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

<u>ELECTRICAL MACHINES I</u>
<u>(EE-346) For T.E.(EE)</u>

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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CONTENTS

| Psychomotor / Cognitive Level: CLO/PLO:				
S.No.	**Date**	**Title of Experiment**	**Total Marks**	**Signature**
1		**To draw the magnetization curve of self excited DC shunt generator (Open circuitcharacteristic curve)**		
2		**To draw the load characteristic curve ofself excited DC shunt generator.**		
3		**To draw the external and internal characteristics of separately excited DCgenerator.**		
4		**Speed control of a DC shunt motor by flux control method.**		
5		**Speed control of a DC shunt motor by armature or rheostatic control method.**		
6		**To find the Constant losses of a DC shuntmotor by no load test.**		
7		**To find out the efficiency and voltage regulation of a single phase transformer.**		
8		**To study the effect of field excitation on the generation of voltage of an alternator.**		
9		**To find out the iron losses of a single phase transformer (open circuit test)**		
10		**To study the effect of applied voltage on the power factor of an induction motor at no load.**		
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 exited 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
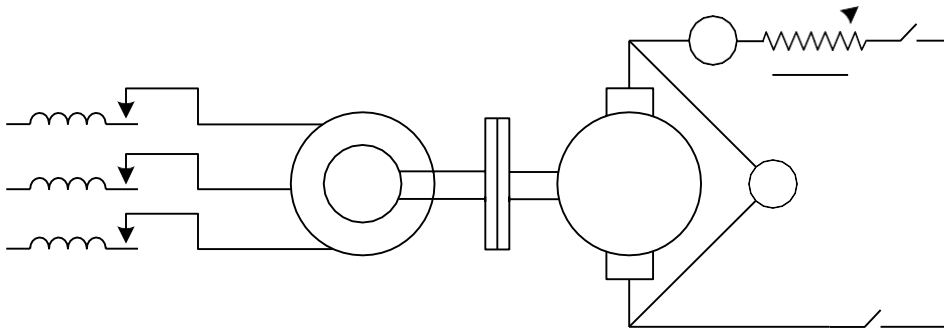
THEORY :-

   The magnetization characteristics also known as "No load" or "Open circuit" characteristics is the realation between emf generated and field current at a given speed.
Due to residual magnetism in the poles, some emf is generated evn when filed 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 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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Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)	(Points /4)				
Remarks					
Instructor's Signature with Date:					

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
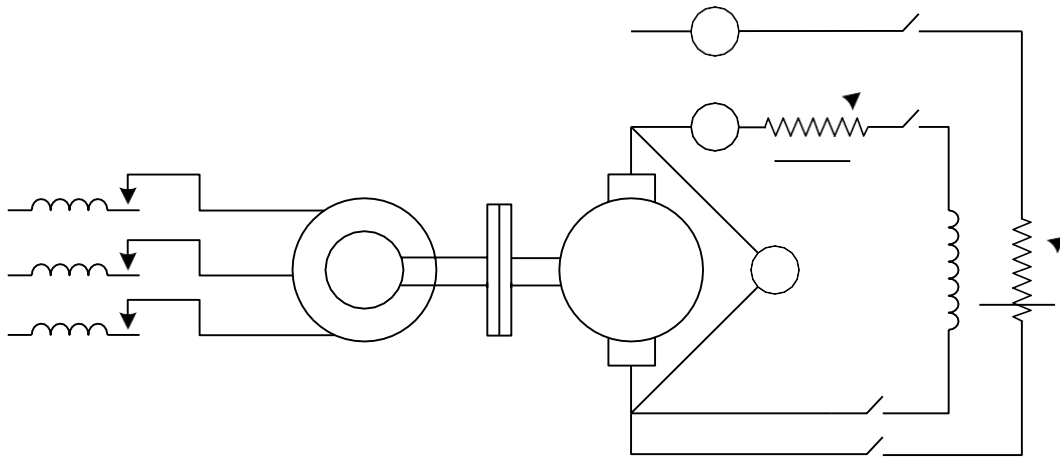
THEORY :-

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 decresed.

II. ARMATURE RESISTANCE :-

As the load current increases, more voltage is consumed in ohmic resistance of armature circuit. Hence the terminal voltage ($V_t=E–I_aR_a$) 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

$$Ia = I_L + I_f$$
$$E = V_t + IaRa$$

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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Weighted CLO (Psychomotor Score)	(Points /4)
Remarks	
Instructor's Signature with Date:	

Psychomotor Domain Assessment Rubric-Level P3
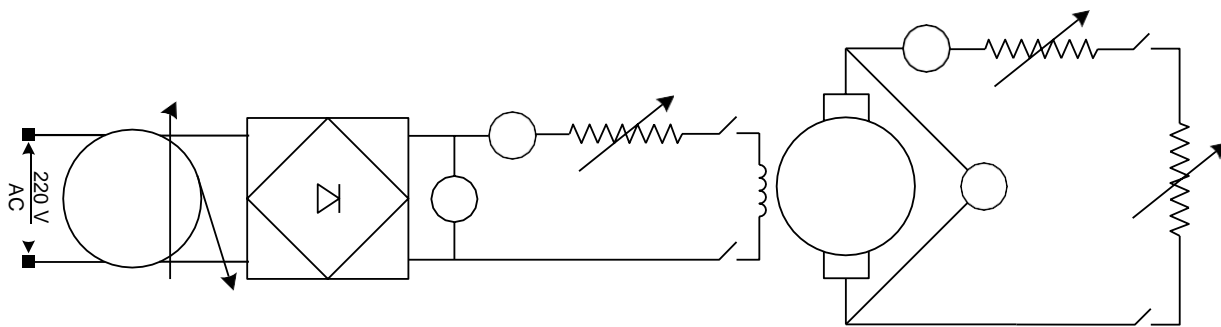
EXPERIMENT # 3

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 therelation 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	$I_L(A)$	$I_f(A)$	$V_T(V)$	$E_a = V_t + I_aR_a$ (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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Remarks					
Instructor's Signature with Date:					

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
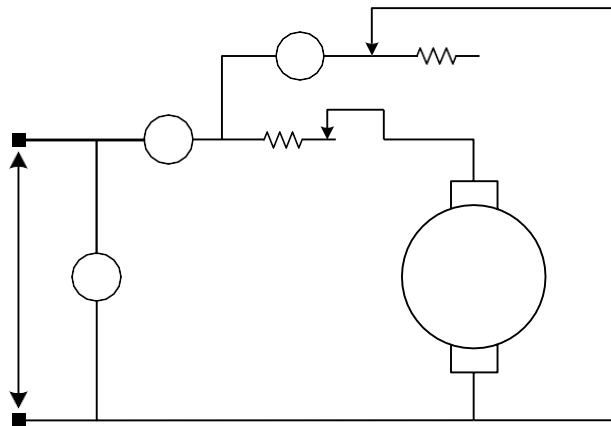
THEORY:

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

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

Putting value of E_b in (1),

$$k \, \varphi \, N = V - I_a \, R_a$$

Therefore,
$$N = (V - I_a R_a) / k \, \varphi$$

It is seen from the above that $N \alpha \, 1/\varphi$. 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
	If(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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Weighted CLO (Psychomotor Score)	(Points /4)				
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
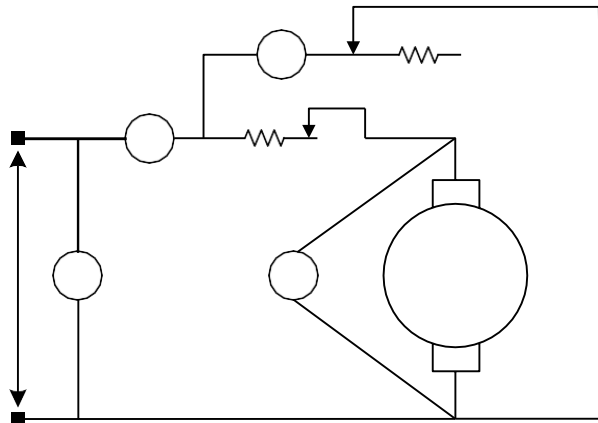
THEORY:

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$$V = E_b + I_a R_a$$
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The equation for back emf is:

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

Or,

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

Putting value of E_b in (1),

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

Therefore,

$$N = (V - I_aR_a) / k\ \varphi$$

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 Va(V)	Speed 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.

Course Code and Title: _____

Laboratory Session: No._____   Date: _____

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Remarks					
Instructor's Signature with Date:					

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
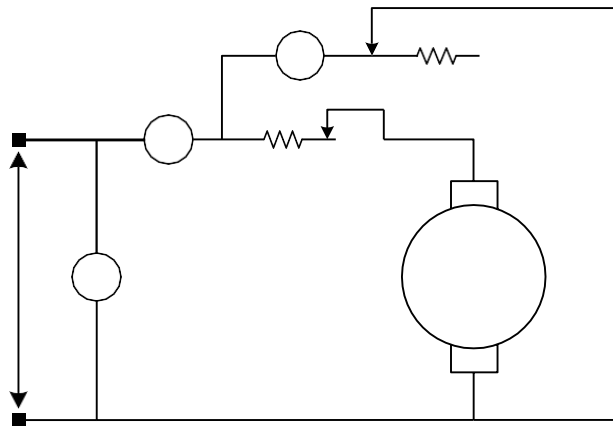
THEORY:

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 whichflux is practically constant i.e shunt and compound wound machines. The motor is run at its ratedvoltage 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.

↳ **Constant losses** $= W_c = V I_o - (I_o - I_{sh})^2 R_a$

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

Input $= V I_o$
Armature copper loss $= I_a^2 R_a$
Total loss $= (I_o - I_{sh})^2 R_a + W_c$
Efficiency $= (Input - Losses) / input$

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:

Power input $= V I_o =$_____

Armature copper loss $= (I_o - I_{sh})^2 R_a=$_____

Constant losses $= W_c = V I_o - I_a^2 R_a=$_____

RESULT:

Constant losses are found to be_____Watts.

NED University of Engineering & Technology
Department of Electrical Engineering

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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
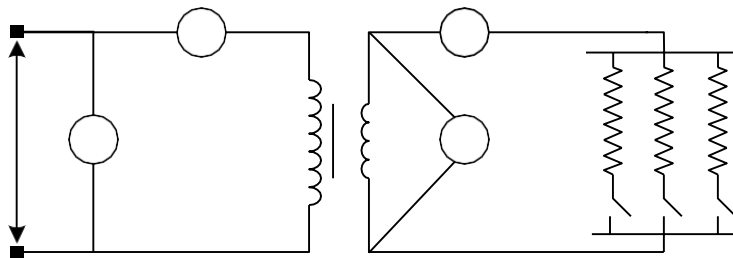
THEORY:

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 VsIs and VpIp gives the efficiency of the transformer and the formula for efficiency and voltage regulation are:

$$\eta = (VsIs / VpIp) \times 100\%$$

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

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	Vp (Volts)	Ip (A)	Vs (Volts)	Is (A)
1				
2				

CALCULATIONS:

1. $\eta\% = (V_sI_s / V_pI_p) \times 100$

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

RESULT:

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

PRECAUTIONS:

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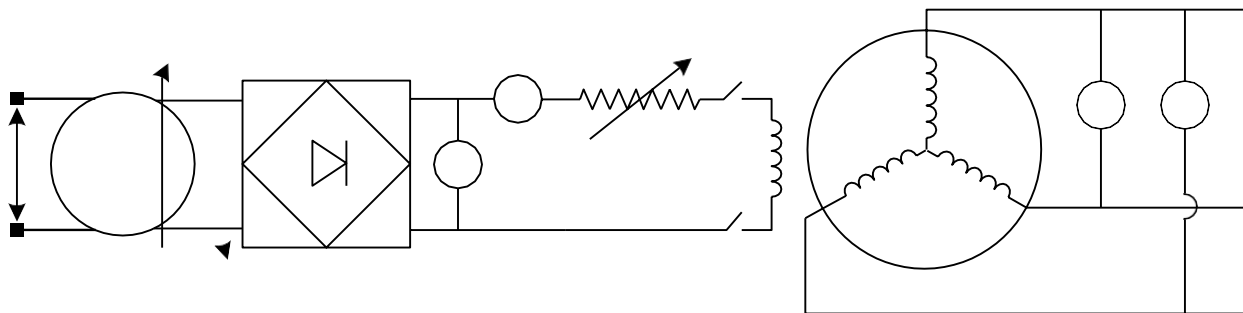3. Voltmeters should always be connected in parallel.

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.
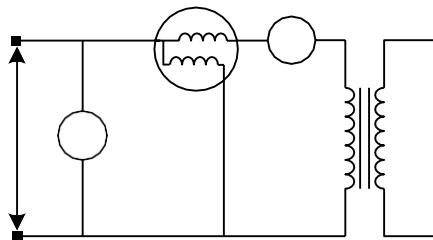
EXPERIMENT # 9

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 Io which is helpful in finding Xo and Ro.

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.
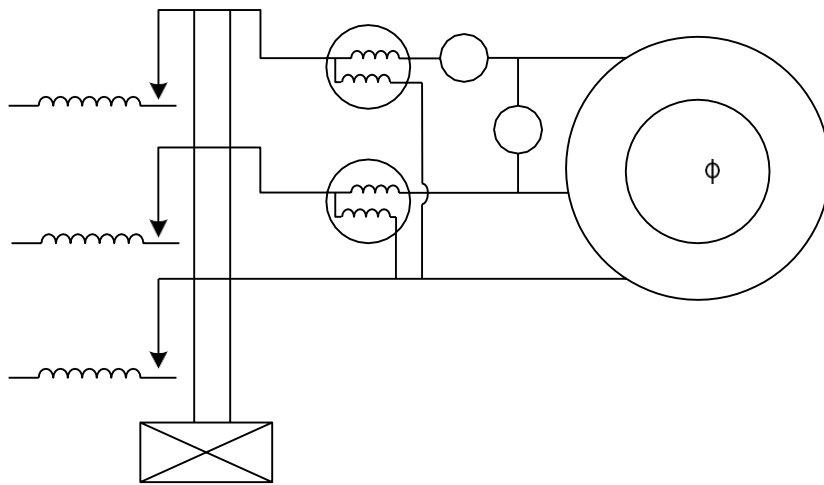
EXPERIMENT # 10

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 consist of a stator and rotor. The stator is connected to the supply & form a rotating field. So an induction motor is like a transformer with stator forming primary and rotor forming the secondary winding with the small air gap in the magnetic circuit. In the test, power is measured by two wattmeter method . One wattmeter measured the negative power because phase angle between current & voltage is more than 90. Due to short circuit rotor at starting time take 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.

$$\text{p.f} = W_1 + W_2 / (3)^{½} \, VI$$

OBSERVATIONS:-

S.No	V(Volts)	I (Amp)	W_1(Watts)	W_2(Watts)	W1+W2	P.F

CALCULATIONS:-

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

PRECAUTIONS:-

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

RESULT:-

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

OPEN ENDED LAB-1

Objective:

To perform the parallel operation of two DC Generator and shift the load of one on another.

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.

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