# ECE 370
# POWER & ENERGY SYSTEMS

## EXPERIMENT 8
## INDUCTION MACHINES

### Objective

The objectives of this laboratory experiment are summarized below:

1. Perform the no-load and locked-rotor tests on a three-phase induction motor.
2. Derive the exact equivalent circuit for a three-phase induction motor from the no-load and locked rotor test data.
3. Plot the efficiency, power factor, input current, and torque of a three-phase induction motor as a function of its speed.
4. Display the transient starting current of a three-phase induction motor on the storage oscilloscope and understand its significance.
5. Gain an understanding of the requirement for induction generator operation and its limitations as a practical generator.

### Pre - Lab

The objective of this pre-lab is to develop a computer program that will calculate the **"exact"** equivalent circuit for a 3ϕ induction motor. When your program is working, test it with this data: DC: 11⅔ V, 1 A; NL: 208 V, 1.46 A, 80 W; LR: 46.3 V, 1.7 A, 85 W; $P_{ROT}$: 0.05 Nm @ 1800 rpm.

### Procedure

Specifications for the laboratory Induction Motor (IM-100) is provided in the Hampden Manual. Figure 1 shows the proper connection scheme.

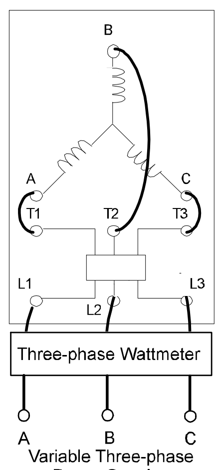


***Figure 1.*** *Induction Motor Wiring.*

The exact equivalent circuit for an induction motor is shown in Figure 2.

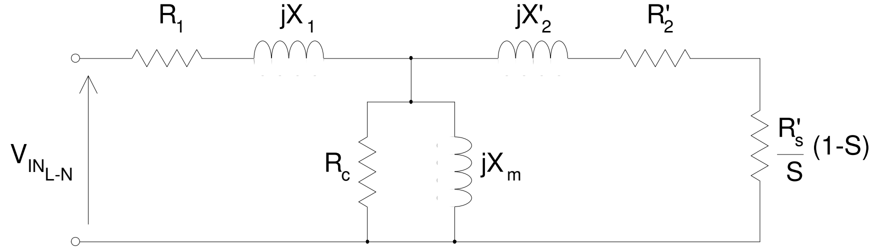


***Figure 2.*** *Exact Equivalent Circuit of an Induction Motor.*

Figure 3 shows the necessary instrumentation for the experiment. Consider an appropriate scheme for connection of the Yokogawa digital power meter to the induction motor for measuring the three-phase real and reactive powers.

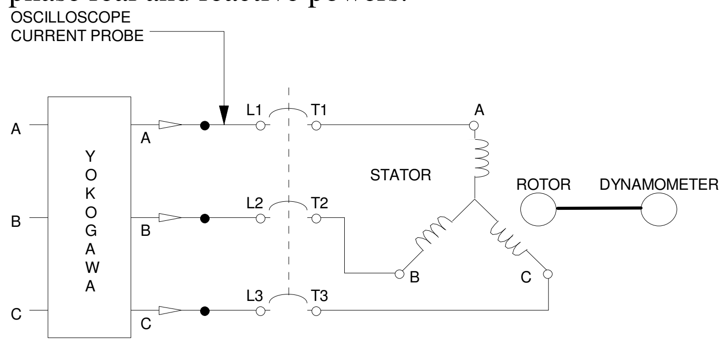


***Figure 3.*** *Test Configuration.*

The dynamometer is operated the same way as it was operated for the dc machine experiments. With the induction motor unexcited, measure its rotational losses at 1800 rpm.

<u>*Part 1 - Development of the Induction Motor Equivalent Circuit*</u>

Set the three-phase variable power supply voltage to zero, and calibrate the torque indicator display by setting it to zero. With the dynamometer shaft locked, slowly increase the voltage and perform the locked-rotor test at the *rated* (1.7 A) induction motor *current*. Record all of the appropriate readings, as well as the torque produced at standstill by the rated current. Switch off and unlock the shaft.

Mechanically decouple the induction motor from the dynamometer and run the no-load test at the *rated voltage*. Record all of the appropriate readings.

Measure the resistance of the stator winding by an ohmmeter. You are wanting to model it as wye-connected, therefore you must half the ohmmeter value.

From the resistance measurement, locked-rotor test, and the no-load test obtain the parameters of the exact equivalent circuit for the induction motor.

<u>*Part 2 - Efficiency, Power Factor, Current, and Torque vs. Speed*</u>

Connect the dynamometer to the induction motor. Use the dynamometer as the load and record the torque, speed, input real and reactive power, input current, and power factor at several operating points. You will be able to measure a very limited range of values from no-load to about 1.5 times the rated current.

Use the recorded data to plot torque, input real power, output power, efficiency, reactive power, input current, and power factor versus speed for the induction motor. This will be your measured results. Use the exact equivalent circuit of the motor obtained in *Part 1* to obtain plots of torque, input real power, output power, efficiency, reactive power, input current, and power factor as a function of speed from zero to 1800 rpm. This will be your analytical results.

Compare the analytical and measured results by plotting them on the same set of axes.

<u>*Part 3 - Transient Starting Current*</u>

Use the storage features of the oscilloscope to display the transient starting current of the induction motor. Proceed with the following steps:

1. Set the oscilloscope time scale (SEC/DIV) to 100 msec. Then disconnect the induction motor from the supply by moving the motor circuit breaker switch to the "off" position.

2. Push the **SINGLE SEQ** button to start the acquisition of a single-shot waveform. Try to push this button when the flat line trace starts at the far left hand side of the oscilloscope LCD display. To cancel the acquisition mode push the **RUN/STOP** button twice.
3. With the dynamometer decoupled and the rated voltage applied to the motor stator, move the circuit breaker switch to the "on" position to connect the motor to the supply. This feature of the oscilloscope will allow you to capture only one sweep of the signal. The first stored trace probably will not be to your liking. In this case, try again.
4. Observe the traces of the motor starting current. You can adjust the channels (VOLTS/DIV) and the time (SEC/DIV) scales to display a good picture after storing a single shot of the waveforms.
5. Use the CompactFlash Card to save this trace of the motor starting current, then print it.

Identify the transient period of the starting current, and explain its impact on the terminal voltage.

<u>*Part 4 - Induction Generator Operation*</u>

Run the induction motor at a very low speed and record the direction of its rotation. Then reduce the motor supply voltage to zero. Connect the dynamometer as a motor, and check that the dynamometer is turning in the same direction as the induction motor. If not, reverse the polarity of the voltage that is applied to the dynamometer field winding.

Energize the induction motor and increase the terminal voltage until the rated voltage is applied to the motor. Then energize the dynamometer and run it at a speed below 1800 rpm. Record the real and reactive power of the induction motor. Increase the speed of the dc motor (dynamometer) to 1825 rpm, by decreasing the field voltage. Repeat the measurements that were taken in Part 2; then repeat all this at 1850 rpm. Pay special attention to the sign of the real and reactive power. Confirm that the induction generator receives its ***reactive power*** from the ac supply.

**Documentation**

The formal report this Lab is due on Monday of tenth week. It will consist of a user's manual for your program along with the test data taken in the lab, so that the program's accuracy can be assessed. Write the report as though you were working in your first job after graduation and your program had been developed to enable non-engineers in your department to analyze motor-sizing problems, i.e., you should explain what data is needed and how to run the software. Assume the person using the program is technically oriented, but may not have an engineering degree. A suggested format for the report is:

- Summary - What is in the report (not what you did in the pre-lab or lab). Write this after you have finished the report.
- Introduction - Background theory, **do not go into too much detail**, assume the reader is technically oriented. Explain what each component in the model represents and how to get the parameter values from the test data.
- User Guide - A **brief** description of what the program does and what the user has to do to make it work. Refer to the code presented in an appendix.
- Results - Present the required graphs with the lab results marked on them. Comment on the accuracy.
- Conclusion - Suggest how the program can be used as one step in a larger study which has to optimize motor selection. One computer program and formal report must be must be produced by each lab group.