

**ELEC 302 Lab 5**  
**Motor Torque, Speed, Losses, and Efficiency**

REFERENCE: Appropriate chapters of ELEC 316 text.

OBJECTIVE: The objective of this experiment is to familiarize the student with the operation of the Prime Mover/Dynamometer module to measure motor torque, speed, power, and efficiency.

EQUIPMENT:	Power Supply Module (0-120Vdc)	EMS 8821
	Prime Mover/ Dynamometer Module (1)	EMS 8960
	Prime Mover/ Dynamometer Module (2)	EMS 8960
	Data Acquisition Interface (DAI)	EMS 9062
	DAI 24V Power Supply	EMS 30004

### **INTRODUCTION:**

In this experiment, you will use two Prime Mover/ Dynamometer modules to measure torque, speed, power, and efficiency of a DC motor. The experiment will be conducted in three parts. The first part will demonstrate operation of the prime mover. The second part will demonstrate the operation of the dynamometer. The final part will demonstrate the measurement of motor efficiency.

The Prime Mover module uses a DC motor, and operates like a linear voltage to speed converter. A positive voltage will produce clockwise rotation of the motor, the higher the input voltage the faster the motor will turn. The Dynamometer is a device, which is used to mechanically load the motor and measure its output torque and speed. The load control knob on the Dynamometer will vary the mechanical load of the device.

In part one of the experiment the friction torque of the Prime Mover module will be measured. The friction torque is the twisting force that is experienced by the Prime Mover module when it is rotating without a mechanical load. The primary components of this torque are the friction of bearings and brushes of the DC motor, and the windage friction resulting from the air resistance of the rotor. When the Dynamometer is coupled to the Prime Mover module the torque on the Prime Mover increases due to the addition of belt friction and machine torque caused by the resistance offered by the Dynamometer.

A motor experiences both electrical losses and mechanical losses. Because of these losses, the mechanical output power of the motor is always less than the input electrical power.

### **PRIOR PREPARATION:**

Complete the following at a time determined by the laboratory instructor.

1. Show that the mechanical power output in watts of a motor can be found from the equation

$$P_{mech} (watts) = \frac{n(rpm) \cdot T(Nm)}{9.55}$$

2. A DC motor turns at a speed of 1460 rpm and produces an output torque of 3.0 Nm. The DC voltage applied to the motor is 100V and a current of 5.1A flows through the motor.
  - a. What is the efficiency of the motor?
  - b. How much are the power losses in the motor?

## **PROCEDURE:**

### **WARNING!**

**High voltages are present in this laboratory experiment!**

**Do not make or modify any banana jack connections with the power on!**

### **WARNING!**

**High speed rotating equipment are used in this laboratory experiment!**

**Ensure that loose clothing, cables, and leads are kept clear of this equipment. Do not open the protective closure when power is applied to the rotating modules!**

## **PART ONE: Prime Mover Operation**

1. Verify the all components required in the equipment section are present at the EMS workstation.
2. Make sure the main power switch of the Power Supply is OFF and the voltage control knob is fully CCW. Set the voltmeter selector switch to position 7-N.
3. Connect the LOW POWER INPUTs for the Prime Mover /Dynamometer Module(1) and the DAI to the 24V supply and turn it on.
4. Check that the DAI USB connector is attached to the computer. Start the computer and the LVDAM EMS application. On the *File* menu open file C:\Program Files\Lab Volt\Samples\E302\_5.dai. The Metering window should display meters for E1, I1, PQS1, N, T, P<sub>m</sub>, and A.
5. Select focus to the metering window by clicking on it. Select *Options -> Acquisition Settings*, set the *Sample Window* dialog box to *extended*. Then click OK, and close the box. Select *View -> check continuous refresh*.
6. Construct the circuit of Figure 1. Use the Prime Mover /Dynamometer Module on the left hand side of the workstation. Note that connection of the torque (T) and speed (N) terminals from the Prime Mover / Dynamometer module to the DAI module requires special (smaller sized) connection wires. Be sure to connect the white ground terminal from the P.M. to DAI module. Set the Prime Mover / Dynamometer controls as follows:
  - MODE switch .....PRIME MOVER (P.M.)
  - DISPLAY switch.....SPEED (N)
7. Turn on the main voltage power supply and adjust the DC supply voltage to about 30 volts dc. Monitor both the installed EMS voltmeter, and the metering window for proper indications. If proper indications are not immediately established, turn the voltage control knob CCW, turn off the power supply, and obtain instructor assistance.
8. Record the measured DC voltage on E1, the speed n indicated on the Prime Mover Display, the speed N indicated in the metering window, and the direction of rotation of the prime mover below.  
  
E1 = \_\_\_\_\_ n = \_\_\_\_\_ N = \_\_\_\_\_ Direction = \_\_\_\_\_
9. On the Prime Mover / Dynamometer, set the DISPLAY switch to the TORQUE position. Record the friction torque T<sub>f</sub>(PM) indicated by the Prime Mover display, and the torque T in the metering window.

T<sub>f</sub> = \_\_\_\_\_(Nm)                      T = \_\_\_\_\_(Nm)

Note that the Torque meter should be set to read in Nm (vice lbf-in). If necessary, on the LVDMS main menu bar select *Tools -> Options -> units -> select -> T(Nm), P(W)*.

10. On the Prime Mover / Dynamometer, set the MODE switch to the DYN position then wait a few seconds. Does the Prime Mover stop rotating? On the Prime Mover / Dynamometer, set the MODE switch back to the PRIME MOVER (P.M.) position. Turn the voltage control knob CCW, and turn off the main power supply.
11. Reverse the polarity of the leads at the Prime Mover Input. Turn on the main voltage power supply and adjust the DC supply voltage to about 30 volts dc. Record the data indicated below.

E1 = \_\_\_\_\_ n = \_\_\_\_\_ N = \_\_\_\_\_ Direction = \_\_\_\_\_

Did the direction of rotation reverse? What is the difference in the speed indicated by meter N?

12. Turn the voltage control knob CCW, and turn off the main power supply. Reconnect the leads to the Prime Mover Input in the original polarity.
13. Turn on the power supply. Open the *Data Table Application* use it to record the Prime Mover Voltage (E1), speed (N), and torque (T) respectively. Use the power supply control knob to increase Prime Mover speed in approximately 300 r/min increments from 0 to 2100 r/min. For each speed setting, record the Prime Mover voltage, speed, and torque in the data table.
14. Turn the voltage control knob CCW, and turn off the main power supply.
15. Open the *Graph window* by selecting it from the *Data Application* toolbar. Make the appropriate settings to obtain a plot of Prime Mover Speed (N) vs. Prime Mover Voltage (E1). Use the edit graph function to title the graph "Lab 5 Plot 1 N vs. E1", name the x-axis "Prime Mover Voltage (V)", and name the y-axis as "Prime Mover Speed (rpm)." Then save or print the graph for your report.
16. Open the *Graph window* by selecting it from the *Data Application* toolbar. Make the appropriate setting to obtain a plot of Prime Mover friction torque (T) vs. Prime Mover speed (N). Use the edit graph function to title the graph "Lab 5 Plot 2 T vs. N", name the x-axis "Prime Mover Speed (rpm)", and name the y-axis as "Prime Mover Torque (Nm)." Then save or print the graph for your report.

## **PART TWO: Dynamometer Operation**

In this part of the lab you will couple two Prime Mover / Dynamometers together using a timing belt. The lab instructor will demonstrate how to install the belt. The Prime Mover / Dynamometer on the left will be used as the Prime Mover. The module on the right will be used as the Dynamometer.

17. After connecting the timing belt, construct the circuit of Figure 2. Be sure to connect the T, and N meters to the Dynamometer.
18. Supply 24V DC power to both Prime Mover / Dynamometer modules as well as the DAI module. On the Prime Mover set the controls as follows:
  - MODE switch .....PRIME MOVER (P.M.)
  - DISPLAY switch.....SPEED (N)
19. On the Dynamometer set the controls as follows:
  - MODE switch .....DYN
  - DISPLAY switch.....TORQUE (T)
  - LOAD CONTROL MODE switch .....MAN.
  - LOAD CONTROL knob.....MIN. (fully CCW)
20. Turn on the main DC power and set the voltage control knob so the Prime Mover rotates at a speed of 1500 r/min.

21. On the Prime Mover set the DISPLAY switch to TORQUE (T) position. Record the opposition torque (T) indicated on the Prime Mover display.

$$T_{PM} = \underline{\hspace{2cm}} \text{ (Nm)} \quad \{n = 1500 \text{ rpm}, T_{DYN} = 0\}$$

Note that the torque indicated in the Dynamometer display still indicates zero even though the machines are mechanically coupled together. This is because the Dynamometer display indicates only the magnetic torque produced by the Dynamometer.

22. Return the DISPLAY switch on the Prime Mover to the SPEED position. On the Dynamometer, slowly turn the LOAD CONTROL knob clockwise until the torque  $T_{DYN}$  indicates 2.0 Nm. What happens to the prime mover speed as the torque ( $T_{DYN}$ ) increases?
23. On the Power Supply module, adjust the voltage control knob so that the Prime Mover rotates at 1500 rpm. Record the opposition torque indicated on the Prime Mover display  $T_{PM}$  and the non-corrected output torque  $T_{NC}$  in the metering window.

$$T_{PM} = \underline{\hspace{2cm}} \text{ (Nm)} \quad \{n = 1500 \text{ rpm}, T_{DYN} = 2.0 \text{ Nm}\}$$

$$T_{NC} = \underline{\hspace{2cm}} \text{ (Nm)} \quad \{n = 1500 \text{ rpm}, T_{DYN} = 2.0 \text{ Nm}\}$$

24. In the metering window, select the torque correction function for meter T (right click meter T, select *Meter Settings*, select *Mode* -> *C*). Meter T now indicates the Prime Mover output torque corrected for belt friction and windage. On the Power Supply module, adjust the voltage control knob so that the prime mover rotates at 1500 rpm. Record the corrected torque indicated in the metering window.

$$T_C = \underline{\hspace{2cm}} \text{ (Nm)} \quad \{n = 1500 \text{ rpm}, T_{DYN} = 2.0 \text{ Nm}\}$$

Note: The corrected torque should be larger than the non-corrected torque.

25. On the Power Supply module, adjust the voltage control knob CCW, and turn off the main power supply.

### **PART THREE: Motor Losses and Efficiency**

26. Verify construction of Figure 2, and 24Vdc power to both Prime Mover / Dynamometer modules as well as the DAI module. On the Prime Mover set the controls as follows:
- MODE switch .....PRIME MOVER (P.M.)
  - DISPLAY switch.....SPEED (N)
27. On the Dynamometer set the controls as follows:
- MODE switch .....DYN
  - DISPLAY switch.....TORQUE (T)
  - LOAD CONTROL MODE switch .....MAN.
  - LOAD CONTROL knob.....MIN. (fully CCW)
28. In the metering window select the torque correction function for meter T. Turn on the Power Supply module, and slowly adjust the voltage control knob so that the prime mover rotates at 1500 rpm.
29. On the Dynamometer, slowly turn the LOAD CONTROL knob clockwise until the torque  $T_{DYN}$  indicates 1.0 Nm. Record the Dynamometer speed (n) and corrected output torque  $T_C$  from the metering window (meters N and T).

$$T_C = \underline{\hspace{2cm}} \text{ (Nm)} \quad N = \underline{\hspace{2cm}} \text{ (rpm)} \quad \{T_{DYN} = 1.0 \text{ Nm}\}$$

30. Compute and record below the Prime Mover mechanical output power  $P_m$  using the equation given in the pre-lab assignment. Also, record Prime Mover mechanical output power  $P_m$  indicated on meter  $P_m$ .

$$P_m \text{ (computed)} = \text{_____ (W)} \quad P_m \text{ (measured)} = \text{_____ (W)}$$

The computed and measured values should be nearly equal.

31. Record the Prime Mover electrical input power  $P_{in}$  indicated on meter PQS1. Compute and record the Prime Mover power losses  $P_L = P_{in} - P_m$ .

$$P_{in}(\text{measured}) = \text{_____ (W)} \quad P_L(\text{computed}) = \text{_____ (W)}$$

32. Compute the Prime Mover efficiency  $\eta$ , and record Prime Mover efficiency  $\eta$  as indicated on meter A.

$$\eta \text{ (computed)} = \text{_____} \quad \eta \text{ (measured)} = \text{_____}$$

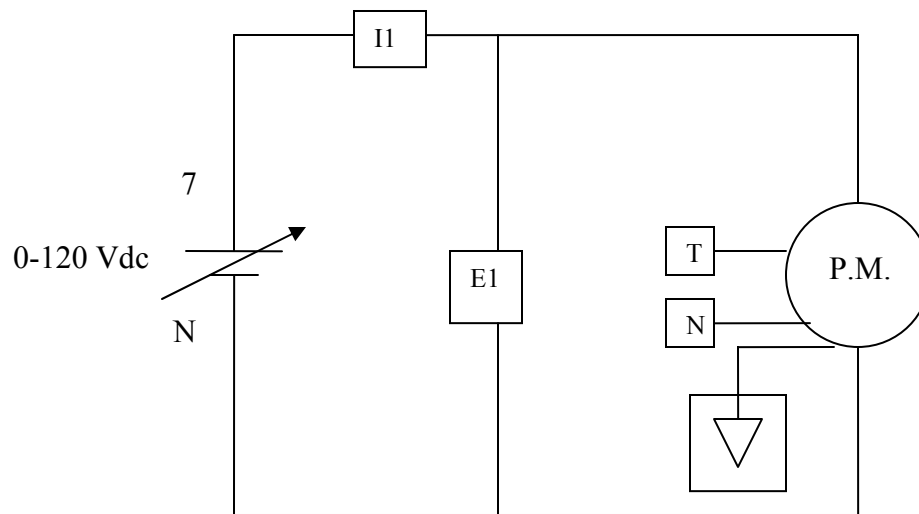
How do these two values compare?

33. On the Dynamometer, slowly turn the LOAD CONTROL knob fully CCW until the torque  $T_{DYN}$  indicates 0 Nm. On the Power Supply module, adjust the voltage control knob so that the Prime Mover rotates at 1500 rpm.
34. Open the *Data Table Application* and use it to record the Prime Mover voltage (E1), current (I1), electrical input power (PQS1), speed (N), output torque (T), mechanical output power ( $P_m$ ), and efficiency (A). On the Dynamometer, adjust the LOAD CONTROL knob so that the torque indicated on its display increases from 0 to 2.0 Nm in increments of 0.2 Nm. For each torque value record the data in the data table.
35. Store or print the data table. On the Power Supply module, adjust the voltage control knob CCW, and turn off the main power supply.
36. Open the *Graph window* by selecting it from the *Data Application* toolbar. Make the appropriate setting to obtain a plot of Prime Mover Efficiency (meter A) vs. Prime Mover mechanical output power ( $P_m$ ). Use the edit graph function to title the graph "Lab 5 Plot 3 Efficiency vs.  $P_m$ ", name the x-axis "Prime Mover Output Power (W)", and name the y-axis as "Prime Mover Efficiency (%)." Then save or print the graph for your report.
37. Turn off the 24Vdc power supply, turn off the computer, and remove all leads. Carefully remove the timing belt

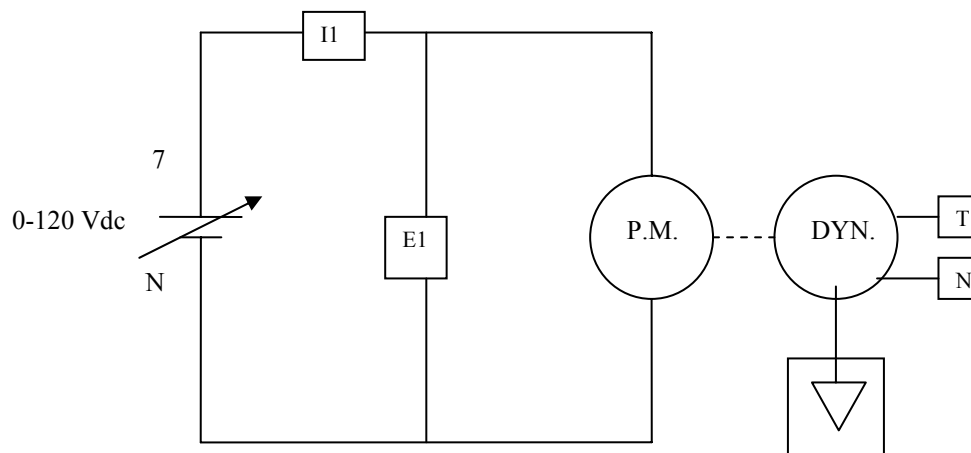
## **REPORT:**

Your report should be completed in the format requested by the instructor. Specifically, it must contain the following items.

1. All data tables (2) and all plots (3). Discuss the shape of plot 2 and plot 3.
2. Why is it necessary to correct the output torque? How does the corrected torque differ from the non-corrected torque and the torque on the Prime Mover Display?
3. Why does the current increase as the mechanical load increases in part three of the lab?



**Figure 1:** Prime Mover Circuit



**Figure 2:** Prime Mover Coupled to the Dynamometer