract from the total input the no load armature copper loss then we get constant losses.

$$\hookrightarrow \text{Constant losses} = W_c = V I_o - (I_o - I_{sh})^2 R_a$$

To find efficiency at any required load, we know that,

$$\text{Input} = V I_o$$

$$\text{Armature copper loss} = I_a^2 R_a$$

$$\text{Total loss} = (I_o - I_{sh})^2 R_a + W_c$$

$$\text{Efficiency} = (\text{Input} - \text{Losses}) / \text{input}$$

PROCEDURE:

- ↪ Make connections according to the given circuit.
- ↪ Keep the armature rheostat at its maximum value and field rheostat at its minimum value.
- ↪ Run motor by pressing the yellow button “ON”.
- ↪ Now reduce the armature rheostat resistance gradually with the help of black wheel.
- ↪ If the motor speed is less than the rated value than move (black wheel on left side) the rheostat to increase resistance of the field (decrease the field current).
- ↪ Read the meters and note down the readings carefully.

OBSERVATION:

S.No	V (Volts)	I _o (A)	I _{sh} (A)
1			

CALCULATIONS:

$$\text{Power input} = V I_o = \underline{\hspace{2cm}}$$

$$\text{Armature copper loss} = (I_o - I_{sh})^2 R_a = \underline{\hspace{2cm}}$$

$$\text{Constant losses} = W_c = V I_o - I_a^2 R_a = \underline{\hspace{2cm}}$$

RESULT:

Constant losses are found to be Watts.

NED University of Engineering & Technology
Department of Electrical Engineering



Course Code and Title: _____

Laboratory Session: No. _____ Date: _____

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment Identification Sensory skill to identify equipment and/or its component for a lab work. 10 %	Not able to identify the equipment. 0	--	--	--	Able to identify equipment as well as its components. 40
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Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)		(Points /4)			
Remarks					
Instructor's Signature with Date:					

EXPERIMENT # 7

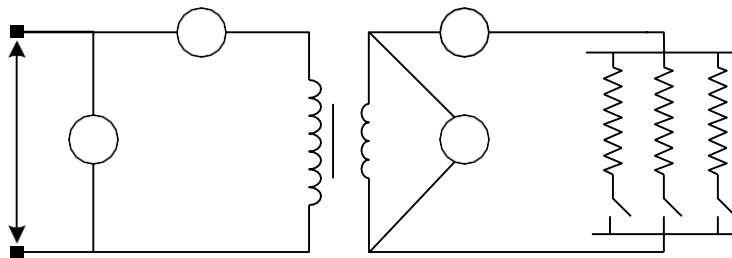
OBJECT:

To find out the efficiency and voltage regulation of a single-phase step down transformer.

APPARATUS:

1. Two Voltmeters (0 – 300V), (0 – 150V)
2. Two Ammeters (0 – 1A)
3. Step- down transformer
4. Variable load

CIRCUIT DIAGRAM



THEORY:

A step-down transformer converts the high voltage at primary side to a lower level at the secondary side. Works on the principle of mutual induction, the transformer secondary winding has an induced e.m.f due to the voltage across the primary winding.

As the number of turns in the secondary winding are less than the number of turns in the primary winding, hence the magnitude of the induced e.m.f in the secondary winding is less than that in primary (as e.m.f induced varies directly with number of turns).

EFFICIENCY OF TRANSFORMER:

The ratio of $V_s I_s$ and $V_p I_p$ gives the efficiency of the transformer and the formula for efficiency and voltage regulation are:

$$\eta = (V_s I_s / V_p I_p) \times 100\%$$

$$V_r = [(V_{SN} - V_{SL}) / V_{SN}] \times 100\%$$

PROCEDURE:

1. Make the connections as shown in diagram.
2. Switch on the AC supply and read the no load secondary voltage when there is no load turned on.
3. Now turn on the load on the secondary side and take readings at different loads.

OBSERVATION:

No load secondary voltage V_{SN} = _____ Volts

S.No	V_p (Volts)	I_p (A)	V_s (Volts)	I_s (A)
1				
2				

CALCULATIONS:

1. $\eta\% = (V_s I_s / V_p I_p) \times 100$

$$\%V_r = [(V_{SN} - V_{SL}) / V_{SN}] \times 100$$

RESULT:

The efficiency and voltage regulation have been calculated and observed to increase with load.

PRECAUTIONS:

1. Connections should be tight and neat.
2. Ammeters should always be connected in series.
3. Voltmeters should always be connected in parallel.

EXPERIMENT # 8

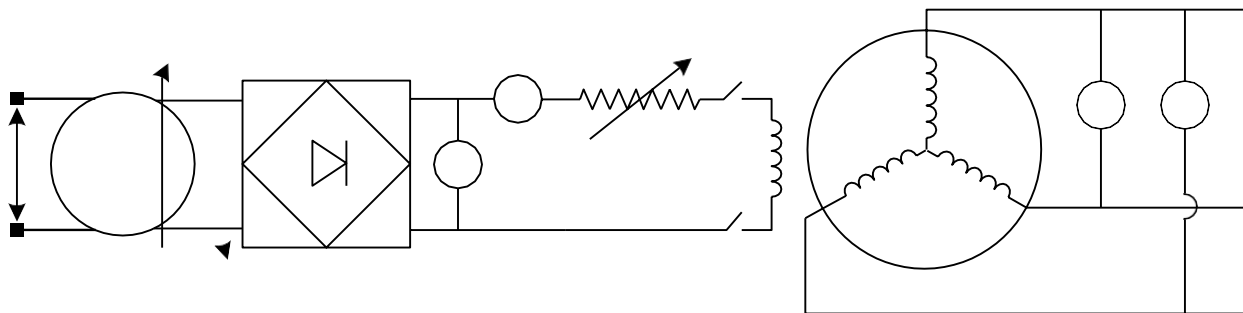
OBJECT:

To study the effect of field excitation on the generation of voltage by an alternator (open circuit magnetization curve).

APPARATUS:

1. One Voltmeter (0 – 600V)
2. One Ammeter (0 – 1.2A)
3. One frequency meter
4. D.C Supply (220 V)
5. Field Rheostat

CIRCUIT DIAGRAM



THEORY:

In A.C generator (alternator), the stationary armature is called stator, the rotating field is called rotor. The advantages are:

- ❖ It is easy to insulate the stationary armature windings for very high voltages.
- ❖ It is easy to collect the high voltage from a fixed terminal.
- ❖ Stator is outside of the rotor (fixed in yoke), so more space is available for 3-phase winding. Direct current is necessary for excitation, voltage is low and so small power is supplied through slip rings.

PROCEDURE:

1. Make the connections as shown in diagram, run it at rated speed 1500 rpm.
2. Note the line voltage at zero excitation.
3. Connect the field to D.C source through an ammeter and excite it. Increase the excitation current every time.

4. Tabulate the readings and draw the open circuit characteristics (O.C.C) or no load magnetization curve.

OBSERVATION:

S.No	Rotor Field Excitation Current (I_f)	Terminal Voltage (V_t)
	Amperes	Volts
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

RESULT:

Voltage increases directly for low exciting current and the curve then bends at higher excitation indicating the effect of saturation.

PRECAUTIONS:

1. Maintain the alternator speed constant throughout.
2. Note the readings carefully every time, when the exciting current is increased.

EXPERIMENT # 9

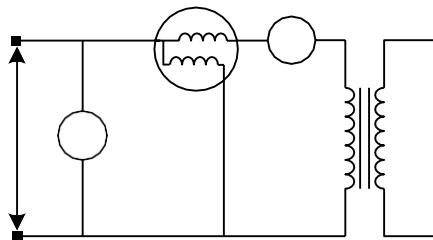
OBJECT: -

To find out the iron losses of single phase transformer (open circuit test).

APPARATUS: -

1. Voltmeter (0 – 300V)
2. Ammeter (0 – 2A)
3. Wattmeter (0 – 120 W)

CIRCUIT DIAGRAM



THEORY: -

The purpose of this test is to determine no load loss or core loss and no load current I_o which is helpful in finding X_o and R_o .

One winding of the transformer which ever is convenient but usually high voltage winding is left open and the other is connected to its supply of normal volt and frequency. A wattmeter, voltmeter and ammeter are connected in low voltage winding i.e. Primary winding in the present case. Normal voltage is applied to primary normal flux will be set up in the core hence normal iron loss will occur which are recorded by the wattmeter. As the primary no load I_o is small usually 2-10% of rated load current Cu losses is negligible small in primary I will in secondary b/c it is open. Therefore the wattmeter reading will show practically the core loss under no load condition.

OBSERVATION:-

S.No	W (watts)	V (Volts)	I_o (Ampere)

RESULT:-

The iron losses of single phase transformer are _____ watt.

EXPERIMENT # 10

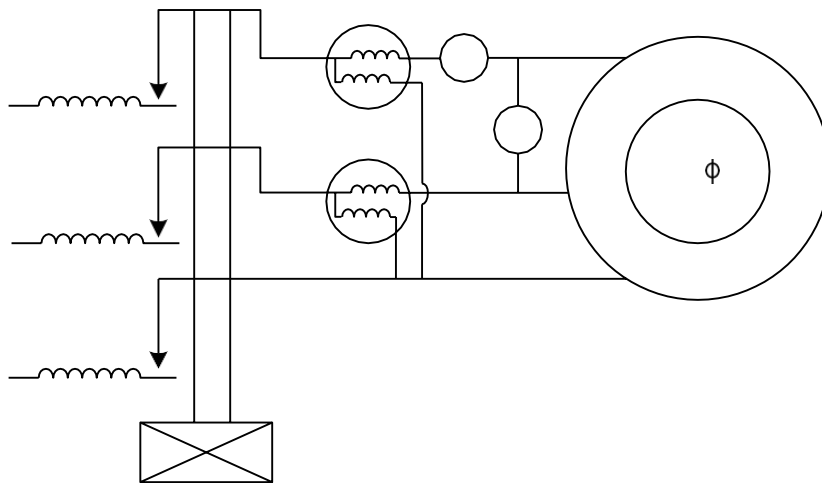
OBJECT:-

To study the effect of applied voltage on the power factor of an induction motor at no load.

APPARATUS:-

1. Bench 10-ES/EV or Bench 14-ES/EV
2. Voltmeter (0-600V)
3. Ammeter (0-6A)
4. Two wattmeters (0-120W)
5. Auto transformer

CIRCUIT DIAGRAM



THEORY:-

The induction motor consists of a stator and rotor. The stator is connected to the supply & forms a rotating field. So an induction motor is like a transformer with the stator forming the primary and the rotor forming the secondary winding with a small air gap in the magnetic circuit. In the test, power is measured by the two-wattmeter method. One wattmeter measures the negative power because the phase angle between current & voltage is more than 90°. Due to short-circuiting the rotor at starting time, it takes a very high current at rated voltage, so it is necessary to supply a reduced voltage by the help of an auto-transformer at the start.

$$\text{p.f} = \frac{W_1 + W_2}{\sqrt{3} VI}$$

OBSERVATIONS:-

S.No	V(Volts)	I (Amp)	W ₁ (Watts)	W ₂ (Watts)	W ₁ +W ₂	P.F

CALCULATIONS:-

Calculate power factor for all above observations using the relation $\text{P.F} = (W_1 + W_2) / (3)^{1/2} VI$

PRECAUTIONS:-

- (i) Avoid loose connections.
- (ii) At starting time auto transformer must be at zero volt.
- (iii) Take readings after the motor has come in the steady state.

RESULT:-

Power Factor decreases with the increase in applied voltage at no load.

Cover Page for Each PBL/OEL

Course Code:	EE-345
Course Name:	Electrical Machines
Semester:	
Year:	
Section:	
Batch:	
Lab Instructor name:	
Submission deadline:	

PBL or OEL Statement: To perform the parallel operation of two DC Generator and shift the load of one on another.

Deliverables:

A well written and well formatted report which includes

1. Advantages of DC generator parallel operation.
2. Necessary conditions for putting DC generators in parallel.
3. Procedure to put DC generators in parallel.
4. Readings and graphs (wherever applicable) taken which DC generators operating in parallel.
5. Conclusion of the experiment
5. Electrical circuit of DC generators operating in parallel.

Methodology: a. Do polarity test and connect them with regard to their polarities.
b. Connect load on parallel connected DC generator and prove the equal load sharing according to the KVA rating of each generator.
c. Shift load of one generator on another and not down the readings of ammeters and voltmeters.

Guidelines:

The report should be maximum 5 pages long which should include figures, calculations, simulation results, readings, waveforms and pictures of setup. Attach this page on top of the report.

Rubrics:

Standard rubrics are attached with the subject manual.

NED University of Engineering & Technology
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