# EE234 Experiment 4: Characteristics of Separately-Excited DC Motor

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## 1 Overview of the experiment

The aim of the experiment was to observe, study and plot the variation of the performance characteristics ($T - \omega$) of the speed of the motor based on :

- Armature voltage ($V_a$) control
- Field current (and hence flux - $\phi$) control

The experiment is based on the following equivalent circuit for the DC motor:

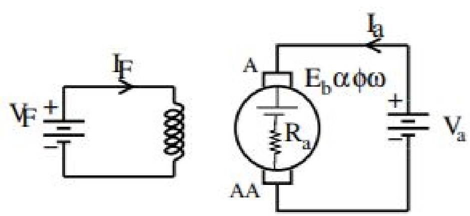


Figure 1: Equivalent circuit for the Separately Excited DC Motor

## 2 Procedure

The following two DC machines were available:

- 1.5 kW DC machine: $R_a = 2.04\Omega$, $R_F = 415\Omega$, Friction and windage loss at 1500 rpm = 53 W
- 1.1 kW DC machine: $R_a = 2.10\Omega$, $R_F = 415\Omega$, Friction and windage loss at 1500 rpm = 53 W.

The former was used as the motor and the latter as the generator since machine 1 is used to drive machine 2 and hence more power is required (which is expected to be lost in the flow of mechanical power between the two machines).

## 2.1 Part 1: Armature Voltage Control

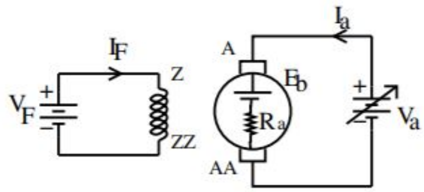


Figure 2: Circuit of the Separately Excited DC Generator for Armature Voltage control

## 2.2 Part 2: Field Current/Flux Control

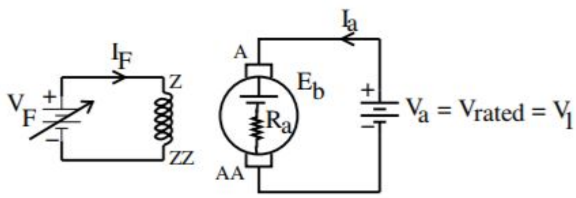


Figure 3: Circuit of the Separately Excited DC Generator for Field Current control

As a result, the connection of the circuit is as shown below:

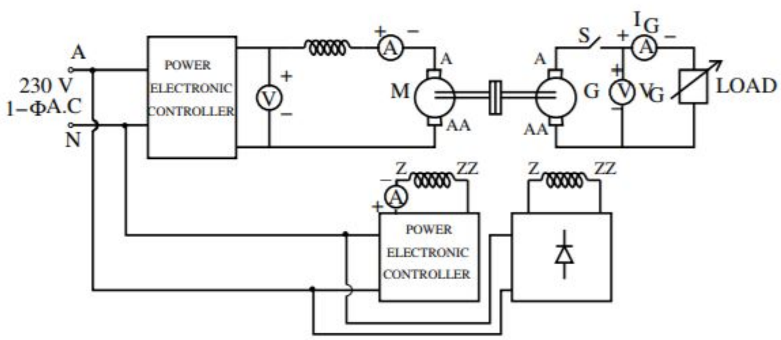


Figure 4: Connections of the Circuit of the Separately Excited DC Generator for various control

# 3 Observations and Calculations

**DC Motor Specifications:**

| | |
|---|---|
| Rated Armature Voltage($V_a$) | 180V |
| Rated Armature Current($I_a$) | 10.5A |
| Rated Power | 1.5KW |
| Rated speed($\omega_m$) | 1500rpm |
| Rated Field Voltage($V_f$) | 220V |
| Rated Field Current($I_f$) | 0.42A |

**DC Generator Specifications:**

| | |
|---|---|
| Rated Armature Voltage($V_a$) | 180V |
| Rated Armature Current($I_a$) | 7.5A |
| Rated Power | 1.1KW |
| Rated speed($\omega_m$) | 1500rpm |
| Rated Field Voltage($V_f$) | 220V |
| Rated Field Current($I_f$) | 0.46A |

## 3.1 Armature Voltage Control

We vary the loads such that in such a way that no load speed is $1495s^{-1}$ and keeping the armature voltage constant.

| $V_{am}$ | $I_{am}$ | $V_{fm}$ | $I_{fm}$ | $V_{ag}$ | $I_{ag}$ | $V_{fg}$ | $I_{fg}$ | $\omega$ | Load |
|---|---|---|---|---|---|---|---|---|---|
| 164 | 1.3 | 192 | 0.40 | 165 | 0.0 | 204 | 0.46 | 1495 | 0 |
| 164 | 1.9 | 197 | 0.40 | 160 | 0.5 | 204 | 0.45 | 1487 | 2 |
| 164 | 2.2 | 197 | 0.41 | 158 | 0.9 | 204 | 0.45 | 1484 | 3 |
| 164 | 2.4 | 197 | 0.40 | 157 | 1.1 | 204 | 0.45 | 1483 | 4 |
| 164 | 2.6 | 197 | 0.40 | 156 | 1.3 | 204 | 0.45 | 1482 | 5 |
| 164 | 2.9 | 197 | 0.40 | 155 | 1.5 | 204 | 0.44 | 1480 | 6 |
| 164 | 3.2 | 197 | 0.40 | 153 | 1.8 | 203 | 0.43 | 1475 | 7 |
| 164 | 3.6 | 196 | 0.40 | 152 | 2.1 | 204 | 0.43 | 1472 | 8 |
| 164 | 3.9 | 197 | 0.40 | 150 | 2.5 | 204 | 0.43 | 1468 | 9 |
| 164 | 4.2 | 203 | 0.42 | 147 | 2.8 | 203 | 0.43 | 1452 | 10 |
| 164 | 4.6 | 202 | 0.41 | 146 | 3.1 | 202 | 0.43 | 1448 | 11 |
| 164 | 4.8 | 202 | 0.41 | 146 | 3.3 | 203 | 0.43 | 1445 | 12 |

Now we keep the armature voltage 85% of the previous rated armature voltage

| $V_{am}$ | $I_{am}$ | $V_{fm}$ | $I_{fm}$ | $V_{ag}$ | $I_{ag}$ | $V_{fg}$ | $I_{fg}$ | $\omega$ | Load |
|---|---|---|---|---|---|---|---|---|---|
| 131 | 1.1 | 205 | 0.41 | 129 | 0.0 | 205 | 0.43 | 1196 | 0 |
| 131 | 1.6 | 204 | 0.41 | 125 | 0.5 | 205 | 0.43 | 1186 | 2 |
| 131 | 2.0 | 204 | 0.41 | 123 | 0.8 | 205 | 0.43 | 1179 | 3 |
| 131 | 2.1 | 205 | 0.41 | 123 | 0.9 | 205 | 0.43 | 1176 | 4 |
| 131 | 2.3 | 205 | 0.41 | 122 | 1.1 | 205 | 0.43 | 1172 | 5 |
| 131 | 2.5 | 205 | 0.41 | 122 | 1.3 | 205 | 0.43 | 1169 | 6 |
| 131 | 2.8 | 204 | 0.41 | 120 | 1.6 | 205 | 0.43 | 1163 | 7 |
| 131 | 3.1 | 205 | 0.40 | 119 | 1.9 | 205 | 0.43 | 1158 | 8 |
| 131 | 3.4 | 205 | 0.4 | 117 | 2.2 | 205 | 0.43 | 1153 | 9 |
| 131 | 3.6 | 204 | 0.41 | 116 | 2.3 | 205 | 0.43 | 1151 | 10 |
| 131 | 3.9 | 209 | 0.42 | 115 | 2.6 | 204 | 0.43 | 1139 | 11 |
| 131 | 4.1 | 208 | 0.42 | 113 | 2.9 | 204 | 0.43 | 1134 | 12 |

## 3.2 Field Control

We apply constant field current and armature voltage and notice the effect of speed on Load.

| $V_{am}$ | $I_{am}$ | $V_{fm}$ | $I_{fm}$ | $V_{ag}$ | $I_{ag}$ | $V_{fg}$ | $I_{fg}$ | $\omega$ | Load |
|---|---|---|---|---|---|---|---|---|---|
| 165 | 1.3 | 187 | 0.37 | 167 | 0.0 | 206 | 0.43 | 1550 | 0 |
| 165 | 1.9 | 188 | 0.37 | 163 | 0.6 | 206 | 0.43 | 1536 | 2 |
| 165 | 2.1 | 188 | 0.37 | 162 | 0.7 | 205 | 0.43 | 1534 | 3 |
| 165 | 2.5 | 187 | 0.37 | 160 | 1.1 | 205 | 0.43 | 1528 | 4 |
| 165 | 2.7 | 187 | 0.37 | 159 | 1.3 | 205 | 0.43 | 1524 | 5 |
| 165 | 2.9 | 187 | 0.37 | 158 | 1.5 | 205 | 0.43 | 1521 | 6 |
| 165 | 3.3 | 187 | 0.37 | 157 | 1.9 | 205 | 0.43 | 1516 | 7 |
| 165 | 3.7 | 187 | 0.37 | 155 | 2.2 | 204 | 0.43 | 1512 | 8 |
| 165 | 4.0 | 187 | 0.37 | 153 | 2.5 | 204 | 0.43 | 1507 | 9 |
| 164 | 4.4 | 187 | 0.37 | 152 | 2.8 | 204 | 0.43 | 1503 | 10 |
| 165 | 4.7 | 187 | 0.37 | 151 | 3.2 | 204 | 0.43 | 1498 | 11 |
| 164 | 5.0 | 187 | 0.37 | 150 | 3.4 | 203 | 0.42 | 1496 | 12 |

We decrease the field voltage to increase the speed of operation

| $V_{am}$ | $I_{am}$ | $V_{fm}$ | $I_{fm}$ | $V_{ag}$ | $I_{ag}$ | $V_{fg}$ | $I_{fg}$ | $\omega$ | Load |
|---|---|---|---|---|---|---|---|---|---|
| 164 | 1.3 | 165 | 0.33 | 171 | 0.0 | 205 | 0.43 | 1598 | 0 |
| 164 | 1.9 | 165 | 0.34 | 168 | 0.6 | 205 | 0.43 | 1586 | 2 |
| 164 | 2.3 | 165 | 0.34 | 166 | 0.9 | 205 | 0.43 | 1580 | 3 |
| 164 | 2.5 | 165 | 0.34 | 165 | 1.1 | 205 | 0.43 | 1576 | 4 |
| 164 | 2.8 | 165 | 0.34 | 164 | 1.3 | 206 | 0.43 | 1572 | 5 |
| 165 | 3.0 | 165 | 0.34 | 163 | 1.5 | 205 | 0.43 | 1568 | 6 |
| 164 | 3.4 | 165 | 0.34 | 162 | 1.9 | 205 | 0.43 | 1565 | 7 |
| 164 | 3.8 | 166 | 0.34 | 161 | 2.2 | 205 | 0.43 | 1561 | 8 |
| 163 | 4.2 | 165 | 0.34 | 159 | 2.6 | 205 | 0.43 | 1558 | 9 |
| 164 | 4.6 | 165 | 0.34 | 158 | 2.9 | 204 | 0.42 | 1555 | 10 |
| 164 | 5.0 | 165 | 0.34 | 156 | 3.2 | 204 | 0.42 | 1552 | 11 |
| 164 | 5.2 | 164 | 0.34 | 155 | 3.4 | 204 | 0.42 | 1550 | 12 |

## 3.3 Reverse of supply Voltage Terminals

We observed that the direction of rotation is reversed and measured the following characteristics.

| | |
|---|---|
| Armature Voltage(V) | 164 |
| Armature Current(A) | 0.10 |
| Field Voltage(V) | 204 |
| Field Current(A) | 0.42 |

## 3.4 Plotting of T-$\omega$ characteristics

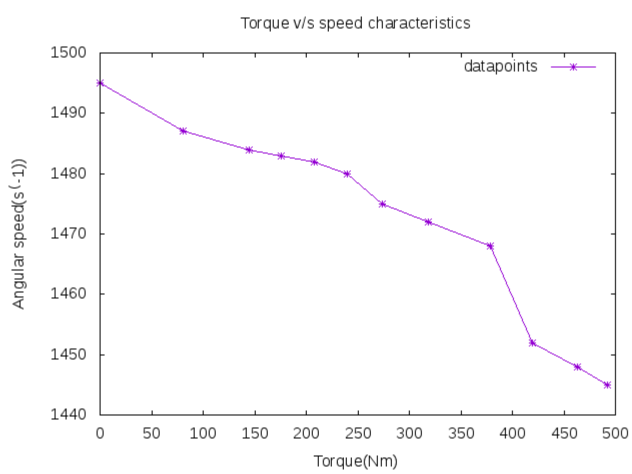


Figure 5: Caption

## 4 Answers

1. The rotor has many coils wound around it. The current through each coil varies with time as the armature rotates. The current flows through it in such a way so as to keep the rotor field constant. It points in a perpendicular direction to stator field.

2. If the field voltage is not applied, the back emf will never be developed and due to small value of armature resistance, huge armature current will flow destroying the equipment. Hence field voltage must be applied first and the armature voltage must be increased in steps to avoid the possibility of large current flow.

3. It depends upon the type of load on which the motor is operating. Passive load gives same type of operation whereas the operation is not identical for active load.

4. Armature reaction gives net decrease in back EMF due to operation of device in saturation region. Hence we get a stabilised torque speed characteristics.

5. Back EMF will be brought down to zero. Hence huge current will flow distroying the equipment

6. We want a motor with high inital torque to start the traction engine. The characteristics of a series motor is well suited for providing high intial torque. Hence we would use a series DC motor.

7. Range of speed is quite limited. The armature voltage has to be changed in a particular slow manner in order to change the rotational speed change. That is rapid change in speed is not permitted. Low starting torque and requirement of additional source.

8. For additional speed change, the field current has to be decreased leading to decrease in back EMF. Thus the device will get affected due to additional current flow. Hence we must not increase beyond a certain value.

9. The current rating of the field wire and armature wire are far from same. Thus they cannot be connected in series.