

Rahul Nadan: EEE131- Electromechanics Laboratory-Lab#8

California State University, Sacramento  
College of Engineering and Computer Science  
Electrical and Electronic Engineering Department

**Lab #8: Measuring Operating Characteristics of a Shunt-excited, Series-excited, and  
Compounded DC Motor**

**Rahul Nadan**

### **Abstract:**

The purpose of this lab was to become familiar with three different kinds of DC motors configuration, which are Shunt-excited, Series-excited, and compound motor. DC motor used as either generator or a motor. Three different DC motors, analyzed under loading conditions to observe the torque speed and torque armature current relationship.

### **Introduction**

#### **1.1.Objective**

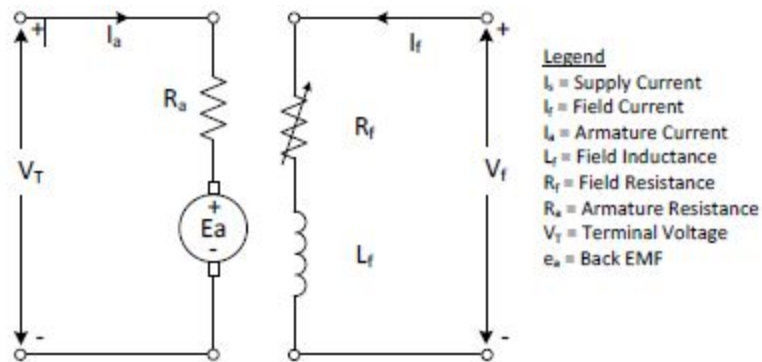
The purpose of this lab is to measure the operating characteristics of shunt-excited, series-excited, and compound DC Motor and see their behavior under different load condition. DC machine used as either a generator and as a motor.

#### **List of Major Equipment:**

- Shunt-excited DC motor
- Separately-excited DC generator
- Multiple wires
- Flux, and Ammeters
- Torque gauge reading in Nm
- Strobotach

### Separately Excited DC Motor:

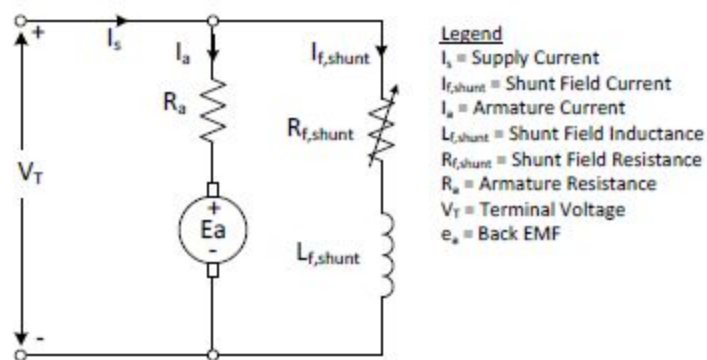
In the separately excited DC motor, the shunt field winding supplied by a separate external DC power source. The external DC power source can be a small DC generator, a solid-state DC power supply, or a battery.



**Figure 1: Equivalent circuit of a separately excited DC motor**

### Shunt-Excited DC motor:

In the shunt-excited DC motor, the field winding connected directly across the armature winding. Therefore, the terminal voltage provides the supply current and the field current.



**Figure 2: Equivalent circuit of a shunt-excited DC motor**

### Series-Excited DC motor:

In self-excited motor that has, its field winding connected in series with its armature. Therefore, its armature current and field current are all equal to each other.

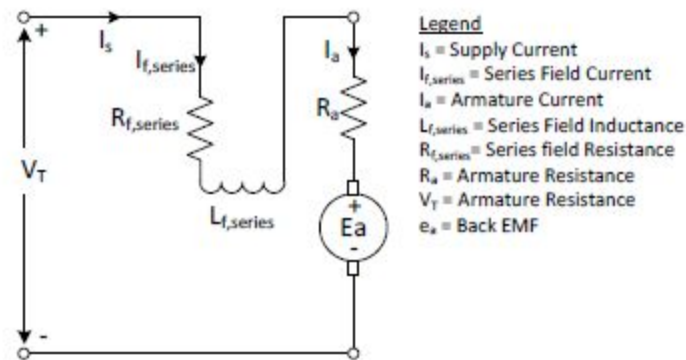


Figure 3: Equivalent circuit of a series-excited DC motor

### Compound DC motor:

The compound DC motor has both series and shunt field winding. The supply current equals to series field current plus shunt field current. Because the current flows into the dot, the total flux is equal to the addition of shunt and series.

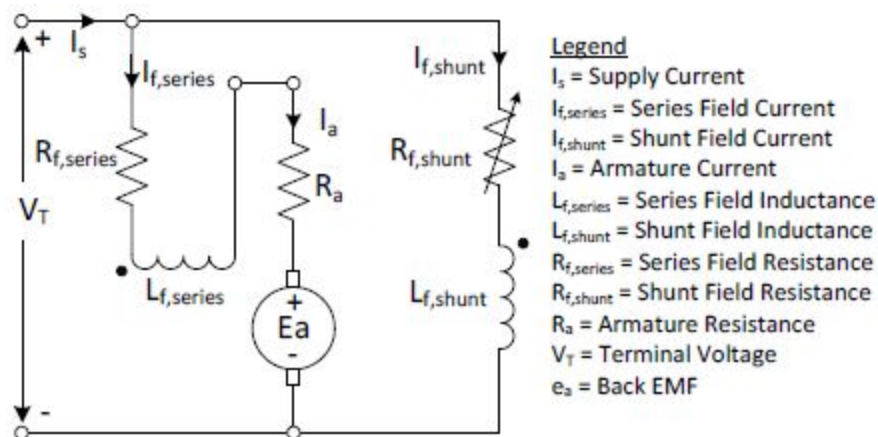
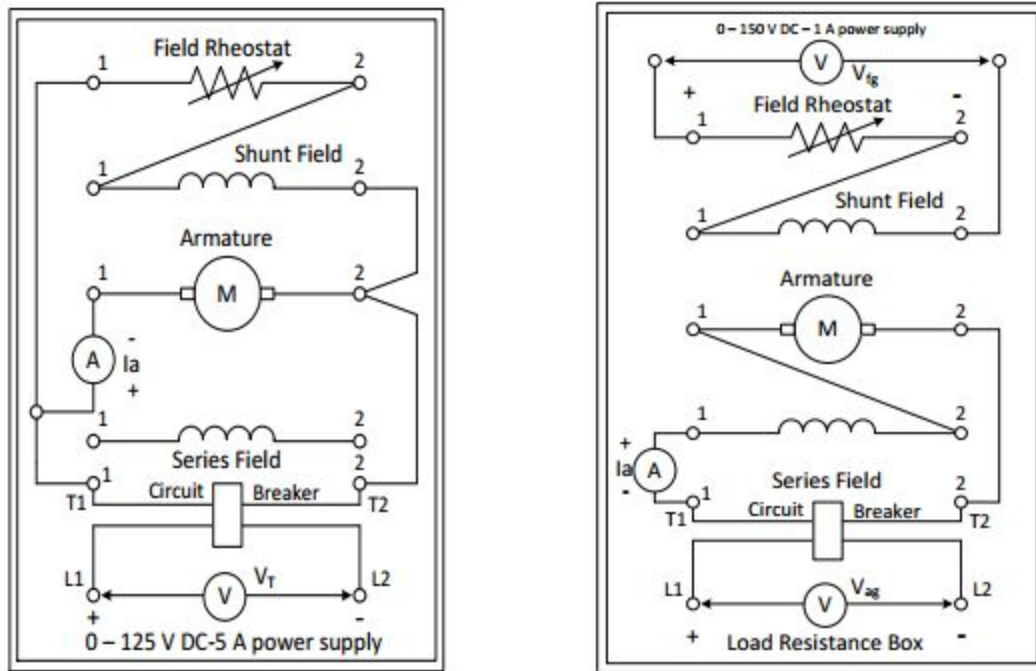


Figure 4: Equivalent circuit of a cumulative compound DC motor

## Implementation and Results

### 2.1. Observing the relationships between torque, internal voltage, and speed

To observe the relationships between the torque, internal voltage, and speed, construct the circuit shown in Figure 5. Set the field resistance of the DC motor to its min and the DC generator to max position. Close the AC circuit breaker, close the circuit breaker for 0-150V DC-1 power supply, and adjust the power supply knob until the DC separately excited generator field voltage become  $V_{fg}=110V$ . Close the circuit breaker of the 0-125V DC-5 power supply and adjust the voltage of the shunt-excited DC motor to  $V_T=0V$ . Now close the circuit breaker of the shunt-excited DC motor and slowly increase the  $V_T$  to 125V. Record the armature current, internal voltage, and mechanical speed in table 1.



**Figure 5: Electrical connection for the shunt-excited DC motor and separately excited DC generator**

Calculations:

$$E_a = V_T - I_a * R_a$$

$$R_a = 6\Omega$$

$$E_a = 125.2 - 0.22 * 6 = 123.9V$$

**Table 1: Measured values of the mechanical speed, armature and field current, and the voltages of a shunt-excited DC motor**

|          | Measured |          |            | Computed |
|----------|----------|----------|------------|----------|
| $I_f(A)$ | $V_T(V)$ | $I_a(A)$ | $N_m(rpm)$ | $E_a(V)$ |
| Max      | 125.2    | 0.22     | 2000       | 123.9    |
| Mid      | 125.0    | 0.27     | 1950       | 123.4    |
| Min      | 125.1    | 0.32     | 1920       | 123.2    |

From Table 1, the relationship between the field current and mechanical speed is directly proportional because as the field current position changes from max to min, the mechanical speed decrease too.

## 2.2. Observing the operating characteristics of a shunt DC motor

Keep the same circuit built in previous step, connect it to load box and set the motor's field resistance to its max position. Record the armature current, the mechanical speed, and the torque of the DC shunt-excited motor in Table 2.

Calculations:

$$P_{OUT\ Mechanical} = \omega * T_m$$

$$\omega = N_m * \frac{2\pi}{60}$$

$$P_{OUT\ Mechanical} = 1675 * \frac{2\pi}{60} * 0.25 = 43.85$$

$$I_{f,shunt} = \frac{V_T}{R_{f,shunt}} = \frac{125}{207} = 0.6038A$$

$$I_S = I_a + I_{f,shunt}$$

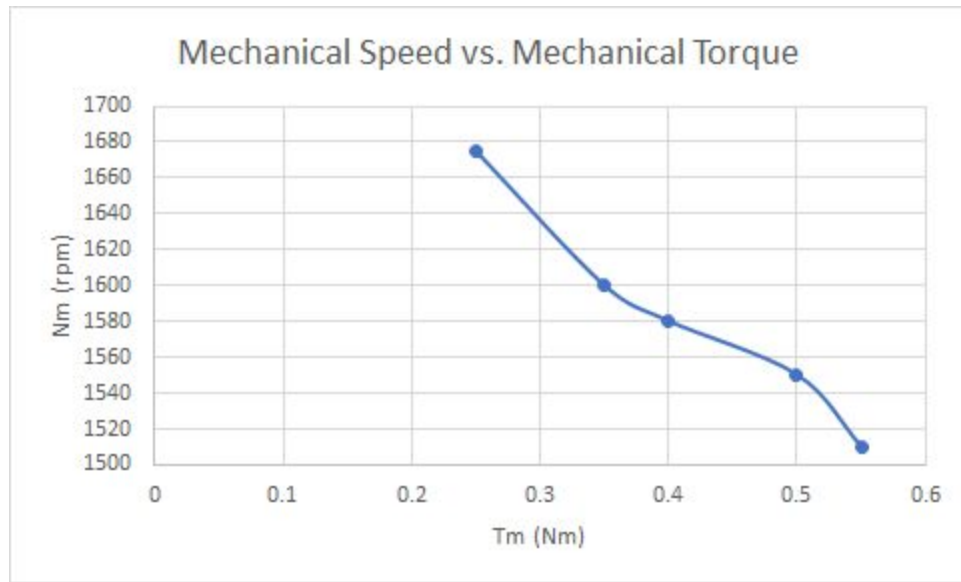
$$I_S = 0.8 + 0.6038 = 1.4038A$$

$$P_{IN\ electrical} = V_S * I_S = 125 * 1.4038 = 175.475$$

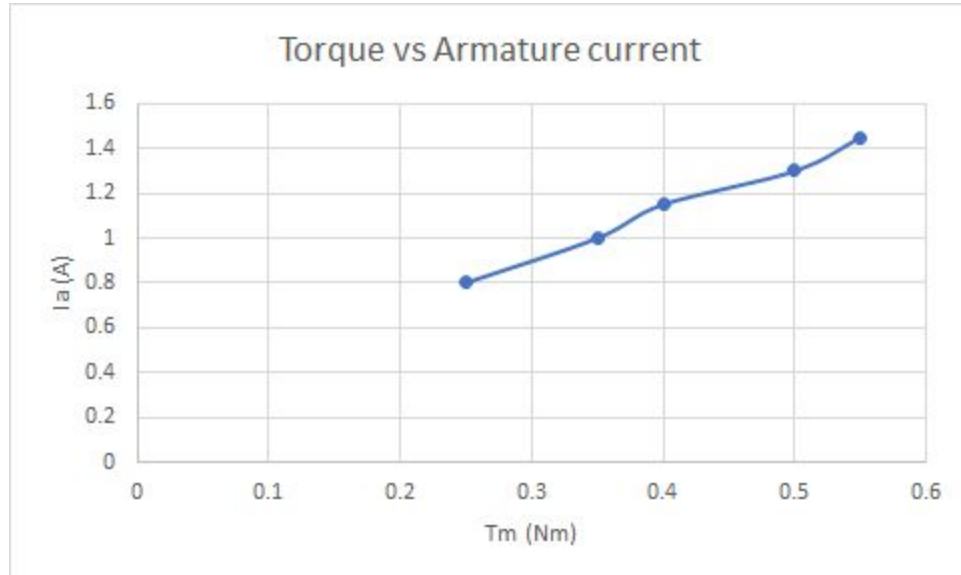
$$\eta T (measured) (\%) = \frac{P_{OUT\ Mechanical}}{P_{IN\ electrical}} * 100 = \frac{43.85}{175.475} * 100 = 24.99\%$$

**Table 2: measured and computed values of the shunt-excited DC motor**

|                 |         |                       |                          |                          |                          |
|-----------------|---------|-----------------------|--------------------------|--------------------------|--------------------------|
| $V_T = 125$ (V) | No-load | 1                     | 12                       | 123                      | 1234                     |
| $N_m$ (rpm)     | 1675    | 1600                  | 1580                     | 1550                     | 1510                     |
| $I_a$ (A)       | 0.8     | $I_m=1,$<br>$I_g=1.5$ | $I_m=1.15,$<br>$I_g=0.3$ | $I_m=1.30,$<br>$I_g=0.5$ | $I_m=1.45,$<br>$I_g=0.6$ |
| $T_m$ (Nm)      | 0.25    | 0.35                  | 0.4                      | 0.5                      | 0.55                     |
| $P_{in}$ (W)    | 175.475 | 200.475               | 219.225                  | 237.975                  | 256.725                  |
| $P_{out}$ (W)   | 43.85   | 58.64                 | 66.18                    | 81.16                    | 86.97                    |
| Efficiency %    | 24.99   | 29.25                 | 30.19                    | 34.1                     | 33.88                    |



**Figure 6: Mechanical speed vs. Mechanical Torque of a shunt DC motor**



**Figure 7: Torque vs. Armature current of a shunt DC motor**

According to Figure 6, the mechanical speed of the motor decreases as the mechanical torque increases. At the same time, the armature current increases while the mechanical torque increases as shown in Figure 7.

The speed regulation of the shunt-excited DC motor was calculated as follows:

$$\text{Speed Reg} = \frac{\omega_{nl} - \omega_{fl}}{\omega_{fl}} = \frac{1675 - 1510}{1510} = 0.109$$

### 2.3. Observing the operating characteristics of Series DC motor

To observe the operating characteristics of series DC motor, rewire the motor side as shown in Figure 8, keep the generator side wiring, and adjust the voltages and follow the direction as stated in the lab handout.

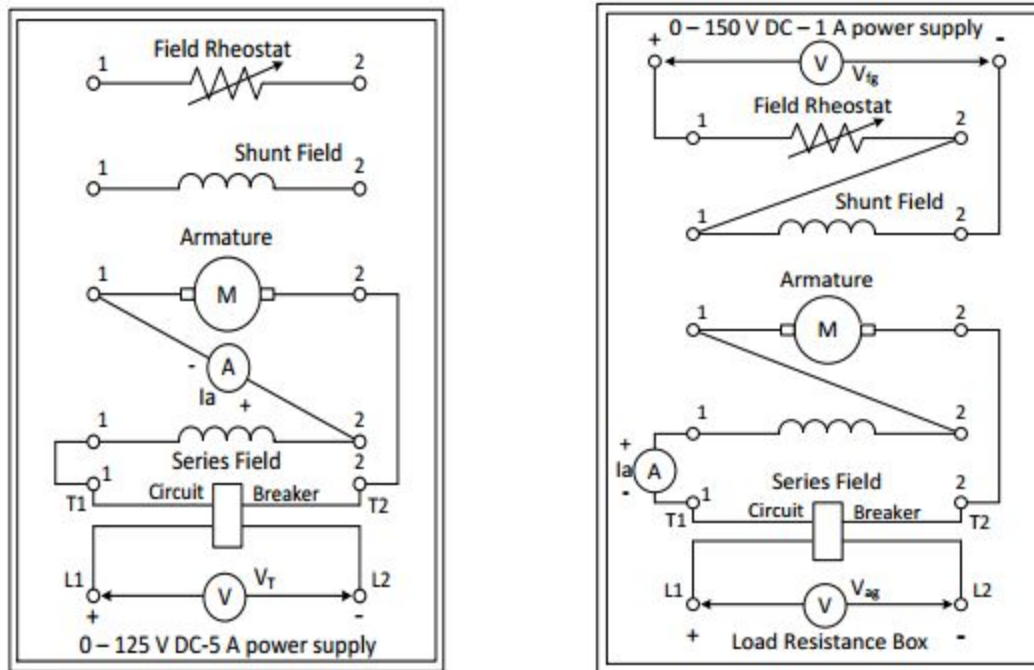
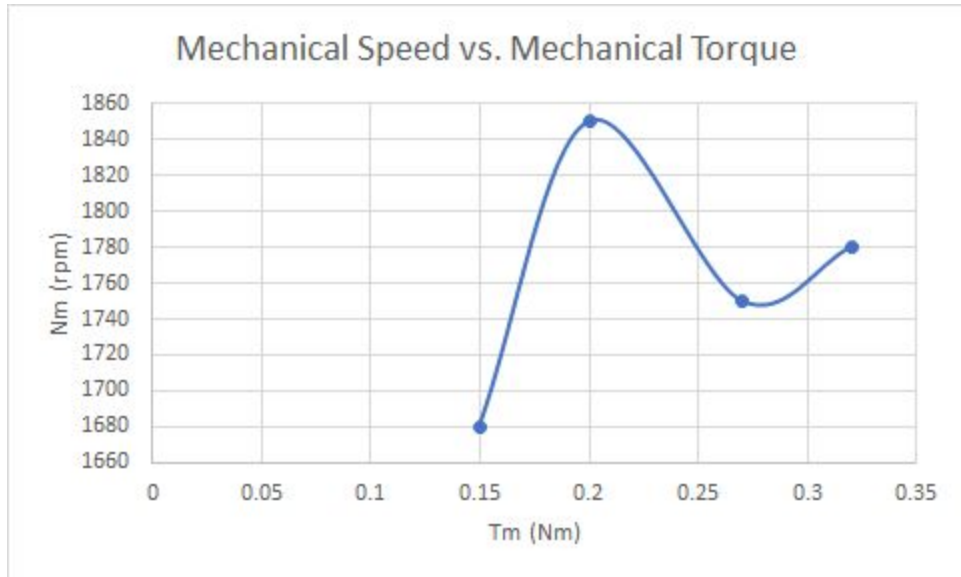


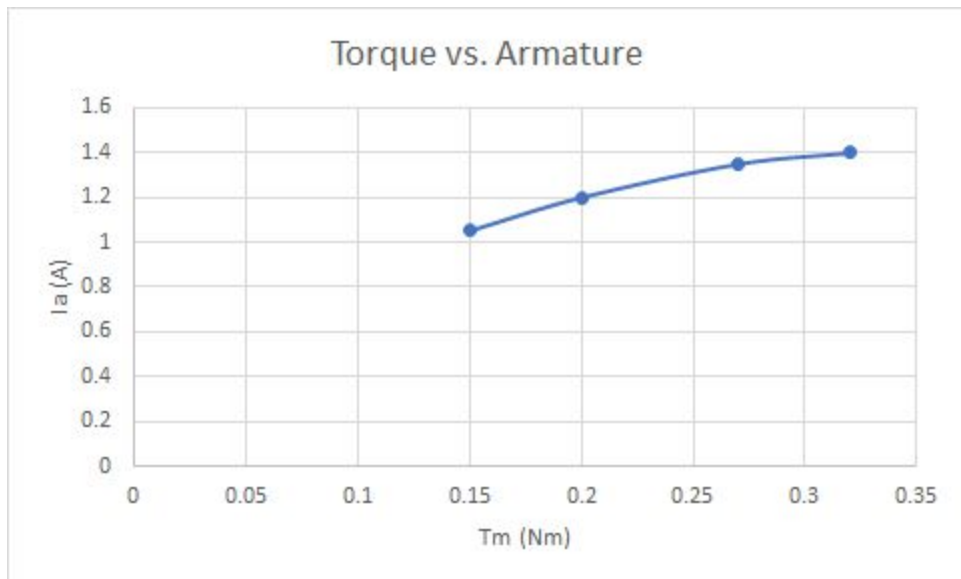
Figure 8: Electrical connection for the series-excited DC motor and separately excited

Table 3: Measured values of the mechanical speed, armature and field current, and the voltages

|                |      |      |      |      |
|----------------|------|------|------|------|
| $V_T = 90$ (V) | 1    | 12   | 123  | 1234 |
| $N_m$ (rpm)    | 1680 | 1850 | 1750 | 1780 |
| $I_a$ (A)      | 1.05 | 1.2  | 1.35 | 1.4  |
| $T_m$ (Nm)     | 0.15 | 0.2  | 0.27 | 0.32 |



**Figure 9: Mechanical speed vs. Mechanical Torque of a series-excited DC motor**



**Figure 10: Torque vs. Armature of a series-excited DC motor**

As the mechanical torque of the series-excited DC motor increases, the mechanical speed decrease and increases; as something might of been wrong for thee speed reading, and the armature current increases as it did in shunt-excited DC motor. This is shown in Figure 9 and 10. However, the speed decrease faster and current increase slower as torque increase in

series-excited motor compare to shunt-excited motor. The speed regulation cannot be calculated because the motor had a load attached when started.

### **Conclusion**

This laboratory exercise was successful in introducing and teaching us about the three different configuration of DC motor. After completing this lab, we learned how DC machines works. It is very interesting to see the effect of the load on the mechanical speed, the torque and the current of the motor. This was actually the first time I experienced a DC motor, and learned a lot from this lab. In shunt-excited, series-excited, and compound DC motor as torque increases, the speed decrease and armature current increases but the drop of speed and increase of current is different in each motor, which facilitate different characteristics. By comparing the operating characteristics of each motor, shunt-excited motor is least efficient but have lower speed regulation compare to the other two DC motors. The series-excited motor have high-speed regulation because as load varies, the speed drop is larger than other two DC motors. The compound motor has speed regulation in between the shunt-excited and series-excited motor because compound motor is mix of shunt and series motors and that is why the efficiency of compound motor is better than shunt-excited but not as good as series-excited motor. These differences between these motors are observed by the graphs and data collected during the test.

### **References**

EEE 131 – Electromechanics Laboratory, CSUS