Torque- speed characteristics of a separately excited dc motor

Introduction

For a dc drive, it is important to study the torque-speed characteristics of a dc motor since the motor characteristics should match with that of the load to which the drive is going to connect.

Aim

1. To obtain the performance characteristics (T-ω) of a separately excited dc motor.

Theory

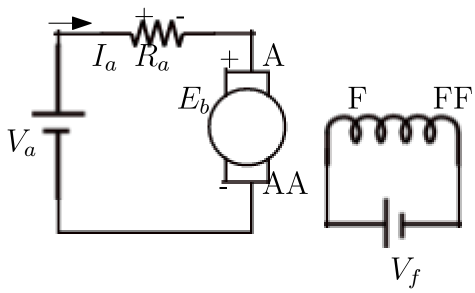

Figure 1: Separately excited dc motor

A separately excited dc motor is shown in figure 1. The armature and the field winding is excited from separate dc sources, V_a and V_f respectively. The effective resistance of the armature winding is given by R_a and current I_a flowing into the armature. The motor back emf or speed voltage is given by E_b. The KVL for the separately excited motor from fig.1 will be $V_a = E_b + I_a R_a$. The armature induced voltage with motor rotating at a speed ω is given by $E_b = K_e \phi \omega$, where ϕ is the field flux and K_e is the machine constant. Similarly the motor torque is given by $T = K_e \phi I_a$. Using the above equations, the expression for speed ω in terms of torque T can be obtained as $\omega = \frac{V_a}{K_e \phi} - \frac{R_a}{(K_e \phi)^2} T_a$.

If we plot the torque-speed expression for the separately excited dc motor, torque-speed characteristics as shown in figure 2 will be obtained. As the torque developed is increased, as given by the torque-speed relation, speed will fall with a gradient of $\frac{R_a}{(K_e \phi)^2}$.

T-ω characteristics with combined armature voltage and field control

$$\omega = \frac{V_a}{K_e \phi} - \frac{R_a}{(K_e \phi)^2} T_a \tag{1}$$

Armature voltage control is applied below base speed, with field flux kept constant at its rated value. From (1), when armature voltage is increased, speed will be increased. Above rated voltage, further increase is not possible to get higher speeds. Then field flux control is used to get speeds above base speed as shown in figure 3. With armature voltage kept constant at its rated voltage, if field flux is reduced, from (1), it is understood that speed will be getting increased. But unlike armature voltage control, T-ω curves will not be parallel to each other as flux is not linearly related to speed as in (1).

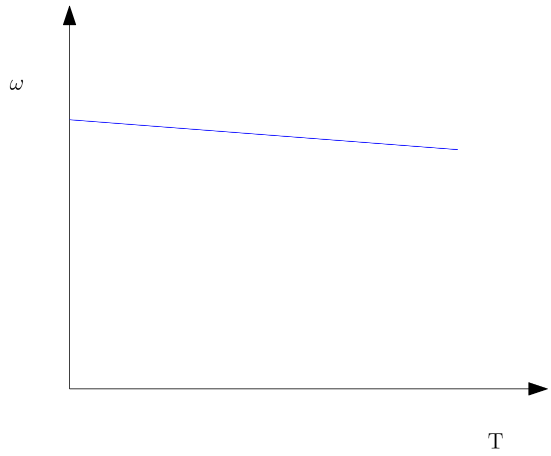

Figure 2: T-ω characteristics of a separately excited dc motor

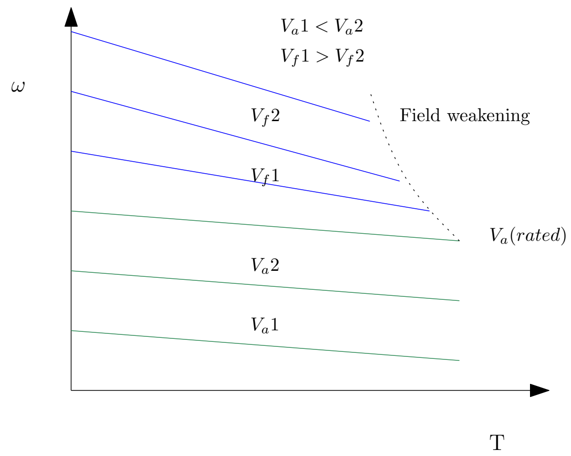

Figure 3: Combined armature voltage and field control

Procedure:

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 dc motor and the other as a separately excited dc generator. The parameters are:

- 1.5 kW dc machine: $R_a = 2.04\Omega$, $R_F = 415\Omega$, Friction & windage loss at 1500 rpm = 53 W.
- 1.1 kW dc machine: $R_a = 2.1\Omega$, $R_F = 415\Omega$, Friction & windage loss at 1500 rpm = 53 W.

Precaution:

* **Always start the motor by applying a low input voltage (V_a) 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.**

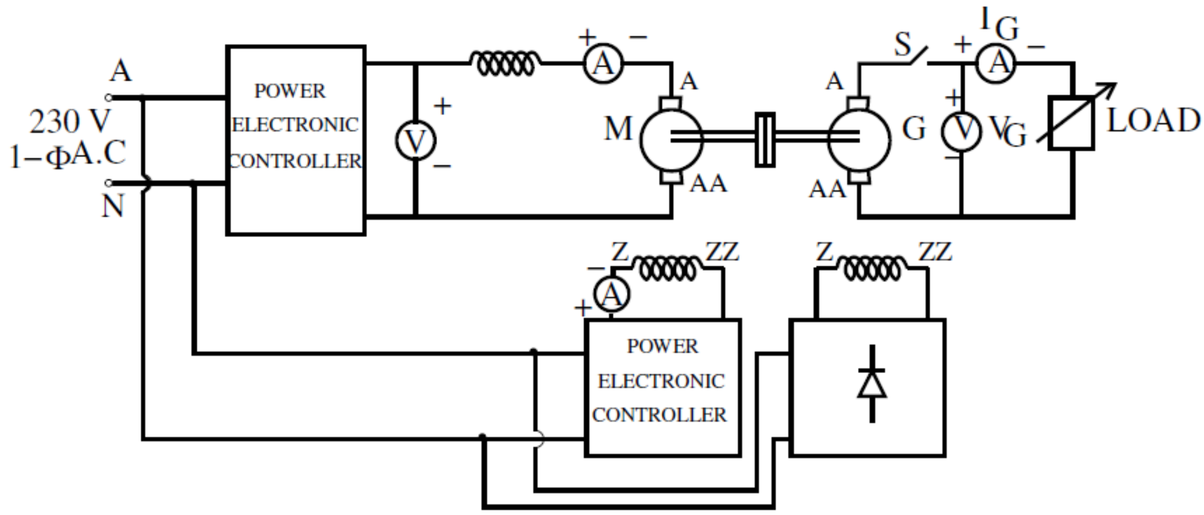

Figure 4: Circuit diagram

Armature Voltage control:

A. Connect the circuit as shown in figure 4. In this experiment the motor is loaded by loading the generator. 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.

B. Switch on the AC supply to the power electronic controller supplying power to the field winding of the motor. Using the knob on the controller, apply the rated voltage to the field winding.

C. Switch on the AC supply to the power electronic controller supplying power to the armature of the motor. Using the knob on the controller, slowly increase the voltage to the armature till the rated value. Also, apply the rated voltage to the field winding of the generator (the output terminals are at the rear side of the controller feeding the armature of the motor). Note down the meter readings, speed and direction of rotation.

E. Close switch S and load the generator in steps till it reaches full load. For each load keep the input voltage to the armature constant & note down all the meter readings and speed. **You may find that beyond a certain load, it is not possible to keep the armature input voltage constant. Do not increase the load beyond this point**. Switch off the load and open S.

F. Now apply 85% of the rated voltage to the armature and repeat the above step. Do not switch off the supply.

Field Control:

A. Using the power electronic controller apply the rated voltage to the armature of the DC motor.

B. Using the power electronic controller suppling power to the field of the DC motor, reduce the field current to 0.4 A.

C. Close S and load the generator in steps till full load. For each load keep the input voltage to the armature and field current constant, and note down all the meter readings and speed. **You may**

find that beyond a certain load, it is not possible to keep the armature input voltage constant. Do not increase the load beyond this point. Switch off the load and open S.

D. Now reduce the field current to 0.38A with armature voltage unchanged at its rated value. Repeat the above step.

E. Reduce the voltage applied to the armature to zero.

Plotting of $T - \omega$ Characteristics:

* Using the plot of efficiency vs output power of the generator, for each output determine the input to the generator.
* Assuming 100% coupling efficiency, the above input power is the output of the motor. Knowing the speed of the motor, determine the torque. Plot T-ω characteristics.

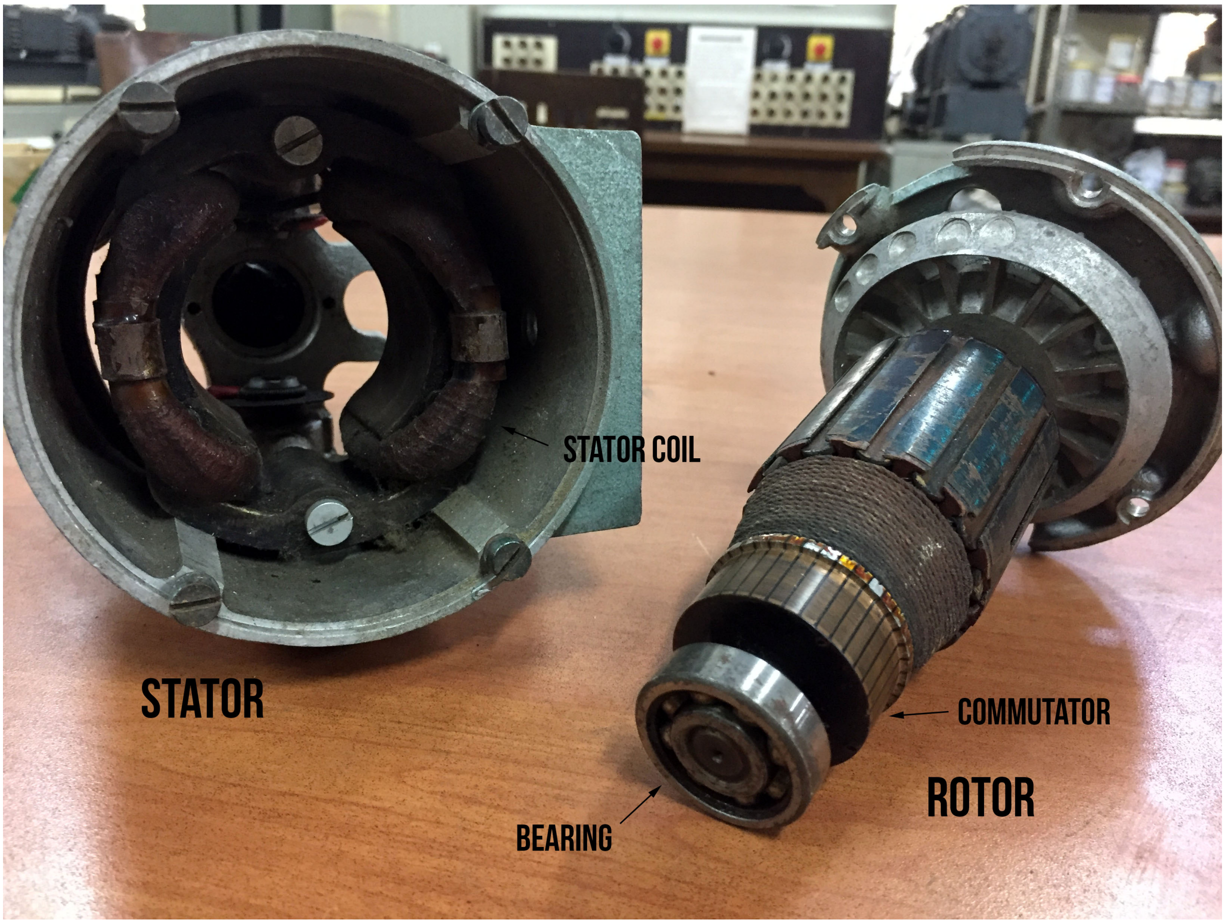

Figure 5: Photograph of 500W DC motor

References

[1] G. K. Dubey. *Fundamentals of Electrical Drives,* Alpha Science International Ltd., 2001.

This document is prepared by *Neethu S.* (Research Scholar, 2014 batch).