Induction Motor Drive Performance

Introduction

Over the past few years, there have been great improvements in power electronics and their application to motor drives. Today, these motor drives are dependable and can provide highly accurate speed and voltage control, and even torque control. Induction motors and drives can be found in applications ranging from electric and hybrid vehicles to machine tools to material handling to plant process applications—anywhere variable speed is necessary.

Variable Speed Drives (also Adjustable Speed Drives or Variable Frequency Drives (VFD))

In the previous lab, it was shown that the normal operating region of the induction motor is over a small speed range (when operated from a constant frequency, constant voltage source). In some application, such as electric vehicle drives, a much wider speed range is necessary. In these applications, a motor drive can apply variable frequency and variable voltage to the motor. Figure 1 shows the schematic of the power section of a typical three-phase induction motor drive. The rectifier creates a dc bus from three-phase (or sometimes single-phase) ac. The six switches ($S1$ through $S6$) convert the dc voltage V_o to ac voltages which are applied to the motor.
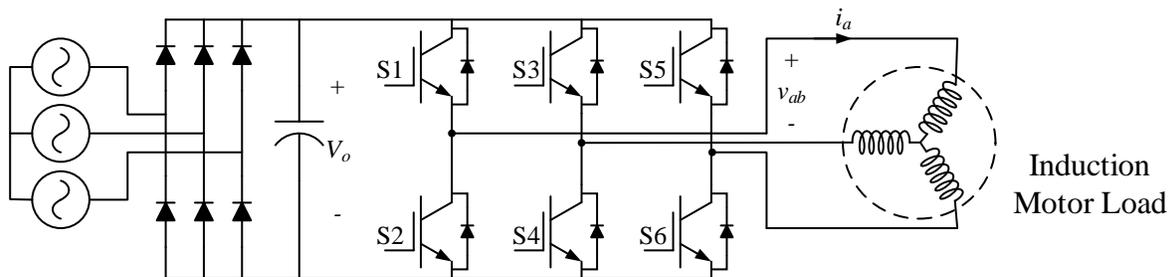
Figure 1. Internal schematic of a typical motor drive.

Figure 2 shows the motor voltage and current (as labeled in Figure 1) waveforms of the motor drive system. The voltage is made from high switching frequency switching between $+V_o$, 0, and $-V_o$. The inductance of the motor filters out the high frequency harmonics and the current is fairly sinusoidal.
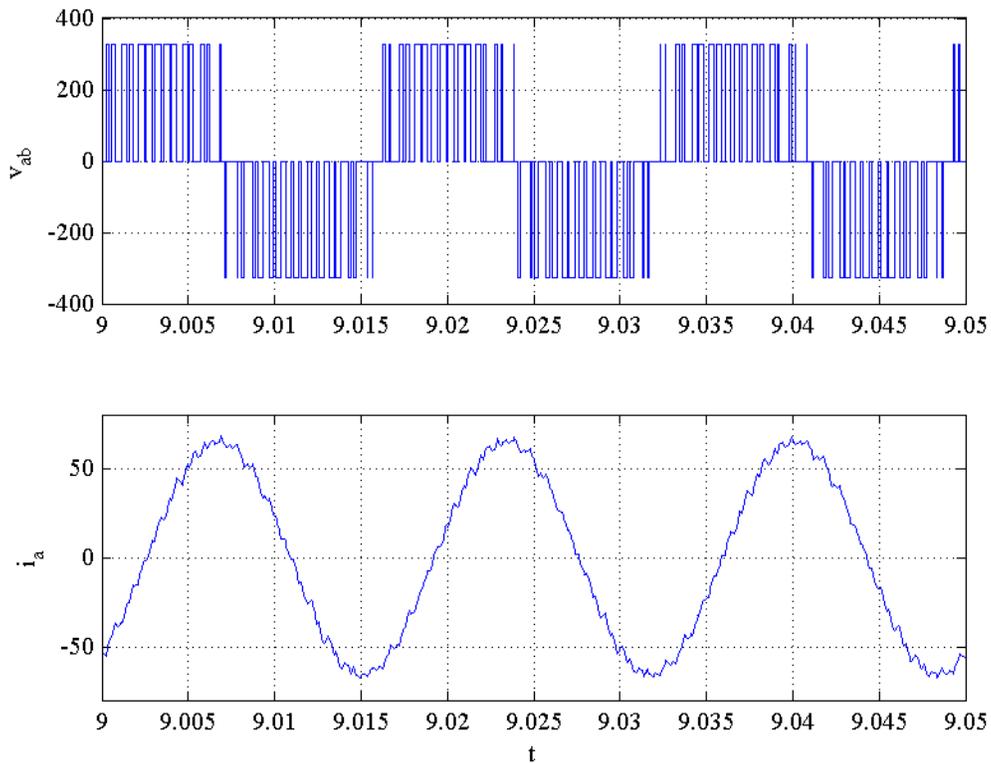
Figure 2. Typical motor drive voltage and current waveforms.

The advantage of the drive system is the ability to control the magnitude and frequency of the applied voltages. In most motor drive systems, the frequency is varied from 0 to 100 Hz (slightly above the motors rated frequency of 60 Hz). The voltage is usually increased in proportion to the frequency in order to maintain constant flux in the motor. The drives used in this lab will respond to an increase in load by automatically increasing the frequency, a feature sometimes called "slip compensation."

Laboratory Software

Figure 3 shows a screen-shot of the software interface for this experiment. The waveforms show the motor voltage and current. As can be seen, the voltage source is not perfect and contains harmonics.   The current also contains harmonics due to the motor tooth saturation.   The induction motor input voltage (line-to-neutral voltage RMS), current (line current RMS), active power, and reactive power are displayed. Also displayed are the armature and field voltages (Va, Vf) and currents (Ia, If) of a dc generator used to apply a load to the induction motor. The user may input speed and torque commands to the dc generator and a speed command to the induction motor, as well as a measured speed. In this experiment, several load points will be taken, with induction motor speed and dc generator torque varied.   **DO NOT ENTER A DC GENERATOR SPEED COMMAND**. As the load is increased (through the armature current), the motor will slow down. After measuring speed and typing it into the software interface, the data can be logged.
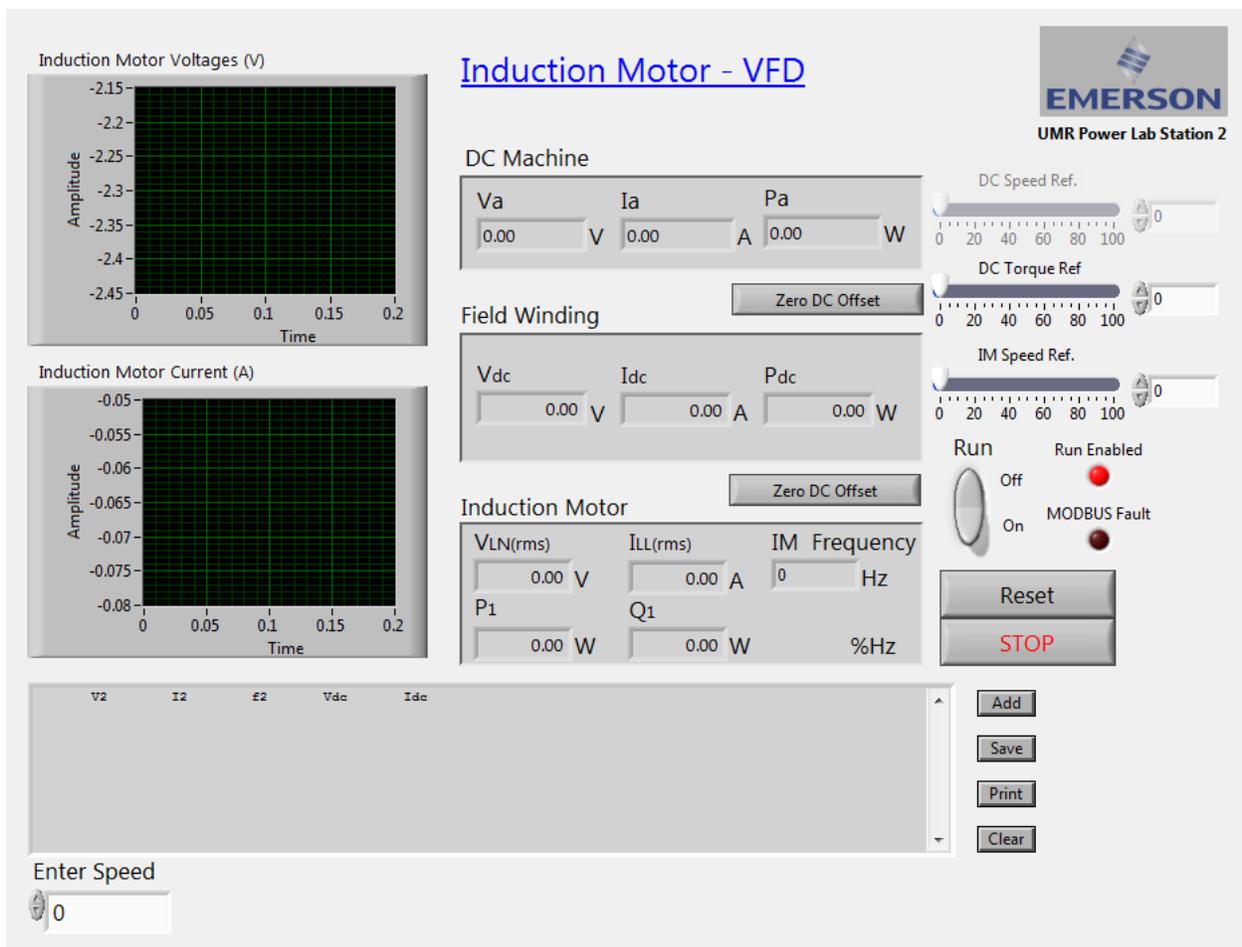
Figure 3. Induction motor load test LabView program.

<u>Laboratory Work</u>

Variable Speed Drive Load Tests

Connect the induction and dc motors as shown in Figure 4.

Have your TA double check your wiring before you turn on the drive.

Once your wiring has been okayed by your TA, turn on the motor drive. Then start the Labview software titled "LabInduction Motor_VFD." After starting it, click the buttons to zero the dc offsets.

You are going to perform three sets of tests. After each adjustment of speed or torque settings, wait for the readings to stabilize, measure the actual speed with the handheld tachometer, enter the speed, and add a datapoint in Labview.

Start with dc torque and IM speed at zero, and click the "Run" toggle switch. Then set the IM speed to 75%. Record this zero-torque point, then increase torque in 10% increments up to 80%, recording each step. Reduce torque back to zero.

Next, set the IM speed to 50%. Record the zero-torque point, then increase torque in 10% increments up to 80%, recording each step. Reduce torque back to zero.

For the third test, start by setting the speed to 90% and then the torque to 30%. Record this point, then reduce the speed setting in 10% increments down to 10%, recording each step.

Decrease the DC torque to zero, then decrease the IM speed to zero and click the "Run" toggle switch to off. Switch off the drives once the motors have stopped.

Wait until the text on the LED screen goes away before removing the cables.

Save the logged data by clicking **Save**.
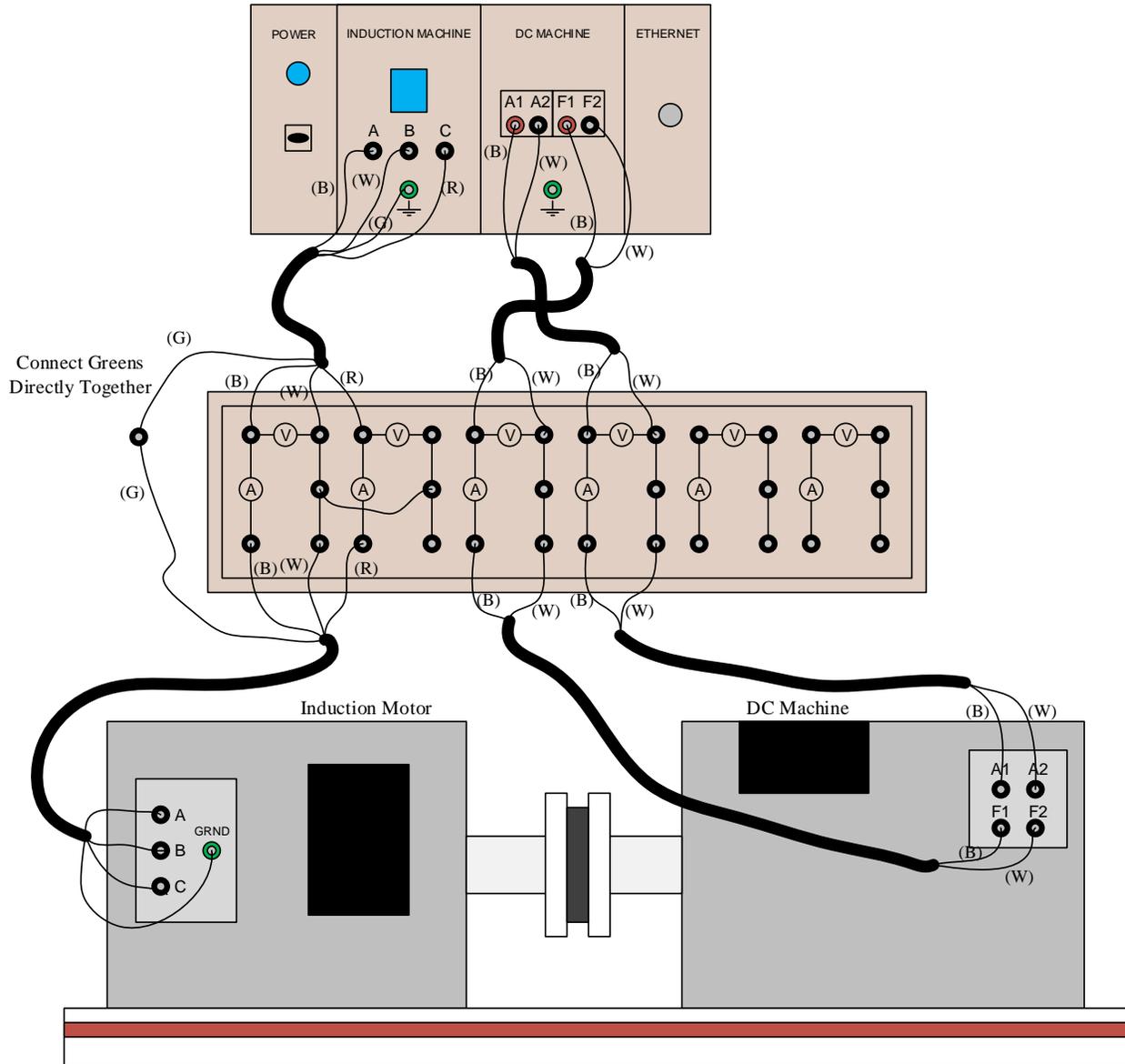
Figure 4. Wiring configuration for the experiment.

Calculations and Questions

1. Construct a plot of torque command vs. armature current. Verify that this is a straight line, and identical for the three sets of data (within experimental error). Discuss any deviations, and also explain the y-intercept.
2. For each constant-speed test, plot IM line current vs. torque command. Discuss. Also, the zero-torque line current is essentially reactive and usually termed "magnetizing current," I_m. The active, torque-producing current magnitude, I_T, is $I_T = \sqrt{I_{LL}^2 - I_m^2}$. Plot I_T vs. torque command for each speed test and discuss.
3. From the constant-torque test, plot I_{LL} vs. speed and discuss. Does it vary significantly? Why or why not?
4. Determine the accuracy of the slip compensation algorithm. The best metric is the root-mean-square error, given by $\sqrt{\dfrac{1}{N}\sum_N (n_{act} - n_{cmd})^2}$ for N points, where n_{act} is the actual (measured) speed and n_{cmd} is the commanded speed.
5. Plot V_{LN} vs. frequency for all tests together. It should include a straight line portion and at least one point that is not on the line. Why?