Lab 9 – AC & Stepper Motors

Format

This lab will be conducted during your regularly scheduled lab time in a group format. There are three lab stations with a different experiment located at each. Each group will get a maximum of 45 minutes to complete each experiment. If you have not finished within that time, you must finish that experiment after all of the other groups have had an opportunity.

Report

A short, group report is due from each lab group for this lab. This short report may be neatly handwritten, and should be stapled in the upper left-hand corner. <u>*At a minimum*</u>, all of the information specifically requested in this lab handout must be present in your report.

Procedures

<u>9.1 PSC AC Motor</u>

The first experiment (shown in Figure L9-1) involves the determination of a small part of the torque-speed curves for a small AC torque motor. A 24 VDC motor/generator is used as the mechanical "load." The AC torque motor's slip/speed can be adjusted over a wide range by the motor speed controller (transformer). The transformer allows you to control the <u>amplitude</u> of the AC voltage applied to the motor. Lower voltages should result in a higher slip, which gives a lower speed for the same load (torque).

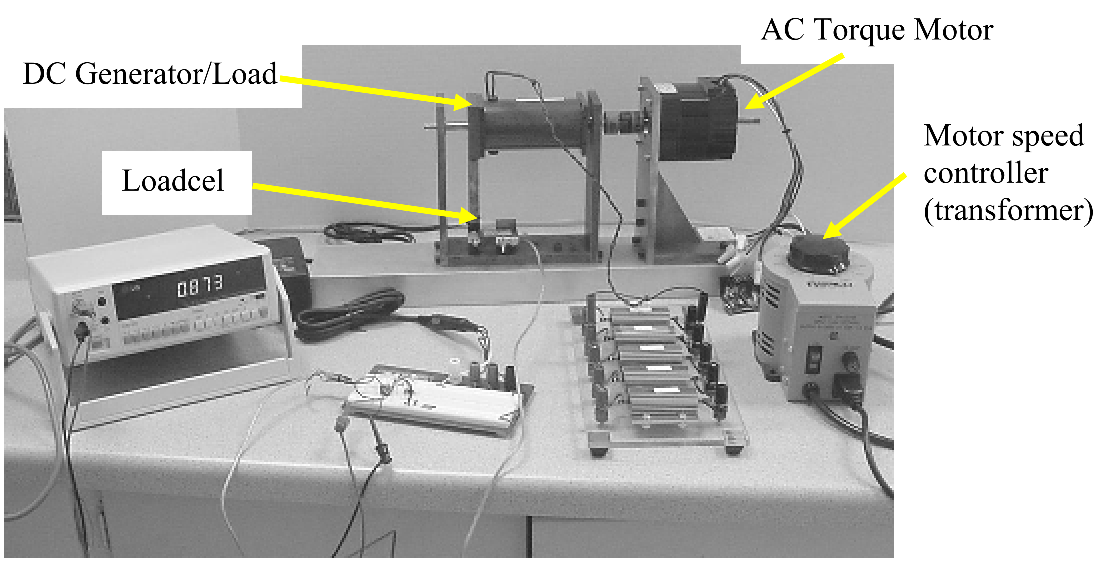

Figure L9-1. Torque AC motor experimental setup

The goal of the exercise is to develop speed-torque curve profiles for the AC motor at two different voltages, 120 VAC and 100 VAC. Each team should test 6 different loads (no external resistance, 15Ω, 7.5Ω, 15Ω & 7.5Ω in parallel, 2Ω, 1Ω) on the DC motor for each setting. The basic process for testing the motor is:

1. Determine the zero load voltage reading for the amplified load cell output. Be sure to move the lever arm away from the load cell before making this measurement.

   The calibration data for the load cell was emailed to you. Use the slope of the calibration curve to get the amplified loadcell sensitivity in lbf/volt.

2. Set the motor speed controller ("variac") at 120 VAC.
3. Vary the load on the motor/generator by changing the resistance across its leads.
4. For each input speed and load combination, record the motor's speed, load cell voltage, and motor/generator voltage.
5. Repeat the process with the motor speed controller ("variac") at 100 VAC.

Make a single plot of the output torque vs. speed relationships for the AC torque motor. There should be two "families" curves in your plot, each curve corresponding to a different motor input setting. Also plot the "rated" torque and speed of the motor according to the nameplate data.

9.2 Four Speed Motor-Fan System

In the second experiment a four-speed AC motor drives a standard centrifugal fan. The input power to the motor is obtained by using a standard home watt-hour meter. The input power for the fan is found from the watt-hour meter by

$$\text{Power}_{in} = \frac{K_h}{t_{rev}} = \frac{K_h\left(\frac{\text{watt}\cdot\text{hr}}{\text{rev}}\right)}{t_{rev}\left(\frac{\text{sec}}{\text{rev}}\right)}\left(\frac{60\text{sec}}{1\text{min}}\right)\left(\frac{60\text{min}}{1\text{hr}}\right)$$

where K_h = watt-hour meter factor (units of watt-hours per revolution of the horizontal disk), typically printed on the front of the meter and t_{rev} = period of the watthour meter disk (seconds required for one revolution).

Specific procedures are listed below.

1. Measure both moment arms (one to loadcell, other to calibration weight hanger).
2. Attach the uncalibrated load cell to the moment arm and calibrate the loadcell and instrumentation amplifier combination with at least 5 calibration weights.
3. Do the following for each of the four fan speeds:
   a) Make several (at least 10) measurements of fan speed (using the hand-held tachometer) and load cell output (using a DMM). Record each of these readings and use them to estimate the *precision uncertainty* of each instrument.

   b) Time one revolution of the watt-hour meter at least 5 times.
4. Calculate the input power and output power for each data point.

Compute and plot average motor efficiency vs. fan speed for the given load. Include error bars from the *precision uncertainty* for both measurements (X - fan speed, Y - motor efficiency)

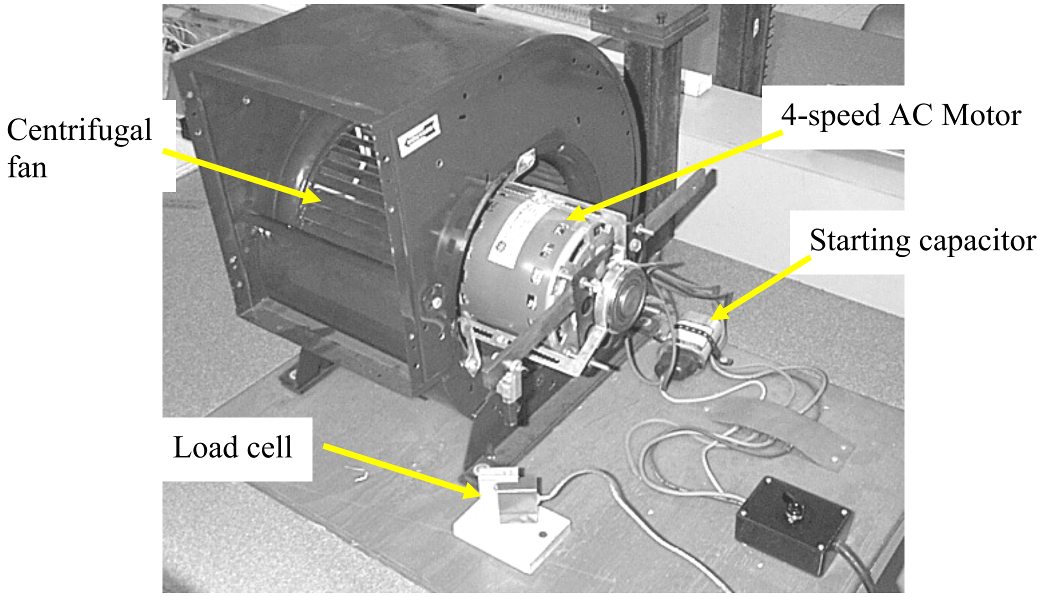

Figure L9-2. Four-speed AC motor experimental setup
(*actual system will look somewhat different!*)

9.3 Wire a PSC AC Motor to Reversing Switch

In the next experiment each group will wire a small permanent split capacitor AC motor (Figure L9-3) to a reversing switch (SPDT). The switch used to reverse the motor will be mounted in a metal outlet box for safety purposes. A second switch (with identical wiring) will be provided to allow your group to correctly identify the wire colors. A schematic of the system component is provided in Figure L9-4. The complete wiring diagram is provided in Figure L9-5.

WARNING – Be very careful that you unplug the AC power before making any wiring changes!

Ask lab monitor for assistance if you are not sure about anything!

Connect the green "earth" ground on the AC plug to the green ground on the case of the motor.

Determine the correct wire colors, wire the system using "wire nuts," and verify proper motor operation (CW, off, CCW).

Provide a complete wiring diagram in your lab report.

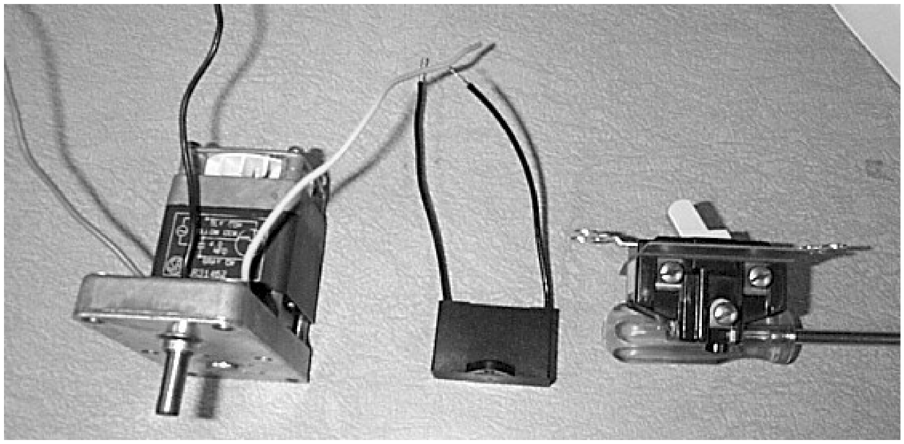

Figure L9-3. PSC AC motor, capacitor, and SPDT switch

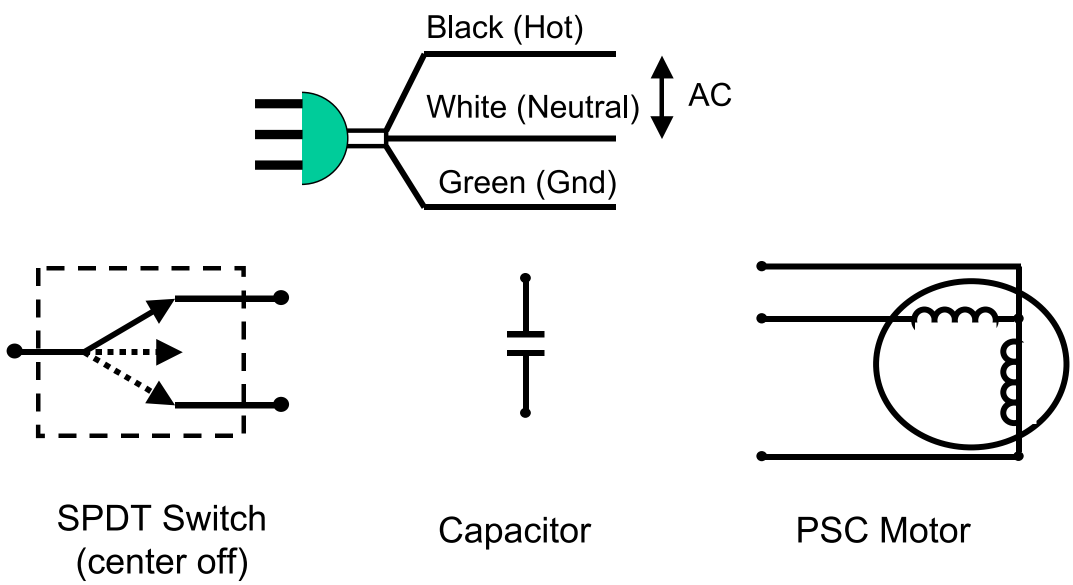

Figure L9-4. Schematics for reversing switch

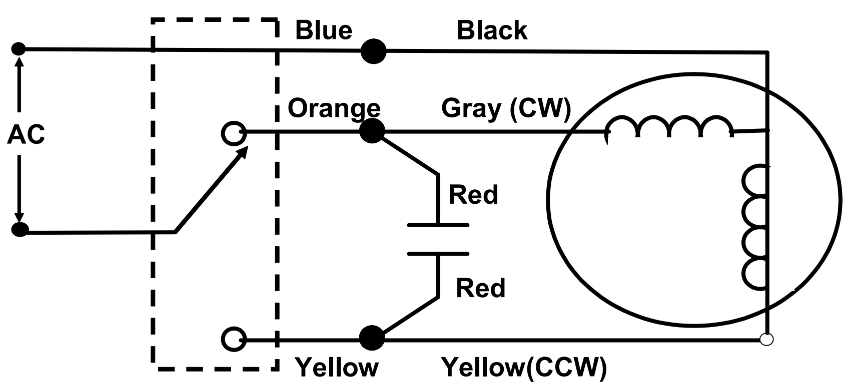

Figure L9-5. Wiring diagram for reversing switch

9.4 Stepper Motor Control

A commercial stepper motor, indexer/controller, and right-angle gearbox system, is shown in Figure L9-6. Switches are used to control direction (CW, CCW) and full/half step modes. The input steps can be provided manually (push button switch) or by a TTL square wave signal from the function generator. Your goal is to determine the velocity and acceleration characteristics (and capabilities) of this stepper motor system.

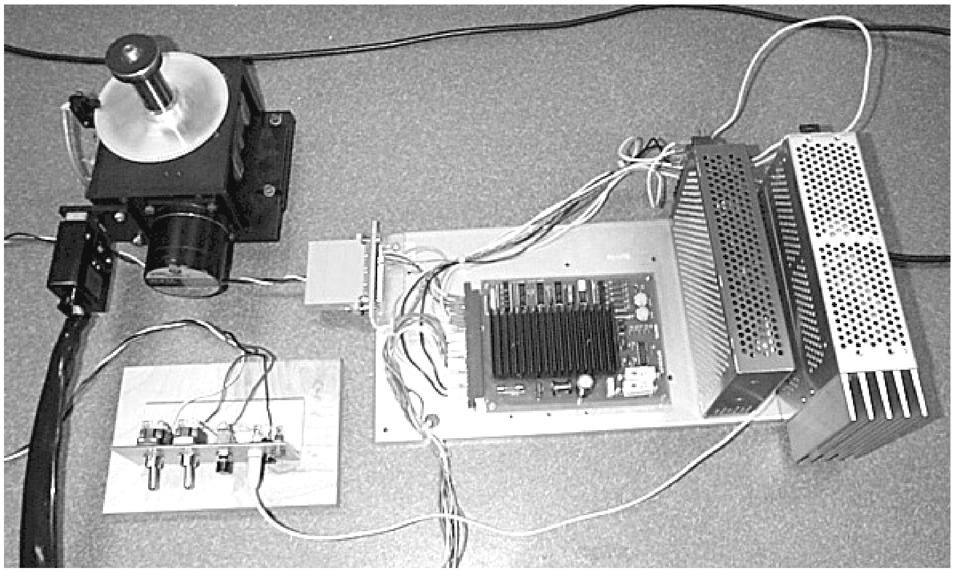

Figure L9-6. Stepper motor and controller

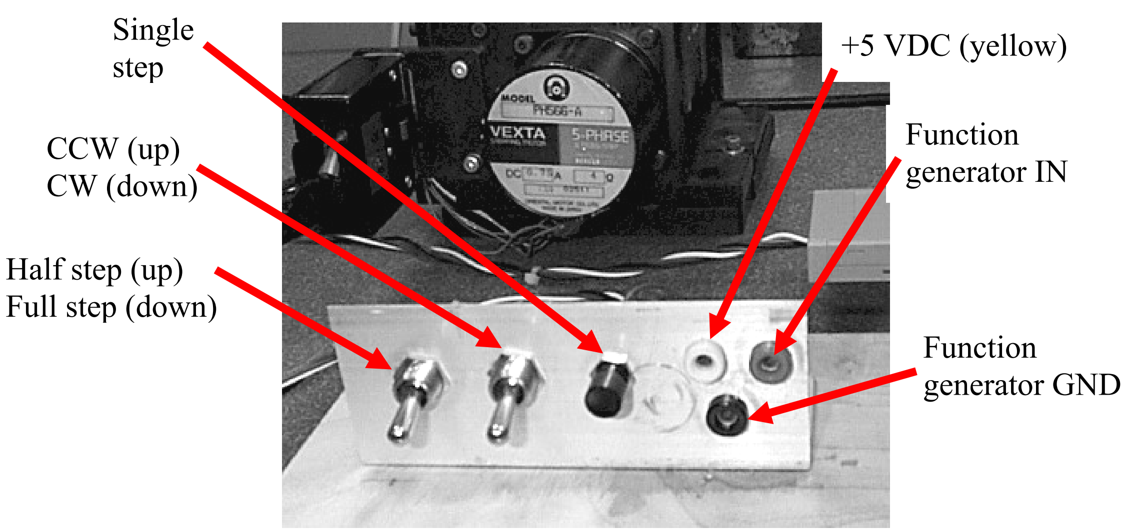

Figure L9-7. Stepper motor interface

The process for testing the stepper motor system is as follows:

1. Connect the function generator (TTL output) to the interface connector shown in Figure L9-7. Operate in full step mode in the clockwise (CW) direction.
2. Set the function generator to a low frequency (about 10 Hz) and observe the output – the disk should be turning slowly. Note that you can more accurately read the frequency output from the function generator with your DMM.
3. Turn the function generator off, set the function generator frequency to a higher value, then turn the function generator back on. Does the stepper motor system start and continue to move? Note that you are "requesting" a very high acceleration from the stepper motor system when you turn the function generator on like this.
4. Repeat step #3 until you find the highest function generator frequency at which the stepper motor will start and continue to run.
5. Repeat steps #2 - #4 with the system in half-step mode.
6. Return to full step mode and set the function generator at approximately 10% of the value determined in step #4.
7. Slowly increase the function generator output until the stepper motor stops running. This frequency (steps/sec) should be significantly higher than the value obtained in step #4. Note that you are "requesting" a much gentler acceleration by ramping the function generator output like this.
8. Repeat steps #6 - #7 with the system in half-step mode.

Record the "stall" speeds obtained in the steps above. Comment on the ability of the stepper motor system to respond to abrupt changes in velocity commands (high accelerations) and more gradual changes in velocity commands (lower accelerations).