

DC Generators

Separate and Shunt Excitation

Power and Machines Laboratory 2

Session 1, 2004

1 Aim

This laboratory illustrates the first principles of electric machinery and familiarizes students with the fundamentals of DC machines. You will learn about the characteristics of a DC generator. These characteristics are no-load (internal generated voltage) characteristic and the terminal voltage characteristic (load characteristic).

2 Safety

You can work individually or with a partner. Groups of three or more are not allowed.

Please be aware of the following hazards.

- (a) Electric motors and generators include parts rotating at high speed (up to 1500 rpm). Care should be taken when operating such machines.

Note that power will be supplied to a machine only if the variable DC voltage control (a big black knob in the center of the power supply panel) is initially set to zero. This prevents the machine from being accidentally operated at high speed. Every time that you wish to start the machine, first set this control to zero.

- (b) You will be working with voltages up to DC 220 V and currents up to 10 A DC. These levels of voltages/currents are dangerous. To avoid electric shock, connecting circuits is permitted only after power has been disconnected. The circuit should be checked by a demonstrator before it has been powered on.
- (c) Don't connect any equipment on your bench to the power supply from an adjacent bench; this might connect the equipment to a different phase.
- (d) Lateral surfaces of the rheostats may become very hot. You should avoid contacts with metallic parts of the rheostats. Also, wire should be kept away from the rheostats to avoid damaging the insulation caused by rheostat overheating.

3 Report

Each student must submit an individual report. Your report which answers the laboratory questions, is to be handed in at the end of the laboratory class.

4 Introduction

Advantages of DC machines arise from a wide variety of operating characteristics which can be obtained by selection of the *method of excitation* of the field windings, i.e., by selection of the method of supplying current to the field windings. The field windings may be *separately excited* from an external dc source, or they may be *self-excited*, i.e., the machine may supply its own excitation. Various field connection diagrams are shown in Fig. 1.

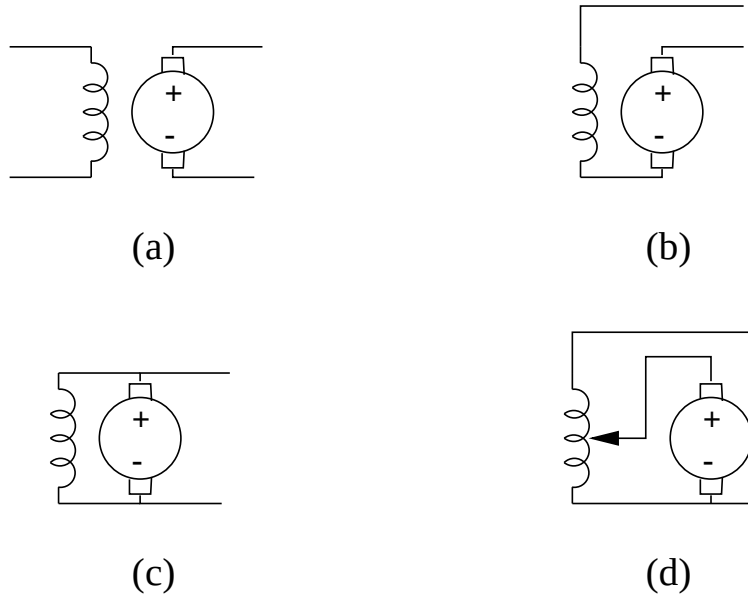


Figure 1: Field circuit connections of dc machines. (a) separate excitation, (b) series, (c) shunt, (d) compound.

The method of excitation profoundly influences both the steady-state characteristics and the dynamic behavior of the machine in control systems.

The connection diagram of a *separately excited generator* is given in Fig. 1a. The required field current is a very small fraction of the rated armature current on the order of 1 to 3 percent in the average generator. Because of this, a small amount of power in the field circuit may control a relatively large amount of power in the armature circuit; i.e., the generator is a power amplifier.

The field windings of self-excited generators may be supplied in three different ways. The field may be connected in series with the armature (Fig. 1b), resulting in a *series* generator. The field may be connected in shunt with the armature (Fig. 1c), resulting in a *shunt* generator, or the field may be in two sections (Fig. 1d), one of which is connected in series and the other in shunt with the armature, resulting in a *compound* generator. With self-excited generators, residual magnetism must be present in the machine iron to get the self-excitation process started.

Typical steady-state volt-ampere characteristics of DC generators are shown in Fig. 2, constant-speed prime movers being assumed. The relation between the steady-state internal generated voltage E_A and the terminal voltage V_T is

$$V_T = E_A - I_A R_A$$

where I_A is the steady-state armature current and R_A is the armature circuit resistance. In a generator, $E_a \geq V_T$; in a motor the opposite holds, i.e., $E_a \leq V_T$.

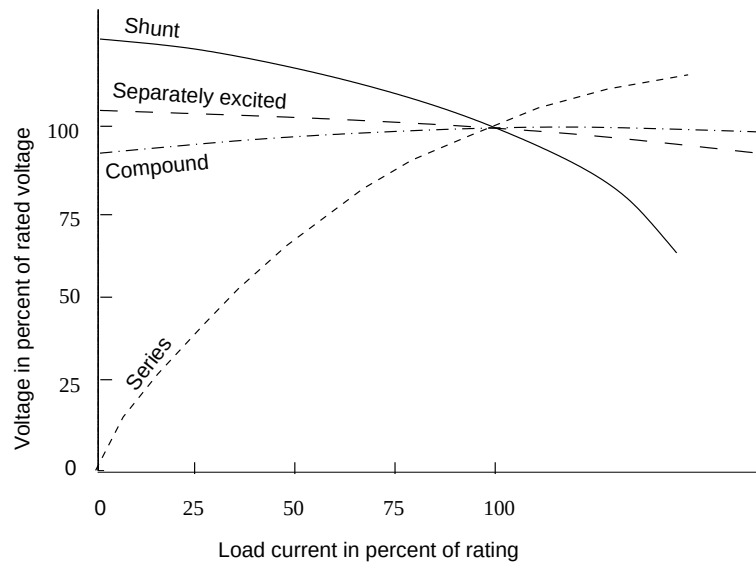


Figure 2: Volt-ampere characteristics of dc generators

The terminal voltage of a separately excited generator decreases slightly with an increase in the load (armature) current, mainly because of the voltage drop in the armature resistance. The field current of a series generator is the same as the load current, so that the air-gap flux and hence the generated voltage vary widely with load. As a consequence, series generators are not often used. The voltage of shunt generators drops off somewhat with load. Compound generators are normally connected so that the mmf of the series winding aids that of the shunt winding (cumulative compound). The advantage is that through the action of the series winding the flux per pole can increase with load, resulting in a voltage output which is nearly constant or which even rises somewhat as load increases. The voltage of both shunt and compound generators can be controlled over reasonable limits by means of rheostats in the shunt field.

5 Equipment

M	= DC machine MV 1036 (electric torque meter), or DC machine MV 1034, or DC machine MV 1028 (2.0 kW, 220 V, 1400 rpm) which will operate as a prime mover
G	= DC machine MV 1006, (1.2 kW, 220 V, 1400 rpm) which will operate as a generator
TG	= Tachometer generator MV 1024, 20.8 V (DVM reading) per 1000 rpm
R_M, R_G	= Shunt rheostats MV 1095 or MV 1905
R_L	= Load resistor MV 1100
I_G, I_M, I_L	= AVOs (ammeters)
V	= AVO (voltmeter)
S	= Switch
F	= Power supply MV 1300.

The two stations with torque meter MV 1036 have the rheostat R_M and two ammeters available on the front panel. For the three other stations with the DC machine MV 1034 / MV 1028, an extra rheostat and two extra AVOs (avometers) are provided. Use them to connect the circuit of Figure 3. All five stations should use a DVM to measure the speed. The rpm meters available on the front panel of torque meters MV 1036 give inaccurate reading, don't use them. **A DVM is used only with the Tachometer generator; for other measurements use AVOs.** AVOs should be switched to the "OFF" position when you finish.

Take extreme care while working with AVOs. Negligent handling of the AVO can damage it; each AVO costs more than \$1000, a repair costs another \$800. When measuring DC voltage, make sure that the AVO is set to measure voltage and not current, and *vice versa*. Before the system is powered, make sure that you have chosen appropriate current/voltage range setting. I.e., if you expect that the current will be of 6 A then the AVO must be set for this current range. **Disconnect power if you need to change any of the settings. Never change AVO's settings while operating the circuit.** Suggested initial settings are shown in circuit diagrams (next to the corresponding circuit element).

6 Ratings

Each electric machine is designed by a manufacturer to operate in a certain range of voltages and currents. The parameters quoted by the manufacturer are known as rating of the machine. Operating the machine at a voltage or current larger than the rated voltage and current for an extended period of time may damage the machine. **Before you start connecting circuits write down the ratings of the machines shown on the rating plates. These ratings must not be exceeded at any time during the laboratory exercises.**

7 Connecting up and starting

This experiment is to check that the machines work as expected.

1. Connect the torque meter MV 1036 or DC machine MV 1034 as motor and the DC machine MV 1006 as generator in accordance with the circuit diagram in Figure 3. The circuit should now be checked by the lab demonstrator.

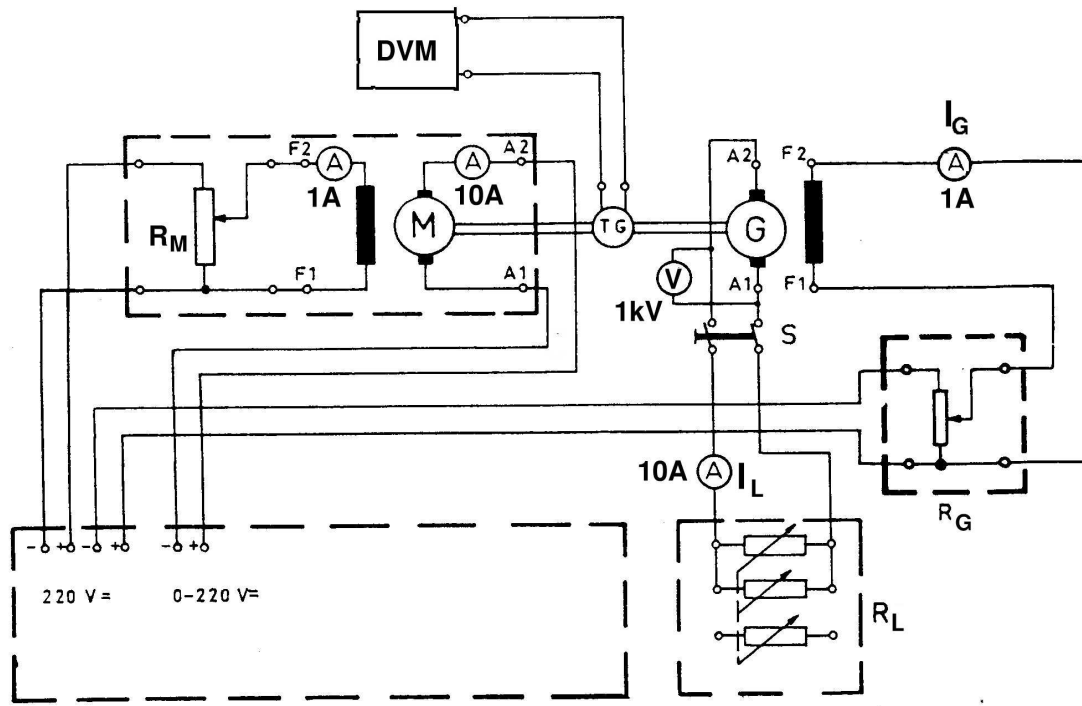


Figure 3: Circuit diagram for the first experiment

2. Turn on the fixed DC voltage switch of the power supply and adjust the shunt rheostat R_M of the motor so as to obtain the maximum excitation current (check the rated excitation current of this machine!)
3. Adjust the shunt rheostat R_G of the DC generator so as to obtain the minimum excitation current.
4. Set the variable DC voltage control of the power supply to zero and turn on the variable DC voltage switch. Then using the variable DC voltage control, gradually increase the rotor voltage to bring the machine to 1500 rpm. Make sure you are not exceeding the current ratings. The machine should rotate in the direction of the arrow. Note the direction of rotation while the machine rotates at a low speed. If necessary, stop the machine and reconnect the field of the motor.

The DVM connected to the Tachometer generator MV 1024 will give the speed of the motor (20.8V for every 1000 rpm).

5. Reduce the variable voltage to zero and stop the machine.

8 Measurement of no-load characteristic $E_A = f(I_G)$, i.e., the internal generated voltage as function of the excitation current

1. Using the procedure described above, adjust the motor to bring the speed to 1400 rpm. This speed must be maintained constant throughout the experiment and must therefore be checked from time to time. The switch S must be off.
2. Vary the excitation current I_G in steps of 0.1 A from zero to maximum and for every step make a note of I_G and the induced voltage read on the voltmeter V . Enter the values in a table.
3. Vary the excitation current in steps of 0.1 A from maximum to zero and for every step make a note of I_G and V .

Observe that, with the increase and decrease of the excitation current, the induced voltage will differ.

4. Stop the machine.

Repeat the above two measurements at a speed of 1200 rpm.

Table 1: No-load characteristic

1400 r.p.m				1200 r.p.m			
Increasing I_G		Decreasing I_G		Increasing I_G		Decreasing I_G	
I_G , A	E_A , V	I_G , A	E_A , V	I_G , A	E_A , V	I_G , A	E_A , V

9 Measurement of the terminal voltage (load) characteristic $V_T = f(I_L)$ of a separately excited generator

The terminal voltage characteristic of a generator describes the voltage across the generator's terminals versus the armature current when the generator is converting power. Normally, this voltage and current are supplied to a load connected to the generator. Hence another name: load characteristic of a generator.

1. Adjust the motor to bring the speed to 1400 rpm. This speed must be maintained constant during the entire experiment and must therefore be checked from time to time.

2. Adjust the shunt rheostat R_G of the DC generator to bring the generator voltage to 200 V. The switch S must be off. Make a note of the setting of the excitation current I_G of the generator. This excitation current must be maintained constant during the entire experiment and must therefore be checked from time to time.
3. Adjust the load resistor R_L to a minimum load. Turn on the switch S and use the load resistor R_L to vary the load current I_L in steps up to the rated current. Steps should not be larger than 1 A; steps of 0.5 A are a good choice. For each step, read the current I_L and the load voltage V.

10 Measurement of the terminal voltage (load) characteristic $V = f(I_L)$ with shunt excitation

In the above experiments the generator was separately excited. Stop the machine and switch it to shunt excitation by disconnecting the excitation circuit from the fixed 220 V DC source and connecting it to generator's armature.

You need to modify the generator connection as follows: (The remainder of the circuit is unchanged):

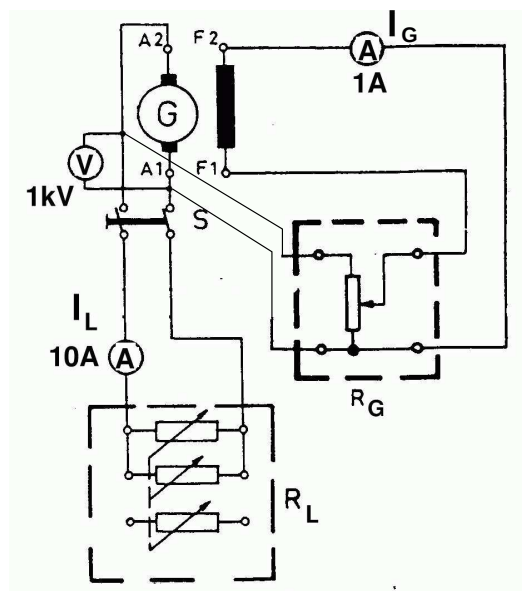


Figure 4: Circuit diagram for the second experiment

1. Make sure that the switch S is off, start the motor and adjust the speed to 1400 rpm. This speed must be kept constant during the entire experiment and should therefore be checked from time to time.
2. Adjust the shunt rheostat R_G of the generator so that the generator voltage becomes 200 V. The setting of the shunt rheostat must thereafter not be changed during the experiment.
3. Adjust the load resistor R_L to the minimum load. Turn the switch S on and using the load resistor R_L vary the load current I_L in steps up to the rated current. Steps should not exceed

1 A if possible; steps of 0.5 A are a good choice. For each step, read the current I_L and voltage V .

Check the speed and **do not change setting** of the shunt rheostat R_G .

Table 2: Load characteristic

Separate $I_G = \text{const}$		Shunt	
I_L, A	V_T, V	I_L, A	V_T, V

11 Clean up

Turn off the power supply switches. Turn off the switch S. Disconnect the equipment and remove all wire from the bench. The AVOs must be turned off as well. Please remove any labels from the rheostats and motors.

12 Laboratory questions

Answer the following questions.

Question 1. What are ratings of the DC machines in this laboratory experiment?

Motor:

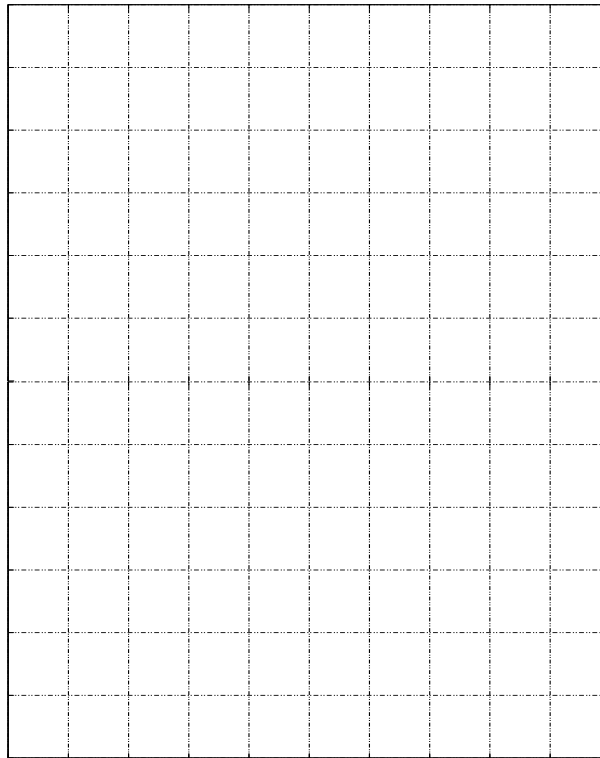
Generator:

Briefly explain the meaning of these ratings and how did you use them

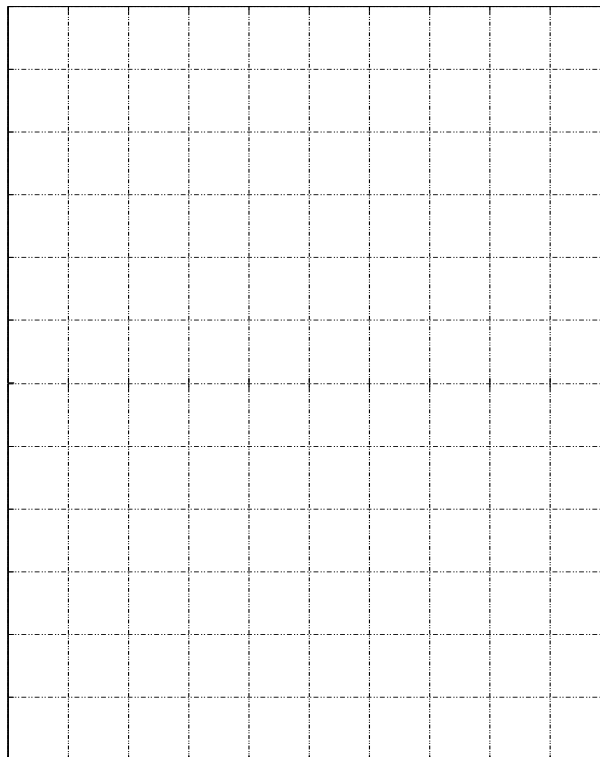
Question 2. Draw the measured no-load characteristic for increasing and decreasing I_G at 1400 and 1200 rpm, respectively, in the same coordinates with common I_G axis. Use the grid provided below or draw the graph on graph paper and attach it to this report.

Why does the no-load characteristic differ for increasing and decreasing excitation current?

Why does the no-load characteristic differ for different speed of rotation?



Question 3. Draw the load characteristic for separate and shunt excitation in the same coordinates with common I_L axis.



- Question 4.** Using the obtained graphs and equivalent schematics of a shunt dc generator and a separately excited dc generator explain why for shunt generators, the terminal voltage V_T drops off more as the load increases, as compared to the voltage drop off occurring in separately excited generators.
- Question 5.** How does the voltage regulation of a dc shunt generator compare to that of a separately excited dc generator? If possible, use results of the experiments to support the answer.
- Question 7.** In the first experiment (Section 7), the field current on the motor was adjusted to a maximum current. Can you explain, why was that done? What would happen if the motor were started with a small excitation current and no load?
- Question 8.** What are advantages and drawbacks of dc shunt and separately excited generators?