LABORATORY SESSION 5
MAGNETIZATION CURVE OF A DC GENERATOR

CAUTION: High voltages are present in this Laboratory Experiment! Do not make any connections with the power on! The power must be turned off before the circuit is modified.

PURPOSE

The objectives of this experiment are to measure the parameters of the machine model and to obtain the dc machine magnetization curve.

DISCUSSION

The dc machine, as a generator was the first device used to provide a significant amount of electrical energy. They are widely used in vehicles that have electric storage batteries. However, most direct current generators are being increasingly replaced by solid-state devices, which convert available ac to direct current for dc drive systems and other dc applications. The dc motor was also the first electrical device to provide rotating mechanical energy. Because of the ease with which their speed can be controlled, dc motors are often used in applications requiring a wide range of motor speeds such as paper and steel industries.

There is no real difference between a generator and a motor except for the direction of the power flow. In the dc machine, the field winding is placed on the stator and the armature on the rotor. The field windings are wound around the poles of the stator and are supplied with dc current, which produces the main magnetic field of the machine. The armature windings are placed in the rotor slots, which are uniformly distributed around the rotor's periphery. Voltage induced in the armature winding is alternating. A mechanical commutator and a brush assembly function as a rectifier or inverter, making the armature terminal voltage unidirectional. The commutator is essentially a mechanical switch that is arranged to short out and then reverse the current direction in each coil of the armature winding consecutively.

The field current in a generator produces an mmf, which results in the field flux in accordance with the magnetization curve. When the machine is driven by a prime mover an emf is induced in the armature. The generated emf in the armature winding is proportional to the field flux times the speed ($E_a \propto \phi n$). The magnetization curve of a generator shows the relation between the field current and the armature terminal voltage on open circuit. The curve is drawn with induced armature voltage on the y-axis and field current on the x-axis. The magnetization curve is of great importance because it represents the saturation of the magnetic circuit of the dc machine.

DC generators are classified according to the manner in which their field flux is produced. These include separately excited generator, where the flux is derived from a separate dc source. When certain conditions are fulfilled, the generator own armature circuit may be employed as a source of field excitation. These machines are referred to as self-excited shunt generator, series generator and compounded generator. The first condition for self-excitation is that there must be some residual magnetism in the poles of the generators. In a shunt generator, the voltage generated by this residual flux produces a field current given by $I_f = \frac{V}{R_f}$. If the flux produced by this current is aiding the residual flux, it will result in the voltage buildup. The voltage will build up to a value given by the intersection of the field resistance line and the magnetization curve. At some resistance value $R_{f_{crit}}$, the resistance line is almost coincident with the linear portion of the magnetization curve. This coincidence condition results in an unstable voltage situation. This resistance is known as the critical field resistance. Thus, for voltage buildup the other requirements are: the field winding must be connected in such a way that its mmf would be aiding the residual magnetism; also, for a given speed the field circuit resistance must be less than the critical field circuit resistance.

PROCEDURE

1. Measurement of Machine Constants

Using the DMM as an ohmmeter, measure the resistance of the armature, the series field and the shunt field of the dc generator (dynamometer).

Armature resistance, $R_a =$_______________

Series field resistance, $R_s =$_______________

Shunt field resistance, $R_f =$_______________

The resistance as measured between the armature terminals is composed of two distinct components. One component is the resistance of the copper winding, and the other is the combined resistance of the carbon brushes and the brush contact. The latter component is not constant and varies approximately inversely as the armature current.

2. Motor and Generator Connection and Operation

A 3-phase ac motor is used to drive the dc generator (dynamometer) at constant speed. Connect the ac motor to the 3-phase 208 V supply through a manual ac starter as shown. Separately excite the dc generator by connecting the dc shunt field through a dc ammeter and two rheostats (use two field rheostat in series) and a pushbutton switch to the 120 V dc source.

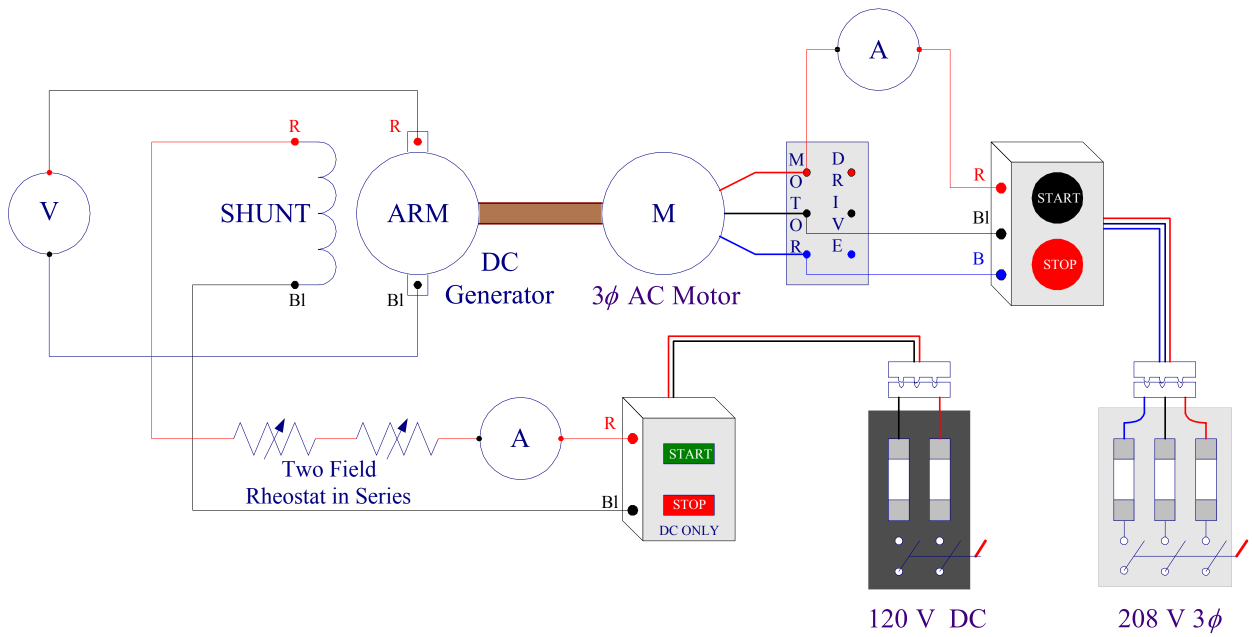

Figure 5.1 Ac motor and dc generator connections

Turn on the ac power and start the ac motor (do not turn on the dc power). The dc generator is now running with shunt field unexcited. Observe and record the following:

Table I (a)

Direction of Rotation (Looking towards the dynamometer from the motor end of the bench)	Speed RPM	Polarity of Voltage	Voltage, Volt

Stop the motor and interchange any two phases connected to the ac motor. Start the ac motor and with the dc power off observe and record the following:

Table I(b)

Direction of Rotation (Looking towards the dynamometer from the motor end of the bench)	Speed RPM	Polarity of Voltage	Voltage, Volt

Stop the motor.

3. Magnetization Curve and Hysteresis Effect

Reconnect the ac motor as per original diagram. Start the ac motor. Turn dc power on and check that the direction of rotation is correct and all meters read upscale. If necessary to minimize, eliminate or reverse the effect of residual magnetism, with the dc power off, reverse the shunt field terminal connections and turn the 120 V DC power supply on and off once quickly. With the shunt field terminal connection back to its proper color-coded connections and with the dc power off ($I_f = 0$) measure and record the generated voltage. With both rheostats set at maximum resistance turn the dc power on. Record the generated voltage and the field current as the field current is increased monotonically from minimum to maximum. Then take data, as field current is monotonically decreased.

Table 2. Data for dc generator magnetization curve

Increasing field current		**Decreasing field current**	
Field current I_f , A	Generated voltage E, Volts	Field current I_f , A	Generated voltage E, Volts
0			
		0	

Turn all power off.
Use the PC or your Laptop to plot the magnetization curve. See the instruction in Appendix.

4. Properties of Self -Excited Shunt Generator

Disconnect the dc motor shunt field from the power supply and connect it to the armature terminals as shown in Figure 5.2.

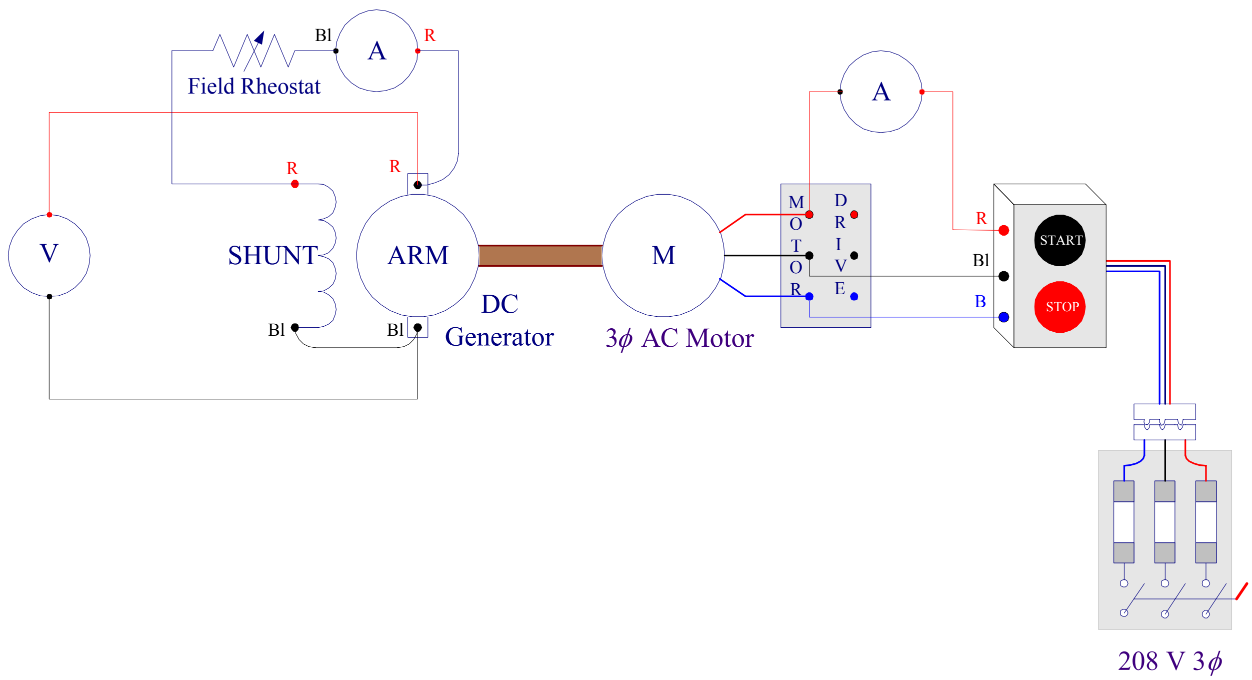

Figure 5.2 Circuit for studying the building up of the voltage of a shunt generator.

Start the motor. Check that the dc voltmeter is reading upscale and can be adjusted to 100 volts. If not, correct circuit before proceeding.

a. Set the field rheostat for minimum resistance and record the voltage and polarity of the armature voltage in the Table III. Repeat the test for the following changes and observe whether the machine does or does not build up in each case.

CAUTION: TURN OFF POWER BEFORE MAKING ANY CHANGES

b. Reverse the shunt field connections to the armature.

c. Reconnect the shunt field as per original circuit, but reverse the direction of rotation by interchanging the two phases of the ac motor terminals.

d. Reverse both the shunt field and direction of rotation.

Table III

Field connections and direction of rotation	**Direction of rotation**	**Voltage, V**	**Polarity**	**Build-up to rated value Y/N**
a. Circuit with color code				
b. Field connections reversed				
c. Direction of rotation reversed				
d. Both field connections and rotation reversed				

Turn the power off.

5. Critical Field Resistance

Reconnect the dc generator shunt field and the ac motor terminals with their proper color codes as in Figure 5.2. Set the field rheostat at its maximum value and start the motor. Gradually decrease the field rheostat to the point that you can just observe a voltage buildup beyond the residual value. Stop the motor, disconnect the shunt field from the armature and measure the field circuit resistance (including the rheostat).

$R_{f_{crit}} =$ ________________

REPORT REQUIREMENTS

1. Comment on the relative values of the armature, series field and the shunt field resistances.

2. With the dc field excitation off, explain the reason for the small generated-voltage as measured in part 2.

3. Plot the magnetization curves for increasing and decreasing of field current (See the Appendix). Discuss the theoretical basis for the shape of the magnetization curve and explain the difference between the two curves.

4. Draw a straight line through origin approximately tangent to the magnetization curve (increasing curve). Determine its slope. What does this value represent? Compare it to the value measured in part 5.

5. Comment on the results of part 4 and enumerate the necessary conditions for the dc shunt generator to build up.

Appendix

In MATLAB, from **F**ile/**N**ew/**M**-File, open the MATLAB Editor and type the following commands and save with a file name having extension m. This program can be used to plot dc generator magnetization curves for increasing and decreasing field current. The functions **polyfit** and **polyval** are used for curve fitting. Enter the recorded values of I_f and E inside the following brackets, as an array for increasing and decreasing filed current recorded in Table II. Run the program to obtain the plot. If necessary change the polynomial order *n* until you are satisfied with the results.

```
If1=[ ]; % Enter increasing field current data as a row array
E1 =[ ]; % Enter corresponding E data for increasing If1
If2=[ ]; % Enter decreasing field current data as a row array
E2 =[ ]; % Enter corresponding E data for decreasing If
n= 2;    % n is polynomial order, if necessary change n to
         % 3rd or higher to obtain a satisfactory curve
c1=polyfit(If1, E1,n); % Returns poly coeff. for increasing If1
c2=polyfit(If2, E2,n); % Returns poly coeff. for decreasing If2
E1fit=polyval(c1, If1); % Evaluates poly values for array If1
E2fit=polyval(c2, If2); % Evaluates polyn values for array If2
plot(If1,E1,'xr', If2,E2,'ob', If1,E1fit,'r', If2, E2fit,'b' )
title('DC Generator Magnetization curve')
xlabel('I_f, Amps'), ylabel('E, Volts')
legend('Increasing I_f', 'Decreasing I_f', 4)
```