

V-I Characteristics of DC Generators

1 Aim

To obtain V-I characteristics of a DC Generators

2 Theory

Equivalent circuit of a DC generator in steady state is as shown in Fig. 1. Note that for generator the current is leaving the positive voltage terminal. The equation is given by

$$V_a = E - I_a R_a \quad \text{or} \quad I_a = \frac{E - V_a}{R_a} \quad (1)$$

Based on the method of excitation dc generators can be divided into two groups.

1. Separately excited generators
2. Self-excited generators

In a separately excited (S.E.) machine, the field winding is connected to a separate voltage source while, in a self excited generator field winding is connected across the armature terminals (provides its exciting current) . In these machines the required field current is a very small fraction of the rated current (could be around 2-3% of the current flowing in the armature circuit at full load). Hence, the field winding has a large number of turns with a thin conductor.

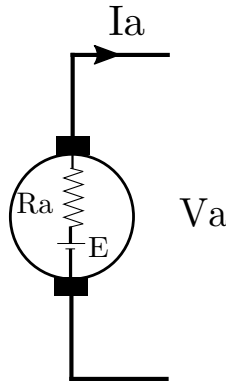


Figure 1: Equivalent circuit of DC generator

2.1 Separately Excited DC Generator

As the name suggests, a separately excited dc generator requires an independent dc external source for the field winding. The equivalent circuit representation under steady state condition is show in Fig. 2. The equations under steady-state are:

$$V_f = I_f R_t \quad R_t = R_f + R_{ext} \quad V_a = E + I_L R_a \quad I_L = I_a \quad (2)$$

When the field current is held constant and the armature is rotating at a constant speed, the induced emf in an ideal generator is independent of the armature current, as shown by the dotted line in Fig. 3

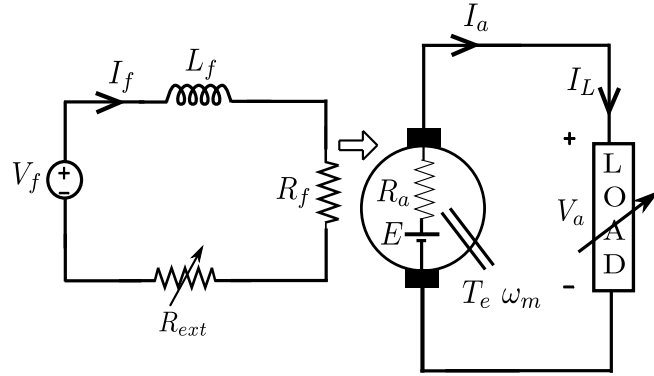


Figure 2: Equivalent circuit of a separately excited DC generator

As the load current I_L increases, the terminal voltage decreases as indicated by solid line. If the armature reaction is neglected, decrease in V_a should be linear and equal to the voltage drop across R_a and carbon brushes. However, if the generator is operated at the knee point in the magnetization curve the armature reaction causes a further drop in terminal voltage.

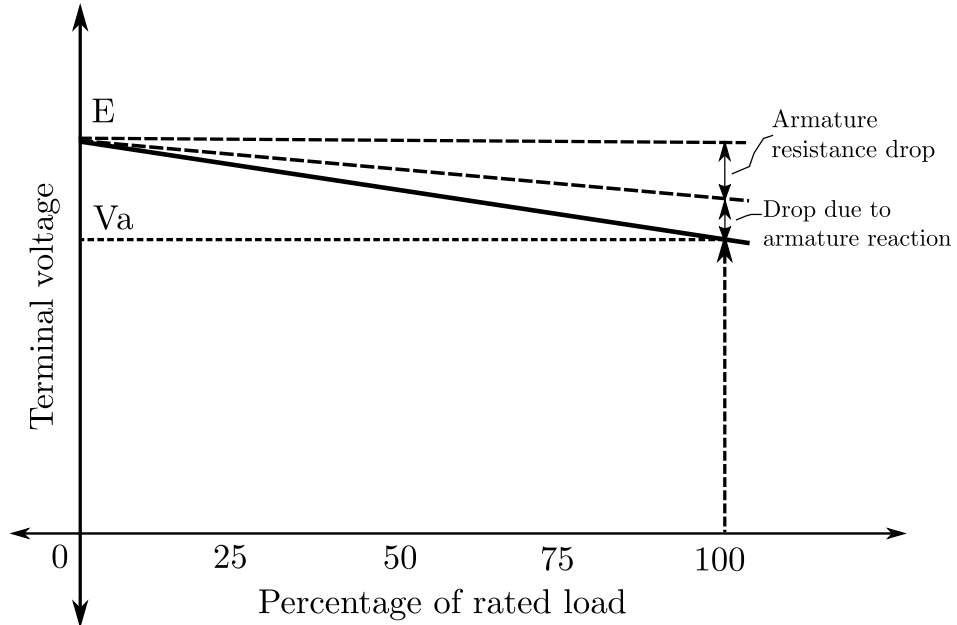


Figure 3: V-I Characteristics of separately excited DC generator

2.2 Self Excited DC Generator

In this generator, the field winding is connected across the armature. Hence, the terminal voltage is also the field voltage and the armature current is the sum of load and field currents. When the rotor of this machine is rotated, the residual flux in the field winding induces some voltage (E_r) in the armature winding as shown in Fig. 4 . Since the field winding is connected across the armature, because of this induced emf a small current starts flowing in the field winding. If the field mmf due to this current aids the residual flux, total airgap flux increases. This increase in flux increases the induced emf which, in turn, increases the field current. This action is cumulative in nature.

If the field winding is connected in such a way that the flux produced by the field current opposes the residual flux, the generator fails to build up. This problem can be corrected by either reversing

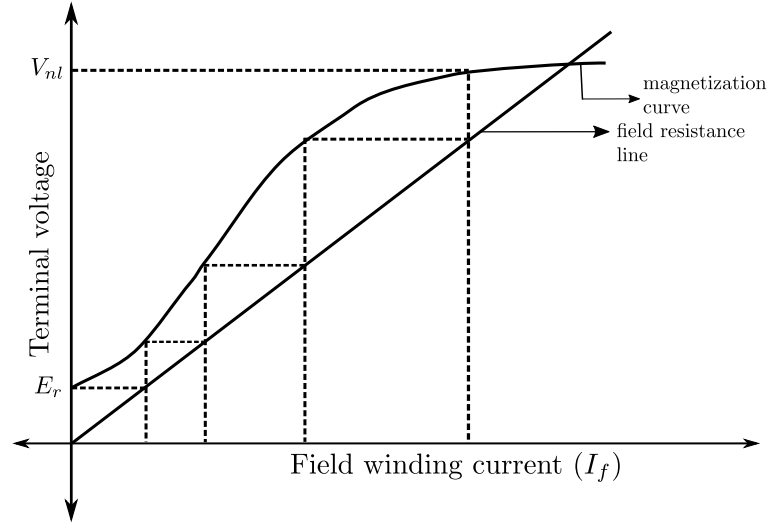


Figure 4: Voltage generation in self-excited DC generator

the direction of rotation or interchanging the field winding connections across the armature. The value of no-load voltage at the armature terminals depends on the field resistance (point of intersection of field resistance line with magnetization curve is the operating point). A decrease in the field resistance causes the generator to build up faster to a higher voltage.

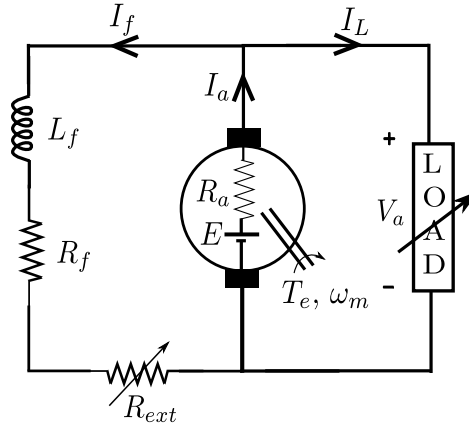


Figure 5: Equivalent circuit of self-excited DC generator

The equivalent circuit representation under steady state condition is shown in Fig. 5. The equations that govern the operation of a self excited generator under steady state are:

$$I_a = I_L + I_f \quad V_a = I_f(R_f + R_{ext}) = I_L R_L = E - I_a R_a \quad (3)$$

Under no load condition, the armature current is equal to the field current, which is a small fraction of load current. Therefore the terminal voltage under no-load condition is nearly equal to the induced emf ($I_a R_a$ drop on no-load is very small). As the load current increases, the terminal voltage decreases due to the following reasons:

1. $I_a R_a$ drop
2. demagnetization effect of the armature reaction
3. decrease in the field current due to the reduction in the terminal voltage (field current can be kept constant in separately excited generator, while in self excited generator this current falls with terminal voltage)

The variation of terminal voltage with load is shown in Fig. 6.

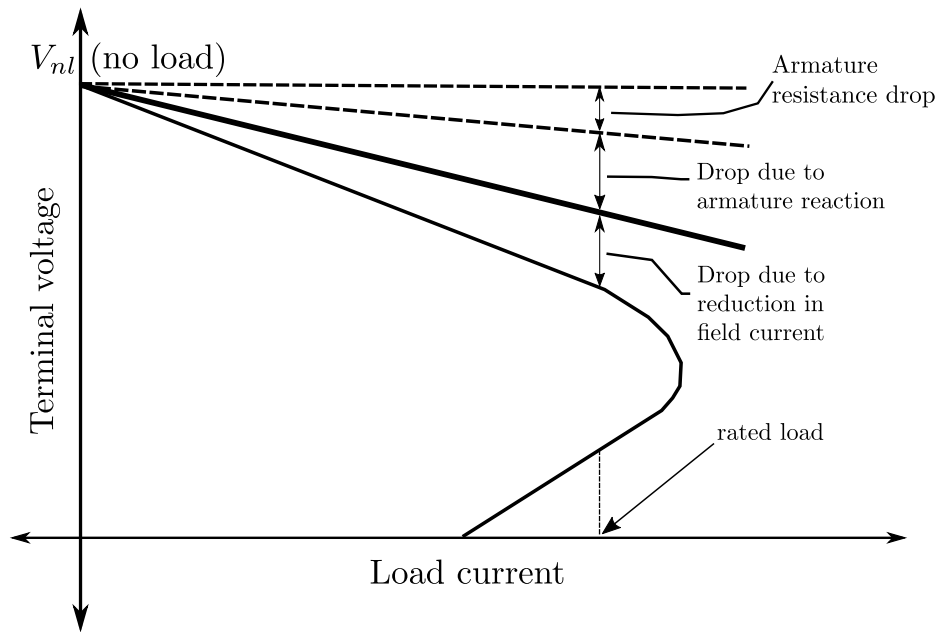


Figure 6: V-I characteristics of self-excited DC generator

3 Procedure

3.1 Note to TAs

There is a DC machine which is cut open.

- Following things are to be shown: carbon brushes, commutator, stator poles, rotor coil, stator and rotor laminations
- Rotate the rotor and show that carbon brushes are stationary while commutator is rotating.

There are three machines mounted on the stand, out of which two of them are DC machines. Note the name plate ratings of these machines and use one of them as a prime mover (motor) and the other as a DC generator (You may have to justify your selection)

- 1.5 kW DC machine: $R_a = 2.04 \Omega$, $R_F = 415 \Omega$,
- 1.1 kW DC machine: $R_a = 2.1 \Omega$, $R_F = 415 \Omega$

Friction and windage loss for both the machines (at 1500 rpm) is 53 W

3.2 Precaution

Always start the motor (prime mover) by applying a low input voltage (V_{in}) to the armature, else the power electronic controller may get damaged due to heavy inrush current. Also, apply the rated voltage to the field winding of the motor. In case the drive has tripped, bring back the voltage control knob on the power controller feeding armature of the DC motor to 'zero position' and then press the 'green' button.

4 Procedure

4.1 For Separately Excited DC Generator

1. Connect the circuit diagram as shown in Fig. 7. Keep the control knob (which is used for applying variable DC voltage to the field winding of the generator) on the field regulator of generator at 'zero output voltage' position. Put off all switches of the lamp load and open the main switch 'S' connected between the load and the armature of the dc generator. Also, open switches S_1 , S_2 and S_3 . These are on machine stand.
2. Using the power electronic controller slowly increase the input to the prime-mover. Speed of the set will increase. By controlling the input to the prime mover adjust the speed to the rated speed of the machine.
3. Using a multi-meter note the voltage due to residual magnetism.
4. Using the knob on the controller feeding the field winding of the generator, increase the input voltage in steps till the generator voltage is equal to its rated value.
5. Close the main switch 'S' and load the generator in steps by switching ON the lamps and for each case adjust the prime mover input such that the speed remains constant. Note down load voltage and current, field voltage and current of the generator, armature current and voltage of the motor. Repeat this procedure till the load current is equal to the rated current of the generator.
6. Put off all the lamps, open the main switch S, reduce the prime mover input and put off the AC supply to the controller.

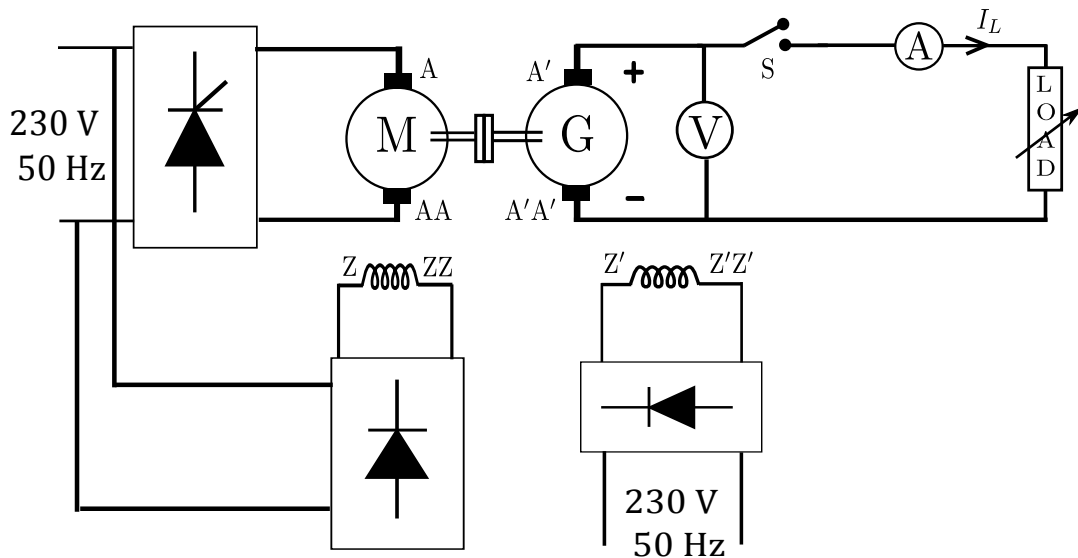


Figure 7: Connection diagram for separately excited DC generator

4.2 For Self Excited DC Generator

1. Connect the circuit diagram as shown in Fig. 8 (you need to connect the field winding across the armature instead of connecting it to a separate supply).

2. Slowly increase the input to the prime-mover. Speed of the set will increase. Observe the voltmeter connected across the terminals of the dc generator. Above a certain speed the voltmeter reading starts increasing (If this does not happen reduce the prime-mover input and switch off the supply. Interchange the field terminals of the generator and repeat the same procedure). By controlling the input to the prime mover adjust the speed to the rated speed of the machine.
3. Close the main switch S. Load the generator in steps by switching ON the lamps and for each case adjust the prime mover input such that the speed remains constant. Note down the load voltage and current, field current of the generator, armature current and voltage of the motor. Repeat this procedure till the load current is equal to the rated current of the generator.
4. Put off all the lamps, open the main switch S, reduce the prime mover input and put off the AC supply to the controller.
5. Incase in step - 2 the machine did self excite in the first attempt, interchange the field terminals of the dc generator and repeat the step - 2.

5 Report

1. Plot the variation of open circuit voltage with field current
2. Plot the variation of terminal voltage with load current for separately excited and self excited generators.

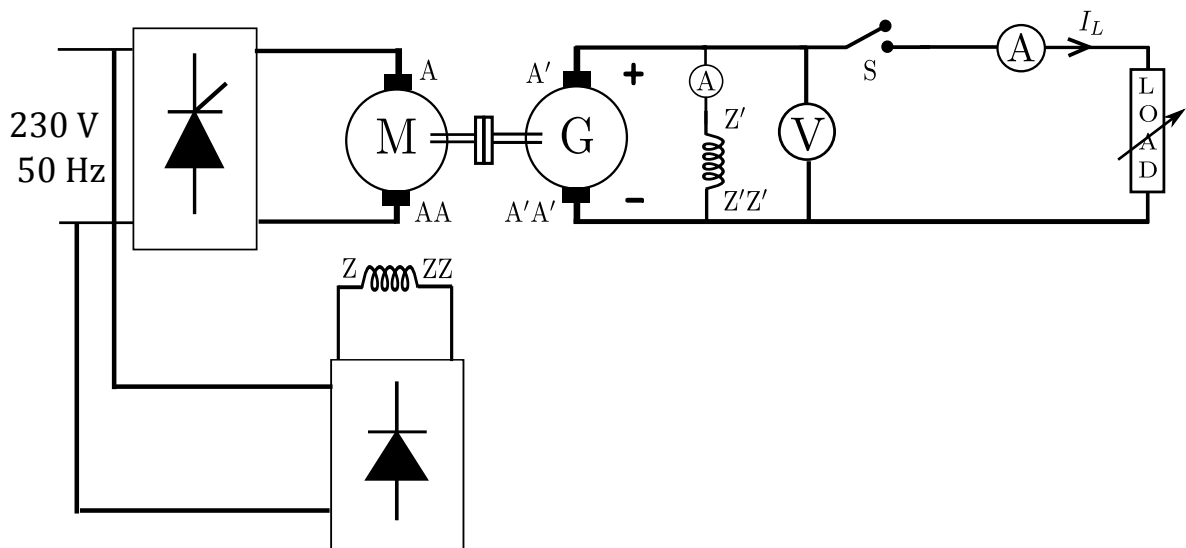


Figure 8: Connection diagram for self excited DC generator

6 Post-lab Questions

1. Of the two machines which one did you choose to operate as motor? Justify your answer.
2. Assume that a given machine has the following name plate ratings:

220 V, 1.5 kW, 1500 rpm dc generator

What do these numbers imply?

3. There are motors without any rotor windings (e.g. stepper motor). Explain how the torque is produced in these machines (Hint: Go through very carefully the theory given in the first page).
4. How is the voltage induced in the armature (coil is rotating in a magnetic field) which is ac, converted to dc?
5. What is the effect of armature reaction?
6. ‘Saturation of the magnetic material is a blessing in the case of self excited generator’ Is this statement true? Justify your answer. (Hint: comment on the following: (a) during voltage build up which is cumulative in nature. (b) if the generator is operated in the linear region of the magnetization curve)
7. In separately excited dc machine, the field winding carries a constant current. Hence, it dissipates power. Suggest a method to eliminate this power loss.
8. What may happen if load terminals are short circuited in (a) separately excited generator (b) self excited generator
9. You have been given the plot of Efficiency Vs input power of the prime mover. Explain how will you obtain the plot of efficiency Vs output power of the generator. How will you obtain this plot incase the plot of Efficiency Vs input power of the prime mover is not available?