EE 330/330L Energy Systems (Spring 2012)
Laboratory 5 Three-Phase Induction Motor

Introduction/Background

In this laboratory, you will take the necessary measurements to determine the equivalent circuit model for a three-phase induction motor. In addition, efficiency and speed-torque curves for the motor will be measured.

Experiment 1- No-Load Test

1) Record the nameplate data for the three-phase induction motor being tested. Based on the nameplate data, determine the number of poles in this induction motor and its synchronous speed n_{sync}. Is the motor Y- or Δ-connected?
2) Connect the induction motor as shown in Figure 1. Ensure that the three-phase breaker is 'off' and that the Proney brake is not connected.
3) Turn 'on' the three-phase breaker to start the induction motor. Measure and record the three line currents $I_{L,A,\text{NL}}$, $I_{L,B,\text{NL}}$, & $I_{L,C,\text{NL}}$, line-to-line/terminal voltages $V_{T,AB,\text{NL}}$, $V_{T,BC,\text{NL}}$, & $V_{T,CA,\text{NL}}$, and powers $P_{1,\text{NL}}$ & $P_{2,\text{NL}}$. For two-wattmeter method, the total power to any three-phase load is the sum of the wattmeter readings (an individual reading may be negative). Therefore, $P_{\text{in,NL}} = P_{1,\text{NL}} + P_{2,\text{NL}}$.
4) Let motor run for 5 additional minutes before moving on to the next experiment. The next tests need the motor windings to be warm for best accuracy. Then, set the three-phase breaker to 'off' and unplug the power cord. Do NOT disconnect any other wires before reading next experiment.

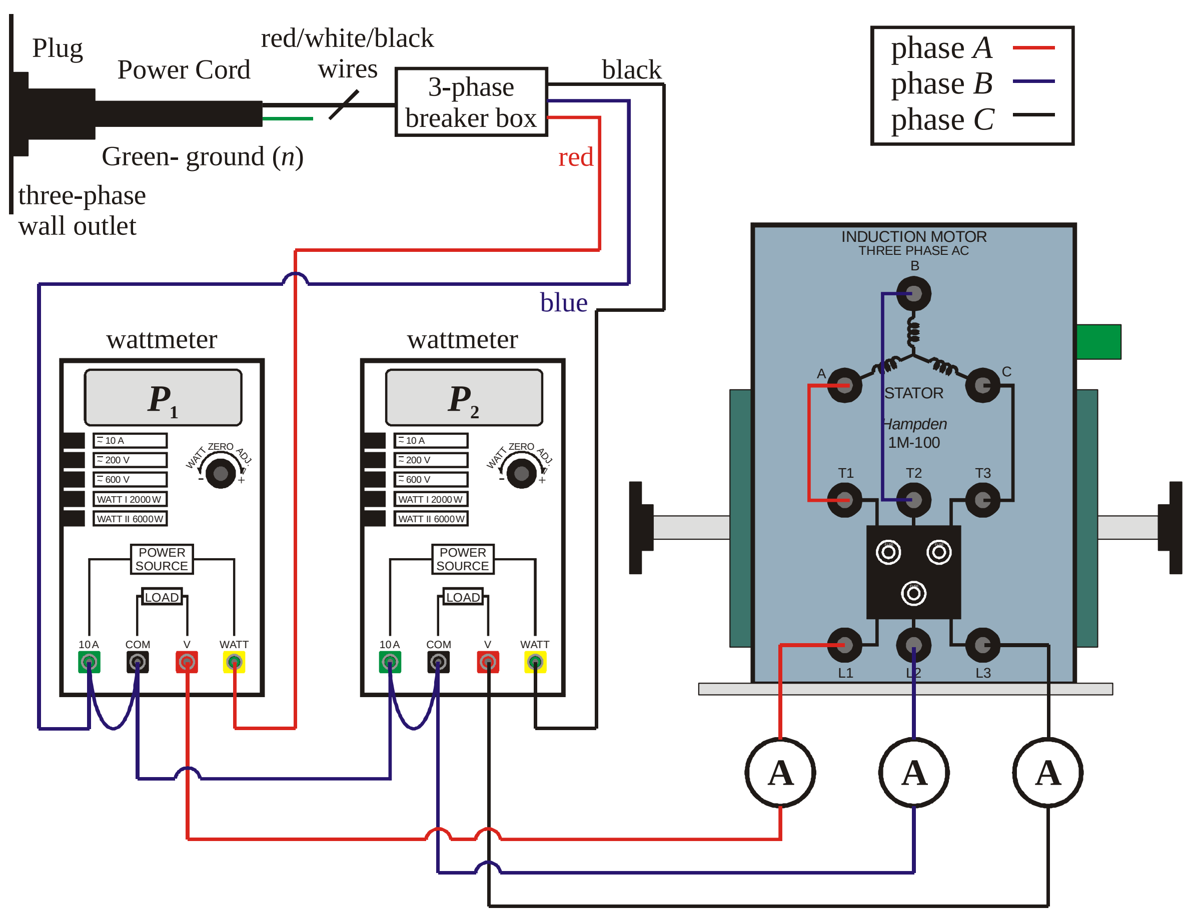

Figure 1 Set-up for No-Load Test (Experiment 1).

Experiment 2- Locked Rotor Test

1) Connect the induction motor as shown in Figure 2. Note that the differences with Figure 1 are the insertion of the variac and connecting the Proney brake.
2) Ensure variac is set to zero (all the way CCW) and that the Proney brake is tightened (CW looking from the top) to 'lock' the rotor (i.e., shaft does not rotate). Turn the three-phase breaker 'on'. Using the variac, slowly increase the applied three-phase voltage until the line currents measured by the ammeters are approximately equal to the rated value taken from the nameplate.
3) Measure and record the three line currents $I_{L,A,\mathrm{LR}}$, $I_{L,B,\mathrm{LR}}$, & $I_{L,C,\mathrm{LR}}$, terminal voltages $V_{T,AB,\mathrm{LR}}$, $V_{T,BC,\mathrm{LR}}$, & $V_{T,CA,\mathrm{LR}}$, and powers $P_{1,\mathrm{LR}}$ and $P_{2,\mathrm{LR}}$. The total locked rotor power is $P_{\mathrm{in,LR}} = P_{1,\mathrm{LR}} + P_{2,\mathrm{LR}}$.
4) Reduce the variac voltage to zero, set the three-phase breaker to 'off', and unplug the power cord. Do NOT disconnect any other wires before reading next experiment.

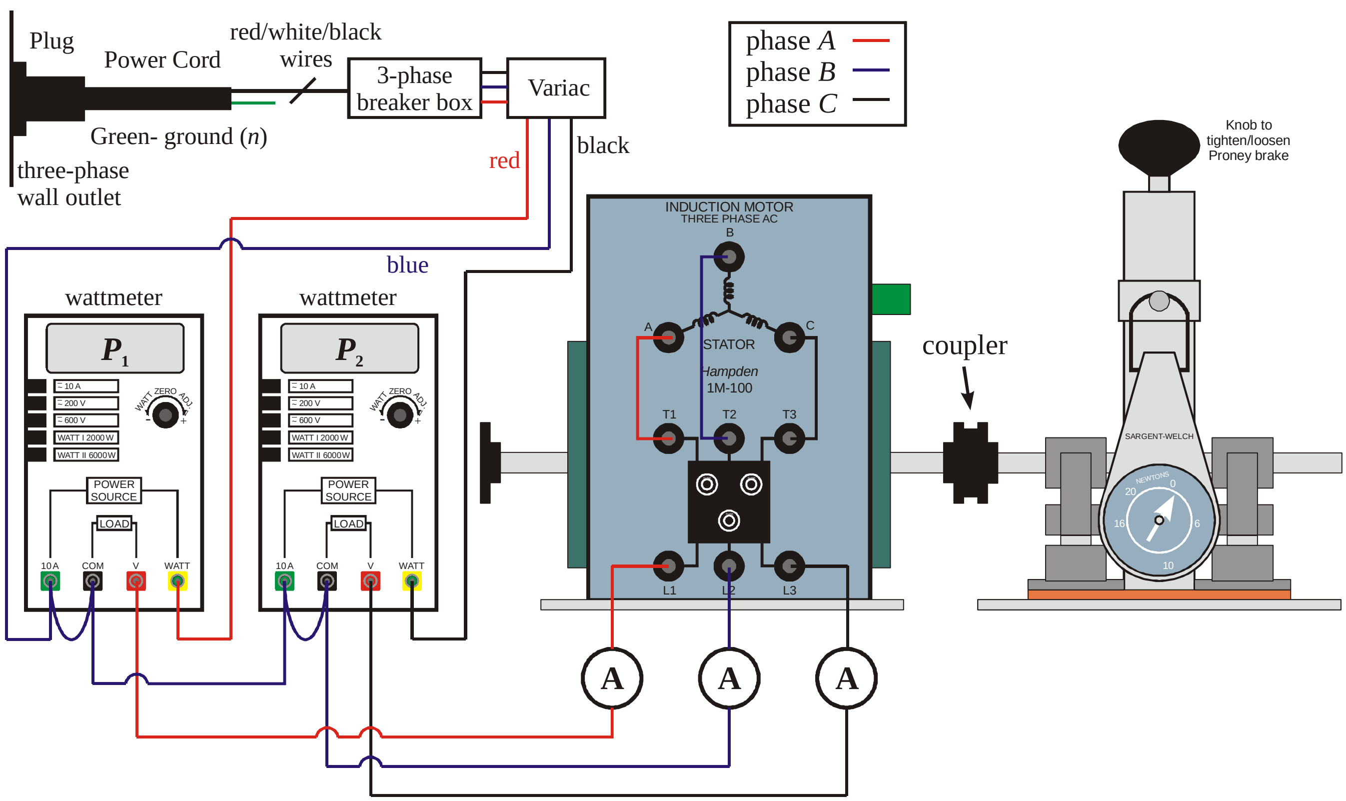

Figure 2 Set-up for Locked Rotor Test (Experiment 2).

Experiment 3- DC Test

1) Disconnect the three wires attached to terminals *A*, *B*, and *C* on the induction motor. Leave other pieces of equipment and wires connected, even if they are not being used. Using an ohmmeter, measure and record the resistances $R_{T1,AB}$, $R_{T1,BC}$, and $R_{T1,CA}$.
2) Next, connect a DC power supply across terminals *A* and *B* as shown in Figure 3 (wires and pieces of equipment not in use omitted for clarity, but left in place). The DC power supply requirements are that it be able to output at least 35 V and 3 A of current.
3) With the power 'off', set the current (limit) to maximum and the voltage to zero on the DC power supply. Turn the DC power supply 'on', and slowly increase the applied DC voltage until the DC current is approximately equal to the rated line current of the motor. Wait. Note that the line current starts to drop. Adjust the DC voltage until the DC current is approximately equal to the rated line current again. Repeat as necessary until readings stabilize or until 5 minutes have elapsed. [Note: Like a light bulb filament, the terminal resistance increases as the armature windings heat up.]
4) Measure and record the DC voltage $V_{DC,AB}$ and current $I_{DC,AB}$.
5) Turn the DC power supply 'off'. Disconnect the DC power supply, ammeter, and voltmeter.

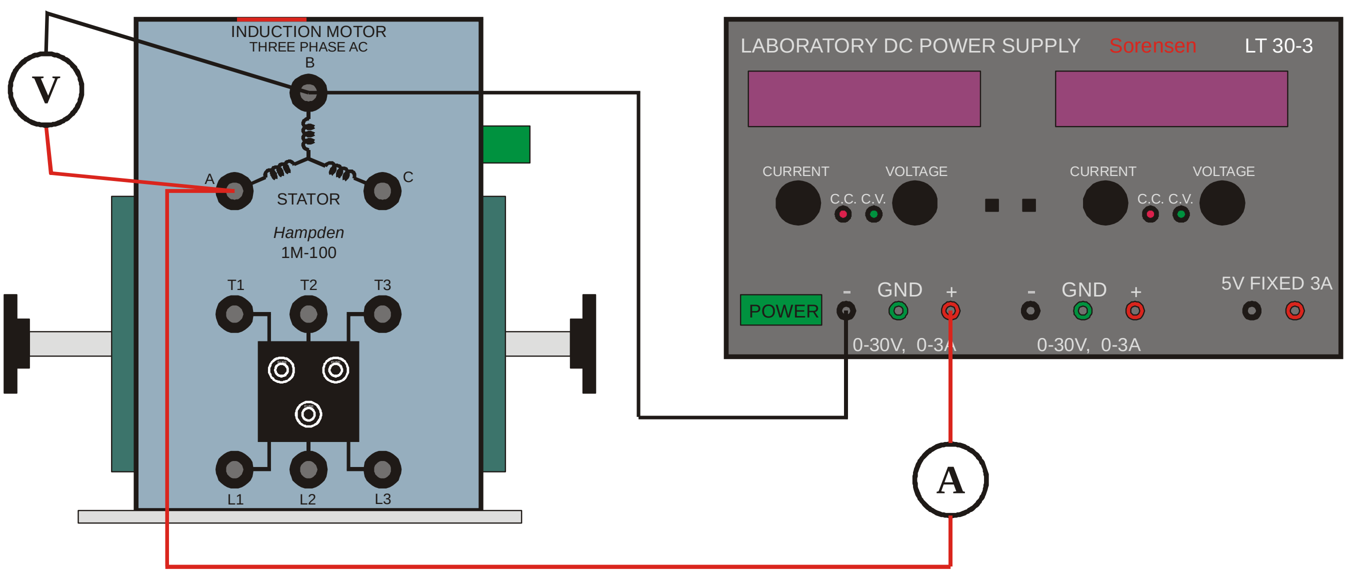

Figure 3 Set-up for DC Test (Experiment 3).

Experiment 4- Load Test

1) Connect the induction motor as shown in Figure 4. Note that it is configured the same as for the locked rotor test with the exception that the variac is not used. Measure the radius R_{proney} of the Proney brake flywheel.

2) Ensure that the Proney brake is loosened (turn CCW looking from top) to allow the motor to rotate freely. Turn the three-phase breaker 'on' to start the induction motor. Ensure that the shaft turns such that the top rotates toward the wall (CW if looking at shaft from Proney brake side). If rotation is in wrong direction, turn three-phase breaker 'off', switch two phases (e.g., swap leads to B and C), and turn three-phase breaker 'on' to reverse direction of rotation. This is necessary to keep the spring scale attached to the Proney brake from popping loose.

3) In a table, starting with the Proney brake loose (scale reads 0 N), measure and record the line currents $I_{L,A,\text{LD}}$, $I_{L,B,\text{LD}}$, & $I_{L,C,\text{LD}}$, line-to-line/terminal voltages $V_{T,AB,\text{LD}}$, $V_{T,BC,\text{LD}}$, & $V_{T,CA,\text{LD}}$, powers $P_{1,\text{LD}}$ and $P_{2,\text{LD}}$, shaft speed n_m (RPM), and applied force F_{app} (N). With the motor running, tighten the Proney brake (turn CW) in steps of 2 N and repeat until the maximum scale value of 20 N is reached (or until the Proney brake won't tighten anymore). Note the needle on the scale will vibrate, adjust Proney brake until your 'eyeball-average' is at the desired value. As a caution, the Proney brake tends to loosen after a minute or so, keep an eye on it to ensure accurate data.

4) Loosen Proney brake, set the three-phase breaker to 'off', and unplug the power cord. Verify all necessary data has been recorded, before disassembling test set-up.

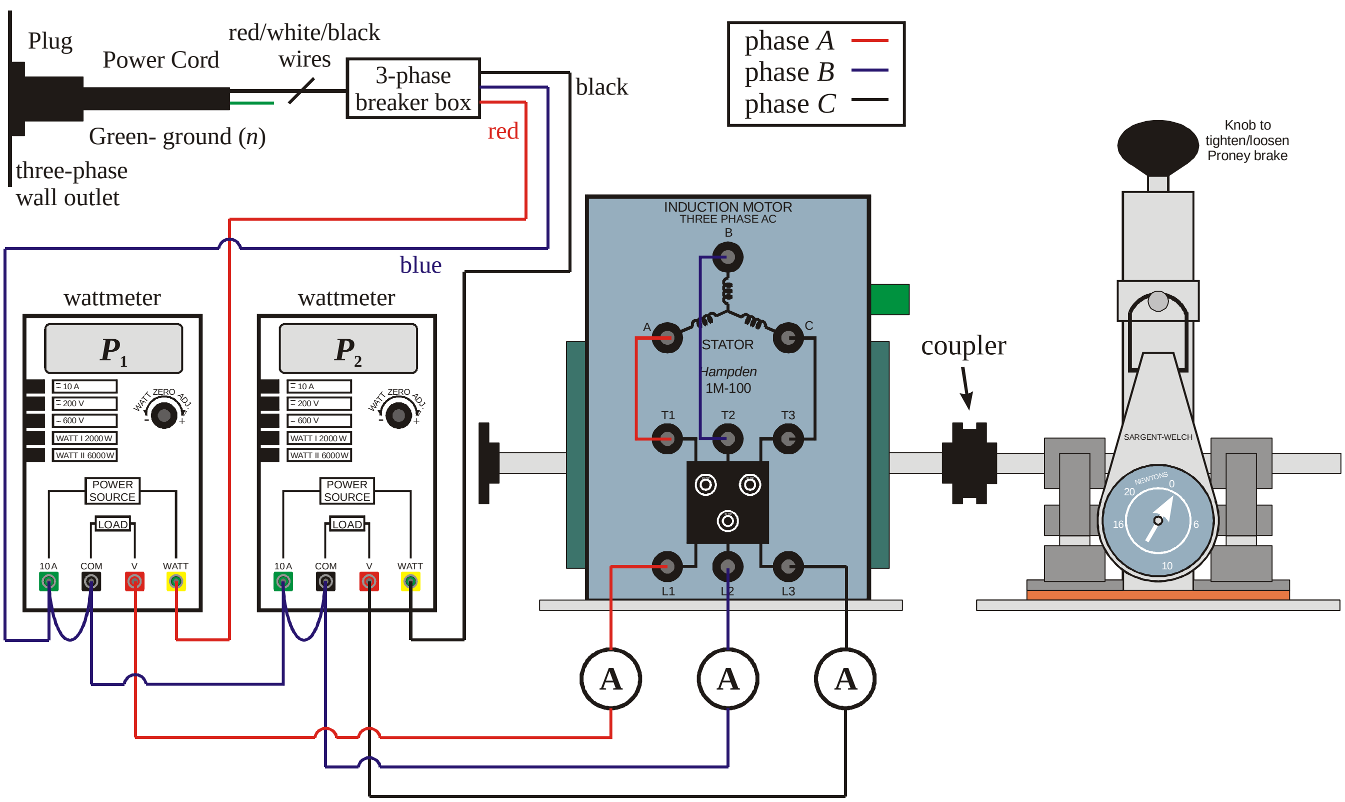

Figure 4 Set-up for Load Test (Experiment 4).

Analysis

1) Using the data from experiments 1-3, determine and sketch a fully labeled approximate per-phase equivalent circuit for the induction motor (e.g., Figures 6-55 and 6-57 of text). Note that R_C is unknown. Use 'Rules of Thumb' given in Figure 6-56 to estimate X_1 and X_2. Where possible, use averaged values for currents and voltages. Detail all calculations/steps and discuss any assumptions/approximations made in the calculations. Comment on the differences between ohmmeter readings and DC test terminal resistances.
2) Using the no-load data, estimate the rotational losses P_{rot}.
3) Using the data from experiment 4, make a table with columns (in order)- $V_{T,\text{ave}}$, $I_{\text{L,ave}}$, P_{in}, n_m, ω_m, slip s, load torque τ_{load}, P_{out}, and efficiency η (%). How do these variables change as the load changes?
4) Plot the measured load torque τ_{LD} versus speed n_m over the range of the measured speeds.
5) Plot the measured efficiency η (%) versus speed n_m over the range of the measured speeds.
6) Using the equivalent circuit, calculate the Thevenin equivalent voltage $\bar{V}_{TH}$ and impedance $\bar{Z}_{TH}$. Assume $V_T = 210\ \text{V}_{\text{rms}}$.
7) Plot the induced torque τ_{ind} versus speed n_m from 0 to n_{sync}. Determine the start-up torque τ_{start}, rated torque τ_{rated} (at $n_{m,\text{rated}}$), pull-out torque $\tau_{\max}$, and the slip $s_{\max}$ & speed $n_{\max}$ at the pull-out torque.

Summary and Conclusions

Summarize and discuss significant findings. How well does this induction motor perform? Are your results consistent with theory? Why/why not?

Lab Report

- The results should be organized into a typed short report. Where possible tabulate results.
- Unless otherwise specified, follow format guidelines contained in course syllabus.
- Include a cover page, Introduction, a body broken down into subsections/paragraphs based on the steps in assignment, and a Summary & Conclusions.
- Put **calculations**, results, and plots/figures in the body of the report in the order specified. Appendices are **NOT** to be used as a "dumping ground" for the calculations, results, and figures. However, long mathematical derivations may be attached as Appendices or done in the logbook **if referenced in the text** of the report. Your logbook is definitely a reference item.

Report and logbook due Monday, April 23, 2012.