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**EE-260:** **Electrical Machines**

Lab 10: Squirrel Cage Induction Motor Characteristics

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# Three Phase Synchronous Generator Synchronization

## Objectives

Using Data Acquisition Interface (DAI):

* Demonstrate the operating characteristics of a three-phase induction motor using the Four-Pole Squirrel-Cage Induction Motor module
* To study the effects of varying the input line voltage on the induction motor characteristic

## Equipment

Hardware

* LabVolt Proprietary Toolkit

Software

* *LVDAC*



## Introduction

The simplest and the most widely used rotor for induction motors is the squirrel cage rotor. The squirrel cage induction motor consists of a laminated iron core which is slotted lengthwise around its periphery. Solid bars of copper or aluminum are tightly pressed or embedded into the rotor slots. At both ends of the rotor, short circuiting rings are welded or brazed to the bars to make a solid structure. The short-circuited bars, because their resistance is much less than the core, do not have to be specially insulated from the core.

## Lab Instructions

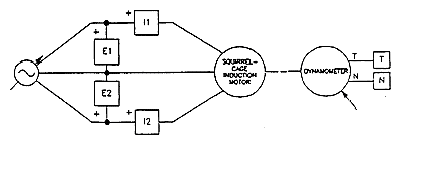
All questions should be answered precisely to get maximum credit. Lab report must ensure following items:

* Lab objectives
* Results (Graphs/Tables) duly commented and discussed
* Conclusion

# Lab Tasks

## Connections

Connect the equipment as shown in Figure 1, and make the appropriate settings on the Prime Mover I Dynamometer.



Figure

## Procedure

1. Install the Power Supply, Prime Mover / Dynamometer, Four-Pole Squirrel-Cage Induction Motor (Wye configuration), and Data Acquisition Interface {DAI) modules in the EMS workstation.
2. Mechanically couple the Prime Mover / Dynamometer to the Four-Pole Squirrel-Cage Induction Motor.
3. On the 'Power Supply’, make sure the main power switch is set to the O (off) position, and the voltage control knob is turned fully counterclockwise.
4. Ensure that the flat cable from the computer is connected to the DAI module.
5. Connect the LOW POWER Inputs of the DAI and Prime Mover / Dynamometer modules to the 24 Vac output of the power supply. On the Power Supply, set the 24 V - AC power switch to the I (on) position
6. Start the Metering application. In the metering window open the set up.
7. Set the Prime Mover / Dynamometer controls as follows:

MODE switch, DYN

LOAD CONTROL MODE switch MAN

LOAD CONTROL knob MIN (Fully ccw)

DISPLAY switch TORQUE (T)

## Characteristics of a Squirrel-Cage Induction Motor:

1. Turn on the Power Supply and set the voltage control knob so that the line voltage indicated by meter E1 is equal to 400 line-voltage of the squirrel-cage induction motor.
2. What is the direction of rotation of the squirrel-cage induction motor?

The motor rotates Clockwise.

1. Record in the following blank space the motor speed indicated by meter N inthe Metering window.

nNOM = 1476 r/min

1. Is the no-load speed almost equal to the speed of the rotating magnetic field (synchronous speed) given in the Discussion?

|  |  |
| --- | --- |
| **Yes ✓** | **No** |

1. In the Metering window, make sure that the torque correction function of meter T is selected. Meter T indicates the output torque of the squirrel- cage induction motor.
2. On the Prime Mover / Dynamometer, adjust the LOAD CONTROL knob so that the mechanical power developed by the squirrel-cage induction motor (indicated by meter Pm in the Metering window) is equal to 140 W (nominal motor output power).
3. Record the nominal speed, torque, and line current of the squirrel-cage induction motor in the following blank spaces.

nNOM = 1075 r/min

TNOM = 2.482 N.m (lbf.in)

INOM = 1.137 A

1. On the Prime Mover / Dynamometer, turn the LOAD CONTROL knob fully counterclockwise. The torque indicated on the Prime Mover / Dynamometer display should be 0 N.m (0 Ibf.in).
2. Record the motor line voltage ELINE line current ILINE active power P, reactive power Q, speed n, output mechanical power Pm and output torque T (indicated by meters E1, I1, C, A, N, Pm and T, respectively) in the data table and Table 1.
3. On the Prime Mover *I* Dynamometer, adjust the LOAD CONTROL knob so that the torque indicated on the module display increases by 0.3 N.m (3.0 Ibf.in) increments up to 1.8 N.m (15.0 Ibf.in). For each torque setting, record the data in the data table and Table 1.

Table

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Eline  V | Iline  A | Pin  W | Q  VAR | n  rpm | Pm  W | τ  N.m | η  % | s  % |
| 382.7 | 0.341 | -27.36 | 207.5 | 1497.4 | 0.278 | 0 | - | 0.17 |
| 382.4 | 0.378 | -3.209 | 207.6 | 1470.2 | 22.96 | 0.3 | - | 2.02 |
| 382.1 | 0.433 | 22.42 | 212.8 | 1439 | 45.35 | 0.6 | 20.27 | 4.23 |
| 381.8 | 0.506 | 49.69 | 222 | 1403.2 | 67.24 | 0.9 | 13.31 | 6.89 |
| 381.3 | 0.587 | 75.87 | 233.1 | 1364.4 | 86.18 | 1.2 | 11.59 | 9.93 |
| 381 | 0.682 | 103.8 | 249.3 | 1319.6 | 104.4 | 1.5 | 100.03 | 13.67 |
| 380.4 | 0.793 | 132.8 | 271.6 | 1264 | 120.2 | 1.8 | 90.51 | 18.67 |
| 380.3 | 0.834 | 142.9 | 280.7 | 1242.2 | 124.7 | 1.9 | 87.22 | 20.75 |
| 379.9 | 0.868 | 151 | 288.6 | 1222.8 | 128.2 | 2.0 | 84.90 | 22.66 |
| 379.3 | 0.923 | 163.8 | 301.8 | 1188.2 | 132.1 | 2.1 | 80.64 | 26.24 |
| 380.1 | 0.963 | 173.2 | 312.7 | 1164.2 | 135.2 | 2.2 | 78.06 | 28.84 |

1. In the data table window, confirm that the data has been stored, edit the table so as to keep only the values of the motor line voltage ELINE line current ILINE active power P, reactive power Q, speed n, output mechanical power Pm and output torque T (data in columns E1, I1, C, A, N, Pm and T, respectively). Then calculate and record the efficiency (η) and the slip(s) in table 2.
2. Does the motor line current indicated in column I1 increase as the mechanical load applied to the squirrel-cage induction motor increases?

|  |  |
| --- | --- |
| **Yes ✓** | **No** |

1. In the Graph window, make the appropriate settings to obtain a graph of the motor- speed (obtained from meter N) as a function of the motor-torque (obtained from meter N, name the x-axis as squirrel-Cage Induction-Motor Torque, name the y-axis as Squirrel-Cage Induction-Motor Speed, and print the graph.



1. Briefly describe how the speed varies as the mechanical load applied to the squirrel-cage induction increases i.e., as the motor torque increases.

**Answer:** The speed of the motor decreases as the mechanical load applied to the motor increases which causes the motor slip S to increase. If the motor is operating in the linear region, a decrease in speed due to any factor results in an increase in torque which causes an acceleration, and the motor again operates at the same point.

1. Indicate on the graph the nominal speed and torque of the squirrel cage induction motor measured previously.
2. Using the graph, Determine the breakdown torque of the squirrel cage induction motor:

T BREAKDOWN = 3.07 N.m (lbf.in)

1. Determine the minimum-speed torque. This torque is a good approximation of the locked-rotor torque of the squirrel-cage induction motor

T LOCKED ROTOR = 2.34 N.m (lbf.in)

1. Compare the breakdown torque and locked-rotor torque with the nominal torque of the squirrel-cage induction motor.

**Answer:** The breakdown and locked-rotor torque of the squirrel-cage induction motor are approximately 2.5 and 2.3 times the nominal torque, respectively.

1. In the Graph window, make the appropriate settings to obtain a graph of the motor active (P) and reactive (Q) powers (obtained from meters C and A, respectively) as a function of the motor speed (obtained from meter N) using the data recorded previously in the data table.



1. Does graph confirm that the squirrel-cage induction motor always draws reactive power from the ac power source?

**Answer:** Yes, by looking at the graph, it is confirmed that the motor draws reactive power from the source at all times.

1. Does graph confirm that the squirrel-cage induction motor draws more electrical power from the ac power source as it drives a heavier load?

**Answer:** Yes, as the motor drives a heavier load, its rotational speed decreases and by looking at the graph, it is confirmed that the real power drawn by the motor increases with an increasing load.

1. Observe that when the squirrel-cage induction motor rotates without load, the reactive power exceeds the active power. What does this reveal?

**Answer:** As the motor’s assembly is inductive in nature, under no load, it acts as an inductor drawing reactive power from the supply.

1. In the Graph window, make the appropriate settings to obtain a graph of the motor line current ILINE (obtained from meter I1) as a function of the motor speed (obtained from meter N) using the data recorded previously in the data table.



**Answer:** The line current increases as the motor’s speed decreases which indicates that a larger torque is required for an increasing load.

1. How many times greater than the nominal line current is the starting line current (use the line current measured at minimum speed as the starting current)?

**Answer:** Nominal line current is approx. 4 times greater than the starting line current.

1. Adjust the line voltage Eline to 300 volts then repeat from step 14 to step 26 but on the Prime Mover / Dynamometer, carefully adjust the LOAD CONTROL knob so that the torque indicated on the module display increases by 0.1 N.m (1.0 Ibf.in) increments take the increment in the load torque.

Table

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Eline  V | Iline  A | Pin  W | Q  VAR | n  rpm | Pm  W | τ  N.m | η  % | s  % |
| 298.6 | 0.264 | -4.451 | 120.6 | 1481.6 | 0.231 | 0.003 | - | 1.24 |
| 298.3 | 0.289 | 3.666 | 122.4 | 1463.6 | 8.205 | 0.107 | 223.81 | 2.48 |
| 298.1 | 0.316 | 11.27 | 124.8 | 1448 | 15.31 | 0.202 | 135.84 | 3.59 |
| 297.7 | 0.351 | 19.79 | 127.3 | 1429.4 | 22.81 | 0.305 | 115.26 | 4.99 |
| 297.5 | 0.39 | 28.43 | 131.5 | 1409.4 | 30.11 | 0.408 | 105.90 | 6.23 |
| 297.3 | 0.435 | 37.98 | 136.5 | 1385.6 | 37.67 | 0.519 | 99.18 | 8.21 |
| 297.1 | 0.474 | 45.24 | 140.9 | 1366 | 43.44 | 0.607 | 96.02 | 9.80 |
| 296.7 | 0.519 | 53.76 | 146.4 | 1343 | 49.39 | 0.702 | 91.87 | 11.69 |
| 296.5 | 0.568 | 62.39 | 153.1 | 1317.6 | 55.44 | 0.804 | 88.86 | 13.84 |
| 296 | 0.631 | 72.77 | 163.3 | 1282.8 | 61.4 | 0.914 | 84.37 | 16.93 |
| 295.7 | 0.696 | 82.67 | 173.9 | 1246.6 | 66.62 | 1.021 | 80.58 | 20.32 |
| 295.9 | 0.755 | 91.58 | 185.3 | 1211.6 | 70.54 | 1.112 | 77.02 | 23.80 |
| 295.6 | 0.823 | 100.9 | 198.7 | 1169.2 | 73.78 | 1.205 | 73.12 | 28.29 |
| 297.6 | 0.907 | 112.3 | 220 | 1105.8 | 74.48 | 1.286 | 66.32 | 35.64 |
| 297.7 | 0.974 | 120.6 | 235.9 | 1061.2 | 77.62 | 1.397 | 64.36 | 41.34 |
| 296.4 | 1.03 | 126.3 | 247.2 | 996.6 | 75.04 | 1.438 | 59.41 | 50.51 |
| 295.4 | 1.24 | 144.9 | 307.4 | 797.6 | 67.85 | 1.625 | 46.82 | 88.06 |

## Direction of Rotation

1. On the Four-Pole Squirrel-Cage Induction Motor, interchange any two of the three leads connected to- the stator windings.
2. Turn on the Power Supply and set the voltage control knob so that the line voltage indicated by meter E1 is approximately equal to the nominal line voltage of the squirrel-cage induction motor. What is the direction of rotation of the squirrel-cage induction motor?

**Answer:** The squirrel-cage induction motor is rotating in an anticlockwise direction.

1. Does the squirrel-cage induction motor rotate opposite to the direction noted previously in this exercise?

|  |  |
| --- | --- |
| **Yes ✓** | **No** |

# Conclusion

In this lab, we practically witnessed the operating characteristics of a four-pole squirrel cage induction motor. We recorded specific readings, such as output torque, mechanical power, speed, etc., to verify the basic concepts of induction motors. Moreover, we plotted the induction motor's torque speed, power, and current characteristics and identified the reasons behind the shape of the graph obtained. This helped in the understanding of the underlying concepts behind these outputs.