ME- 471-482

National Institute of Technology, Durgapur
Department of Electrical Engineering
Electrical Machines Laboratory

Title: Voltage regulation of an Alternator.

Object: To perform the Open – Circuit and Short Circuit tests on an alternator and predict its voltage regulation from the test data.

Theory:

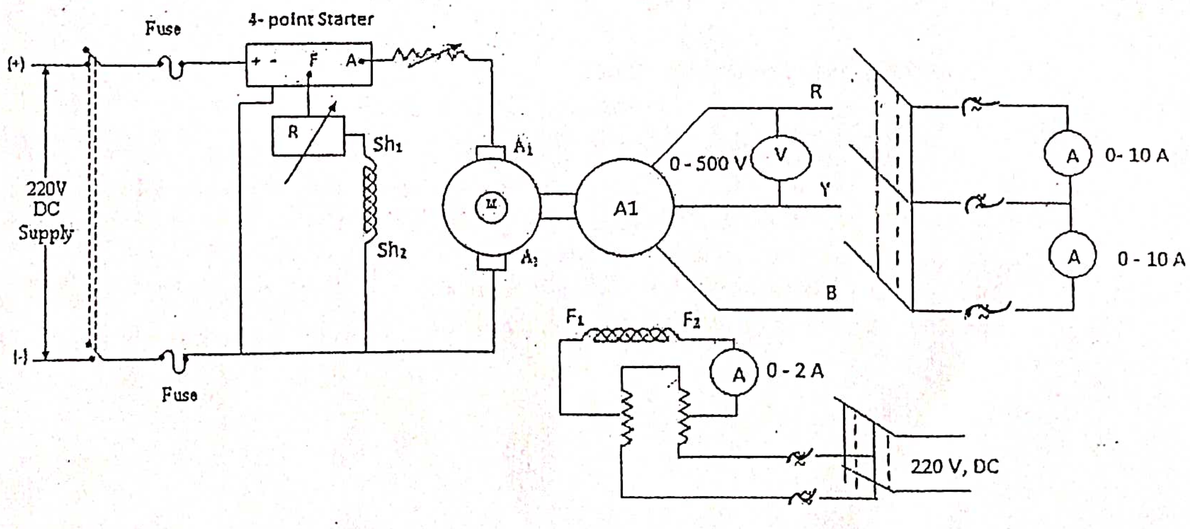
Open Circuit Test: This is an important test since on it depend the characteristics of parameters, regulation, excitation current and core loss of the machine. The machine is to be driven at constant speed with excitation current varied over complete range so as to yield the open circuit characteristics of the machine up to about 125% of the rated voltage.

Short- circuit Test: This is to find the short circuit characteristics. The machine is to be driven at a rated speed with terminals carefully short – circuited through ammeter and the field excitation current is slowly increased such that the armature current varies from zero to about 125% of its rated current.

Apparatus Required:

Name of the Equipments	Specification	Quantity

Circuit Diagram:



Armature Resistance: For a rough approximation the effective resistance of the armature can be taken as 1.5 times the resistance as obtained by DC measurement.

Voltage Regulation: the voltage regulation of an alternator is the voltage rise at the terminal when the load is removed, the speed and excitation remaining constant. The voltage rise is the numerical difference between E_t, the open circuit voltage and V, the terminal voltage for the same excitation, expressed as a fraction.

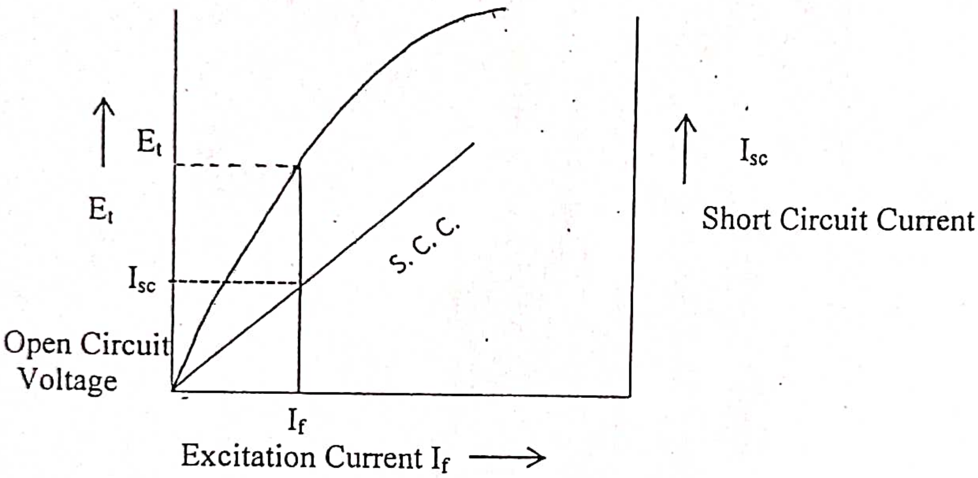
$$= (E_t - V) / V \text{ per unit}$$

Methods of predicting Regulation from no – load tests:

1. Synchronous – impedance method
2. Magneto motive force (MMF) method
3. ASA method, making use of Potiey reactance which will be taken up with a separate experiment.

Synchronous impedance method:

Open – circuit and short- circuit characteristics are plotted on the same graph paper with suitable voltage and current scales.



Open Circuit and Short Circuit Characteristics

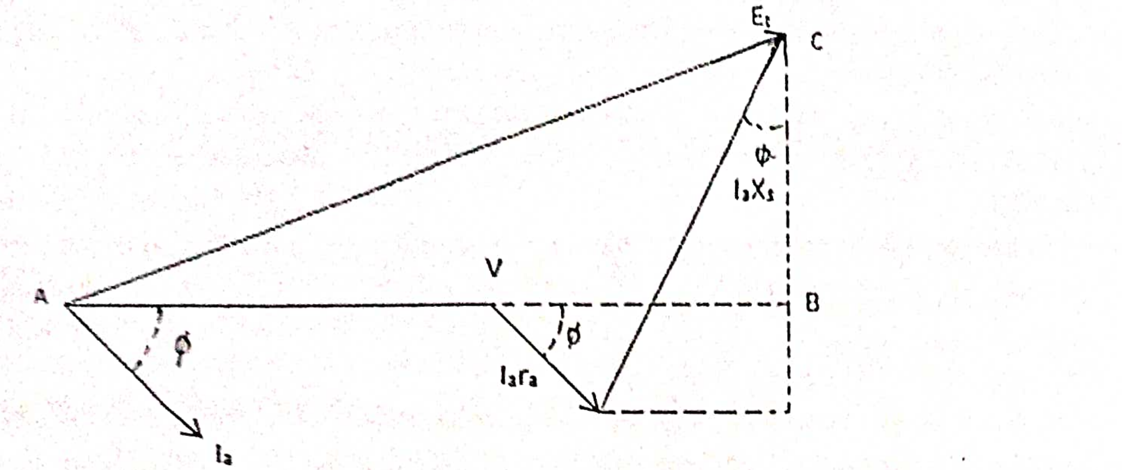
From the S. C. C, the excitation current I_f is read corresponding to a short circuit current I_{sc}. This excitation current gives the corresponding excitation voltage E_t which is read from open-circuit characteristic.

Therefore, the synchronous impedance

$$Z_s = \frac{Et}{Isc} = \frac{\text{Opep-circuit voltage for a certain field current}}{\text{Short-circuit current for the same field current}}$$

Since, the resistance r is known from D.C measurement, the synchronous reactance is known.

After knowing synchronous impedance, a vector diagram of voltages in the machine is drawn. For example, a vector diagram is drawn below for a current I_a.

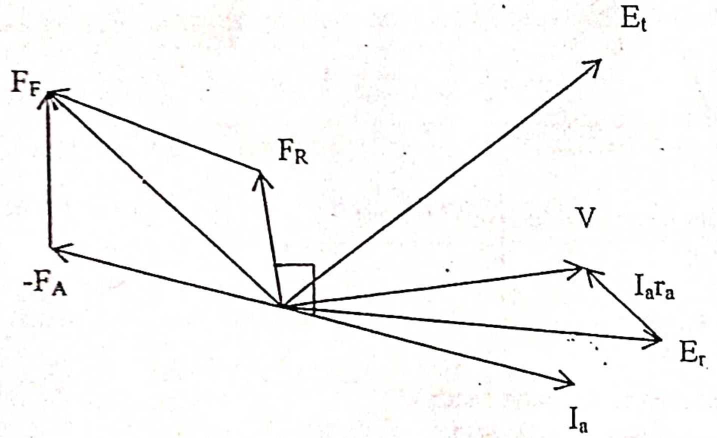


$$E_t = \sqrt{AB^2 + BC^2} = \sqrt{(V + I_a r_a \cos\emptyset + I_a X_s \sin\emptyset)^2 + (I_a X_s \cos\emptyset - I_a r_a \sin\emptyset)^2}$$

Hence Regulation is calculated.

Magneto motive force Method:

In the synchronous-impedance method of determining regulation, a vector diagram of voltages is employed. In MMF method the vector diagram of magneto motive forces is used. To obtain regulation by this method, the open-circuit and short-circuit characteristic curves are to be referred. Procedure is given below. Leakage reactance is neglected.



Terminal voltage per phase is used as reference vector Armature resistance drop $I_a r_a$ is added to the terminal voltage to get the Air gap voltage Er, neglecting leakage reactance. From O. C. C. resultant MMF (F_R) in the air gap is obtained in terms of excitation current. F_R is drawn 90^0 ahead of E_R.

Armature reaction MMF (F_A) in terms of excitation current for the armature current considered is obtained from short – circuit characteristic. This MMF will be in the same phase as the armature current.

Now

$\overline{F_R} = \overline{F_F} + \overline{F_A}$

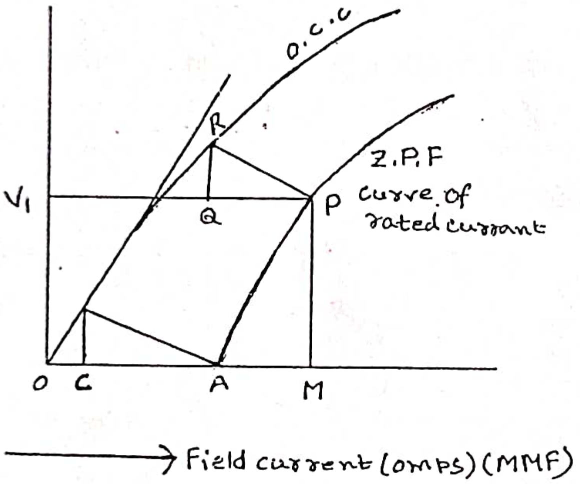
So excitation MMF $\overline{F_F} = \overline{F_F} - \overline{F_A}$

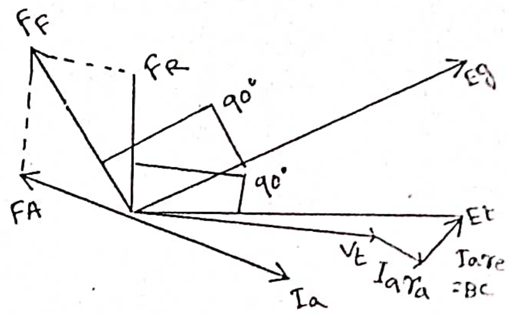
So, vectorically the excitation MMF F_F is obtained. Corresponding excitation voltage E_t is read from the O. C. C.

Hence regulation is calculated.

Zero power – factor method:

1. Connect three reactor – coils in delta across the terminals of the alternator, running at synchronous speed.
2. Adjust the alternator excitation to obtain rated armature current (neglect resistances of reactors) and read the corresponding terminal voltage OV_1 at excitation OM, represented by point P.
3. OA is the excitation required to circulate rated current in the armature, when the armature terminals are short circuited. Draw PQ equal and parallel to AO. Draw QR parallel to the slope of the O. C. C. at O. Join RP. Draw BA parallel to RP. The triangles RQP and BOA are equal. Draw BC perpendicular to OA.
4. BC is the leakage –reactance drop, and CA is the armature –reaction M. M. F. at rated current of the alternator. Use these valves in computing generated voltage (Eq).





Reports:

1. Give sample calculations for each method.
2. What are the errors in these methods?
3. Write a note on the concept of synchronous reactance.
4. Develop the space and time phase diagrams for cylindrical rotor synchronous machines.
5. In an alternator explain why short-circuit characteristic is a straight line while open- circuit characteristic is a curve.
6. What is the importance of computing voltage – regulation?
7. How does synchronous reactance depend on air gap of an alternator?
8. What is short –circuit ratio? Explain its importance.
9. Develop an equivalent circuit of an alternator.
10. What should be the normal excitation of an alternator?

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Title: Study of Characteristics of DC Shunt Generator.

Objectives: To observe the effect of the field current speed on the induced e. m. f. and also the effect of speed at constant field current on the include e. m. f. as the shunt generator at no – load & external load characteristics of a Shunt Generator by actually loading the machine.

Theory: Under no – load operation, the induced e.m.f. is directly proportional to the field current with a constant speed. It is also known as open circuit characteristics (O.C.C). The graph is plotted between no – load induced e.m.f. (E_0) and the field current (I_f). For a generator at no load the induce e.m.f. is equal to the terminal voltage. When the generator is loaded, there is fall in the terminal voltage of the Shunt generator due to:

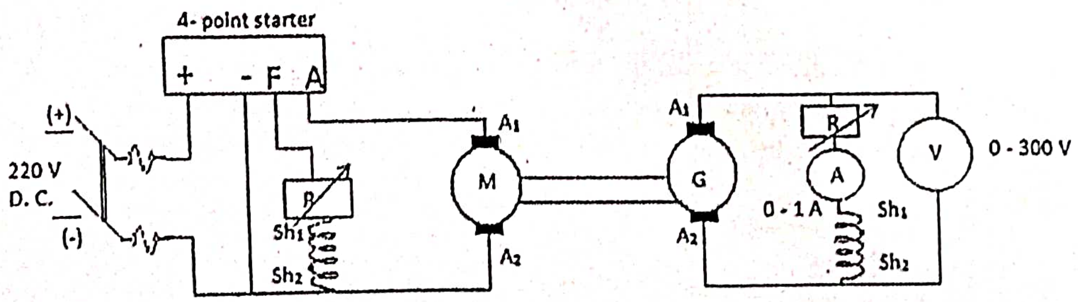
1. I_aR_a drop in armature winding.
2. The effect of armature reaction
3. Brush contact resistance

When the current flows through the armature winding, it sets up armature flux which opposes the main – field flux. Thus available include e.m.f in the armature winding is reduced. Hence the induced e.m.f is decreased thereby causing a reduction in terminal voltage. As the load on the generator is increased, these drops also increase as they are proportional to the load current.

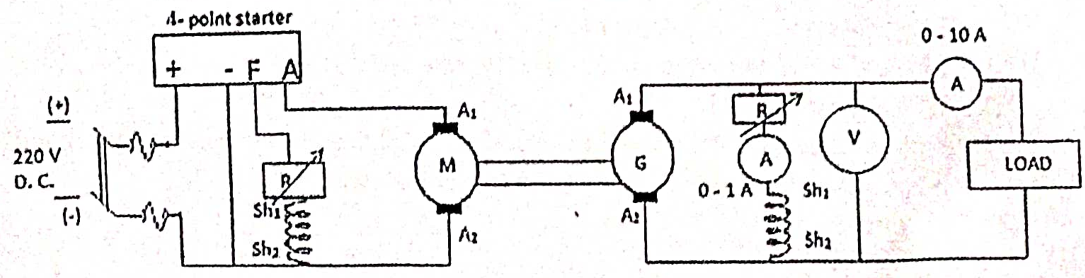
Apparatus Required:

SL. No.	Name of the Equipment's	Specification	Quantity

Circuit Diagram:



Circuit Diagram to determine no – load characteristic of DC Generator



Circuit Diagram to determine load Characteristic of DC generator

Observations:

1. **No – load test**

(A)

No – load test (at constant speed)

SL. No.	Speed in r.p.m.	Generator Field current (A)	Generator no load induce e.m.f (volt)

(B)

No –load test (at constant field current)

SL. No.	Speed in r.p.m.	Generator Field current (A)	Generator no load induce e.m.f (volt)

Load test:

SL. No.	Speed in r.p.m.	Generator Field current (A)	Load current (A)	Generator Terminal Voltage (V)

Procedure:

1. Connect the machine under test as shown in the circuit diagram in fig (a). Start the machine with help of starter. Run it at rated speed. Record the generator armature voltage. Now excite the generator. Increase the field current and record the armature voltage till it 25 % of rated value and then decrease the field current and record the armature voltage. Keep the speed constant during this part of the experiment with the help of the field regulator of the motor.
2. Keep the field current of the generator constant. Increase the speed of the motor with the help of the motor regulator till the speed 125% of the rated speed and record the armature voltage.
3. Connect the machine under the test as shown in the circuit diagram. Adjust the speed of the motor at rated value and terminal voltage at no–load rated value with the help of field regulator. Load the generator 1 – 8 A and record the corresponding terminal voltage.

Report:

1. Name of the experiment.
2. Objective.
3. Circuit diagram.
4. Apparatus used.
5. Draw the curves: Field current vs e. m. f. and load current vs terminal voltage.
6. Define the critical resistance and find its value from graph.
7. Why a starter is used?
8. What with happen if the speed & excitation are changed when you perform experiment?
9. What conclusion you can draw from the graph plotted by you?

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Title: No- load and Blocked –Rotor tests of an Induction Motor.

Object: To predetermine the performance characteristics of an induction motor from (i) equivalent circuit (ii) circle diagram.

No - load Test: This test gives the core loss, windage and friction loss, magnetising current and no load power factor. Faculty operations of the machine are also revealed.

Normal frequency supply is made to the motor through an auto – transformer. Instruments are included to measure voltage, current and power by two – wattmeter method. Input voltage is gradually increased from zero up to rated value taking at least 5 sets of reading which are recorded in tabular form.

Blocked – Rotor Test: This is similar to short-circuit test of a transformer. The stator is supplied with a low voltage of normal frequency through an auto-transformer. The voltage is raised gradually from zero taking at least 5 readings for current and power until the current reaches 150% of the rated current. The readings are recorded in tabular form.

Wattmeter connections, wattmeter multiplication factor and stator connection connections are to be noted.

Starter resistance is measured by DC volt ampere method.

Apparatus Required:

Name of the Equipments	Specification	Quantity

Observations:

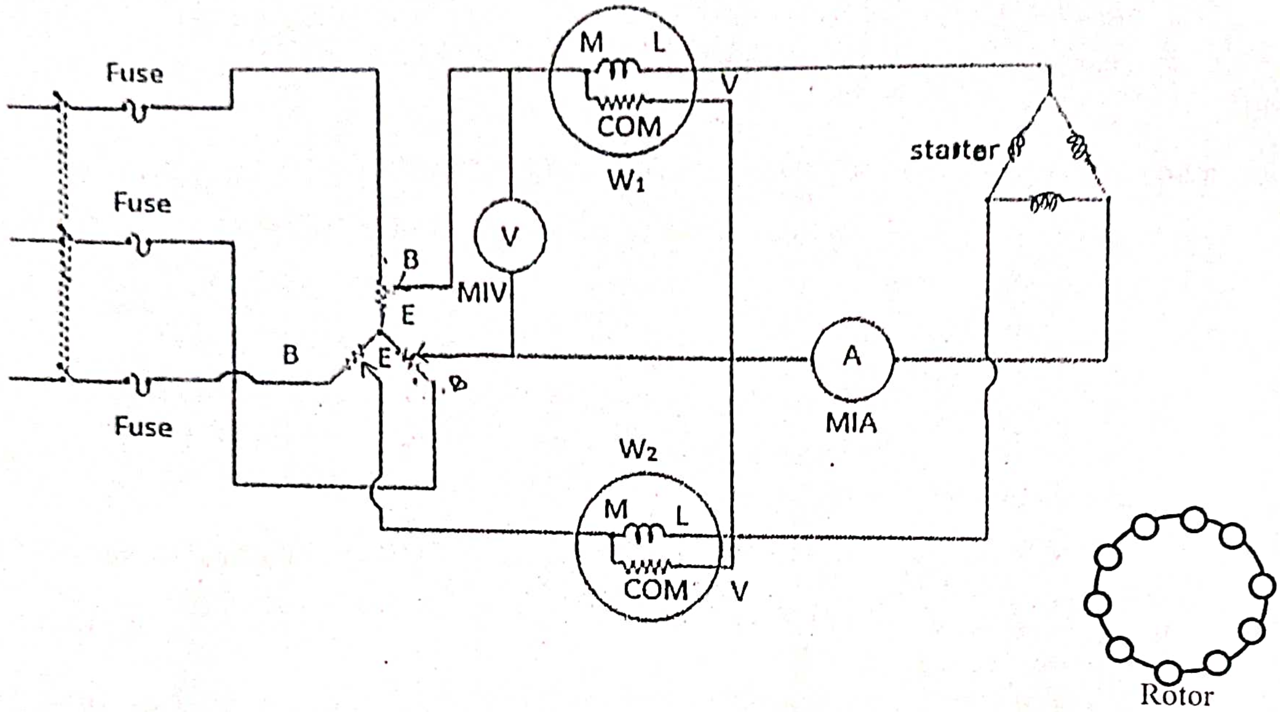
No- Load Test:

SL. No	Voltage (volts)	Current (Amps.)	Wattmeter Reading			Speed	Remarks
			W_1	W_2	$W_1 \pm W_2$		

Blocked Rotor Test:

SL. No	Voltage (volts)	Current (Amps.)	Wattmeter Reading			Remarks
			W_1	W_2	$W_1 \pm W_2$	

Circuit Diagram:



Report:

1. Derive the equivalent circuit of the induction motor under test from no – load and blocked – rotor test data. Determine the full performance characteristics of the motor under full & load condition.
2. Draw the circle diagram and compile a chart giving a full performance of the motor. Plot the following curves:
   Torque in Newton metre, Line current and slip vs output in KW.
3. Draw the torque-slip characteristic of the motor.
4. What is the difference between approximate equivalent circuit and exact equivalent circuit?
5. 'An induction motor at no-load operates at a very low power factor' – explain.
6. 'Circle diagram of an induction motor is nothing but a current locus diagram' – explain.
7. Explain how power scale is obtained from current scale.
8. Why is an autotransformer essential in both the tests?
9. How can you separate the mechanical losses and coreloss from the no–load loss?
10. Why is it necessary to employ a starter to start an induction motor?
11. Draw the equivalent circuits and corresponding vector diagrams for no-load and blocked-rotor conditions of the motor.
12. 'An induction motor refuses to take start' – what may be the possible reasons?
13. Make a comparative study of different methods of starting an induction motor.
14. In what respects an induction motor is similar to a d. c shunt motor?

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Title: Speed control of a DC shunt motor.

OBJECT: To study the speed control of a DC Shunt Motor by two methods:

a. Armature voltage control: Variation of speed with armature voltage at constant field current (below the rated speed).
b. Field current control: Variation of speed with field current at constant armature voltage (above the rated speed).

Theory: Motor is defined as electro-mechanical device, which is used to convert Electrical energy to mechanical energy. In case of shunt motor, the field is connected in parallel to the armature. So, the field current depends on supply voltage and we can control that by connecting a variable resistance with the field.

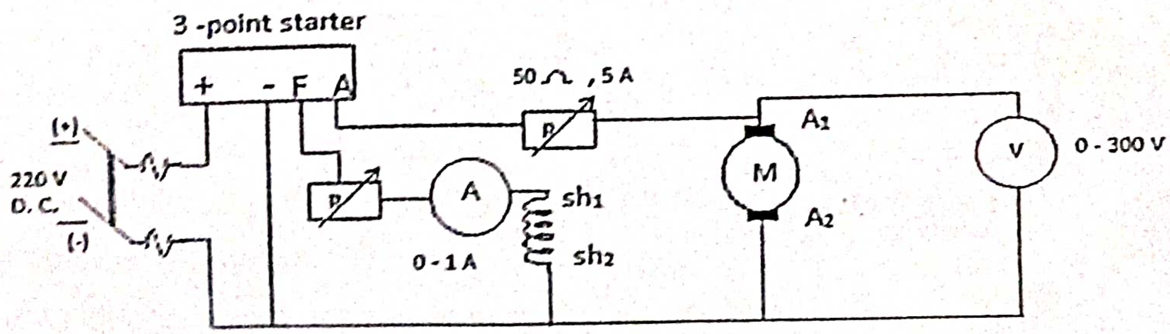
We know that Speed (N) in r. p. m. = $(V - I_aR_a)\ 60\ A/Z\ \phi\ P$

Where, V= Terminal Voltage
Ra=Armature Resistance
I_a= Armature current
Z= No armature conductors
A= No of parallel path
P= No of pole
ϕ= flux/ Pole
In a particular motor, P, Z, A, R_a are constant. So the speed depends on V, i. e., armature terminal voltage, I_a and ϕ.

Apparatus Required:

Name of the Equipments	Specification	Quantity

Circuit Diagram:



Circuit Diagram for speed control of DC shunt motor

Observation:

Armature Voltage Control

SL. NO.	Field Current(A)	Armature Voltage(V)	Speed (r.p.m)

Field Current Control

SL. NO.	Armature Voltage(V)	Field Current(A)	Speed (r.p.m)

Procedure:

1. Connect the machine under the test as shown in the circuit diagram. Start the machine with the help of starter by moving the handle of the starter from OFF to ON position slowly.
2. Armature voltage control: Keep the field current constant at normal value corresponding to normal speed. Vary the voltage across the armature by the rheostat and record the speed corresponding to the armature voltage at no –load.
3. Field Control: Keep the voltage across the armature at rated value. Decreases the field current of the motor in step with the help of field regulator and record the corresponding speed for decreasing and increasing field current at no –load.

NOTE:

1. The speed of the machine should not exceed about 125% of the rated speed.

Report:

1. Name of the experiment
2. Objective
3. Circuit Diagram
4. Apparatus used.
5. Neat tabulation of observation sheet.
6. Draw curves: (a) Speed vs. Field current at constant armature voltage (b) speed vs Armature voltage at constant field current.
7. Why should the field regulator resistance be not at its maximum value at the time of starting?

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Title: Open Circuit and load Characteristics of a DC series Generator.

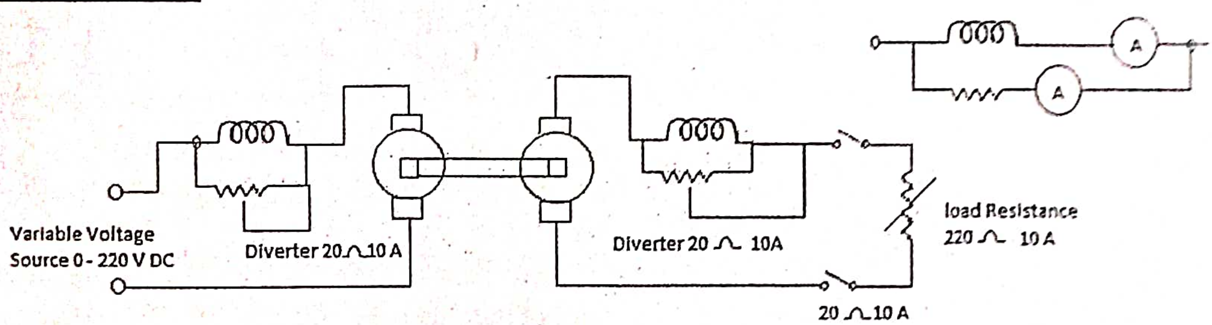
Object: Object of the experiment is to determine and draw from test data O. C. C. and load characteristic curves for such generator. Study of various aspects of limitations and usefulness of such generators in Industry, Utility, Concerns and domestic use.

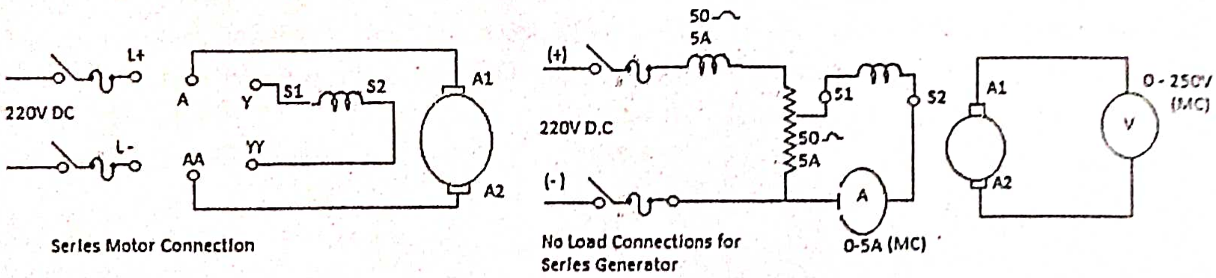
Theory: Refer A. E. Clayton, C. L. Dawes Vol, L & G. PP 174 – 175 3rd Edition

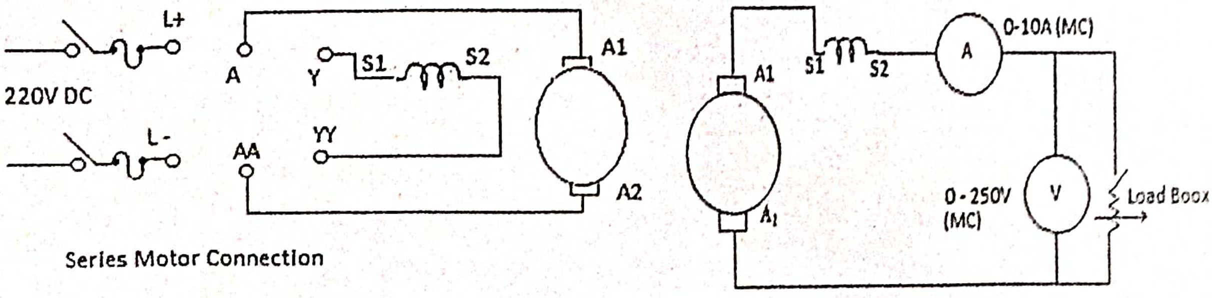
Apparatus Required:

Name of the Equipments	Specification	Quantity

Circuit Diagram:







Connection for Load Characteristics for Series generator

Performance: Before starting the experiment, measure resistances of armature, series field of both motor and generator. Chose diverters of suitable rating. Start the motor from very low voltage to avoid racing. With increase in speed current the load resistance through a switch across the output voltage of the generator.

For O. C. C. test the field of the generator may also be excited from a separate source for obtaining data. Otherwise varying the load resistance the field current may be varied. Also varying both diverter and the load resistance the required data for E vs. I_f can be recorded.

Observations:

Open circuit Test:

No of Observation	Field Current (Amps)	Induced e. m. f (Volts)	Speed (rpm)

Load Test:

No of Observation	Load Current (Amps)	Terminal Voltage (Volts)

Report: Draw E vs. I_f Curves

E vs. I_L Curves

Question:

1. How data for internal characteristics could be obtained?
2. Why this generator is used as constant current generator?
3. State some of its uses.
4. Draw speed torque characteristic of series motor and hence try co-relating with the load characteristics of the generator.

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Title: Study of the equivalent circuit of a single – phase transformer

Object: To perform open circuit test and short circuit test on a single – phase transformer and find the parameter from the tests and draw the equivalent circuit diagram and also calculate the efficiency of the transformer.

Theory: The various elements of the equivalent circuit can be determined from the reading of the two tests conducted on a single phase transformer namely, Open circuit test and Short circuit test.

Open circuit test: In this test, the rated voltage is applied to the primary, and the secondary is left open circuit. The applied primary voltage (V_1) is measured by voltmeter, no load current (I_0) by ammeter and no-load input power by wattmeter. As the rated normal voltage is applied to the primary, therefore, normal iron losses will occur in the transformer core. Hence wattmeter will record the iron loss and small copper loss in primary. Since no load current (I_0) is small (2 – 10 % of the rated current), Cu losses in primary under no load condition are negligible as compared with iron loss. Hence the wattmeter reading practically gives iron losses in the transformer. It is reminded that iron losses are same at all load. This gives I_0, Cos ϕ_0, I_w, I_μ.

Short circuit test: In this test, the secondary (low voltage winding) is short circuited by thick conductor and variable low voltage is applied to primary. While performing short circuit test, low voltage winding is always short- circuited and measurements are made on the high voltage side. The low input voltage is gradually raised till at voltage V_{sc}, full load current I_{sc} flows in the primary, then I_2 in the secondary also. There is no o/p from the transformer under short circuit conditions. Therefore, i/p power is total loss and this loss is entirely copper loss. It is because iron loss in the core is negligible since the voltage V_{sc} is very small. Iron loss is proportional to the square of flux and hence to the square of applied voltage. Since applied voltage V_{sc} under S. C. condition is about $1/10^{th}$ of the normal voltage, the iron loss will be $1/100^{th}$ of normal value. Consequently Iron loss negligible under S. C. condition.

Apparatus required:

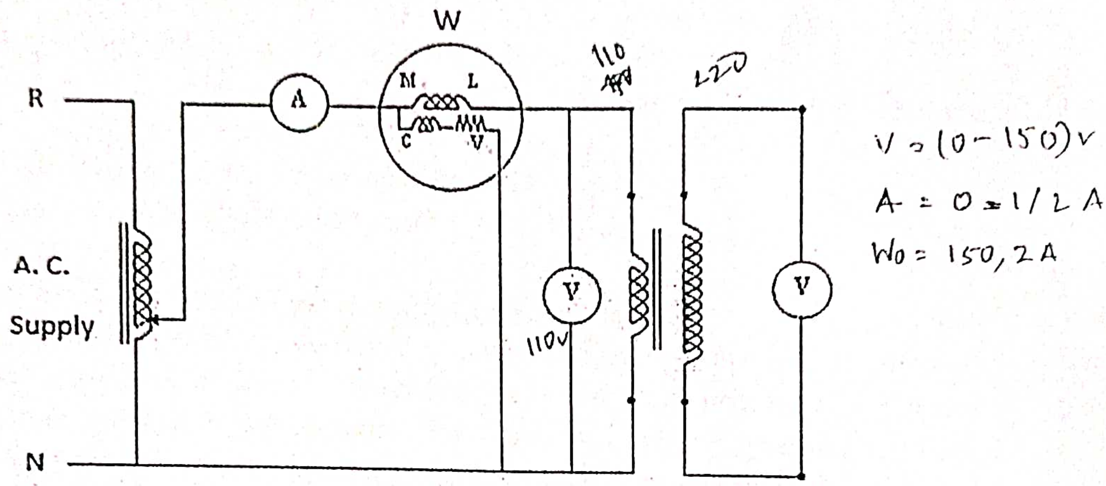
For O. C. test:

Name	Specification	Quantity

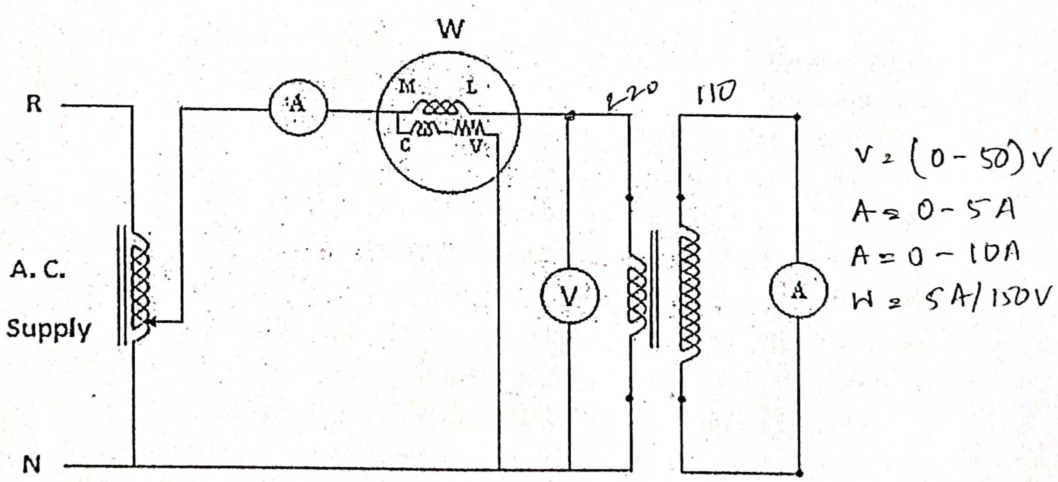
For S. C. test:

Name	Specification	Quantity

Circuit Diagram:



[Open Circuit Test]



[Short Circuit Test]

Observations:

Open circuit test:

Observation	Primary voltage V_1 (Volt)	Primary current I_0 (Amp)	Power input W_0 (watt)	Secondary Voltage (V_2) (volt)	Voltage Ratio(V_1/ V_2)

Short circuit test:

No of Observation	Primary voltage (V_{sc}) (Volt)	Primary current I_{sc} (Amp)	Power input W_{sc} (watt)	Secondary Current (I_2) (Amp)

Calculation:

For open circuit test

Iron, P (i) = wattmeter reading = W_0

No load current = Ammeter reading = I_0

Applied voltage = voltmeter reading = V_1

Input power, $W_0 = V_1.I_0 Cos\phi_0$

No load pf $cos\phi_0 = W_0/V_1.I_0$

$I_w = I_0. Cos\ \phi_0$ = iron loss component

$I\mu = I_0.Sin\ \phi$ = magnetizing component

$X_0 = V_1/ I\mu$ =no load reactance

$R_o = V_1/ I_w$= no load resistance

For short circuit test

Full load Cu- loss, P_c = wattmeter reading = W_{sc}

Applied voltage, V_{sc}= voltmeter reading

Full load primary current = Ammeter reading I_{sc}

$P_c = I_{sc}^2 R_{01}, R_{01}=P_c/ I_{sc}^2$= Total resistance of the transformer referred to primary

Total impedance referred to primary, $Z_{01}= V_{sc}/ I_{sc}$

Total leakage reactance referred to primary, $X_{01}=\sqrt{\{Z_{01}^2-R^2_{01}\}}$

Short circuit pf, $\cos\phi_{sc}=P_c/ Vsc.Isc$

Efficiency η = o/p / i/p

Full load o/p = 1 KVA =1000 x pf Watt. = 1000.1 Watt (for unity pf).

I/p= o/p + W_o + W_{sc}=1000+W_o+W_{sc}

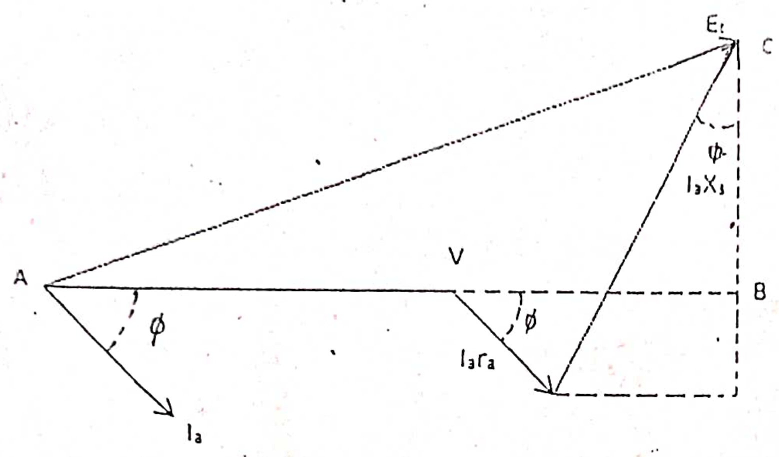
η =1000*100/ (1000+ W_o+ Wsc) %

Report:

1. Name of the Experiment
2. Objective.
3. Circuit Diagram.
4. Apparatus used.
5. Calculate the equivalent circuit parameters and efficiency.

Answer the following questions in your report

1. Why is it advisable to use a low power factor (LPF) wattmeter under No- load test?
2. Why is iron - loss under the short – circuit test considered as negligible?
3. What are precautions you have to maintain to perform the short – circuit test?



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