University of Utah
Electrical & Computer Engineering Department
ECE 3600 Lab 3

3-Phase Synchronous Motor & Generator

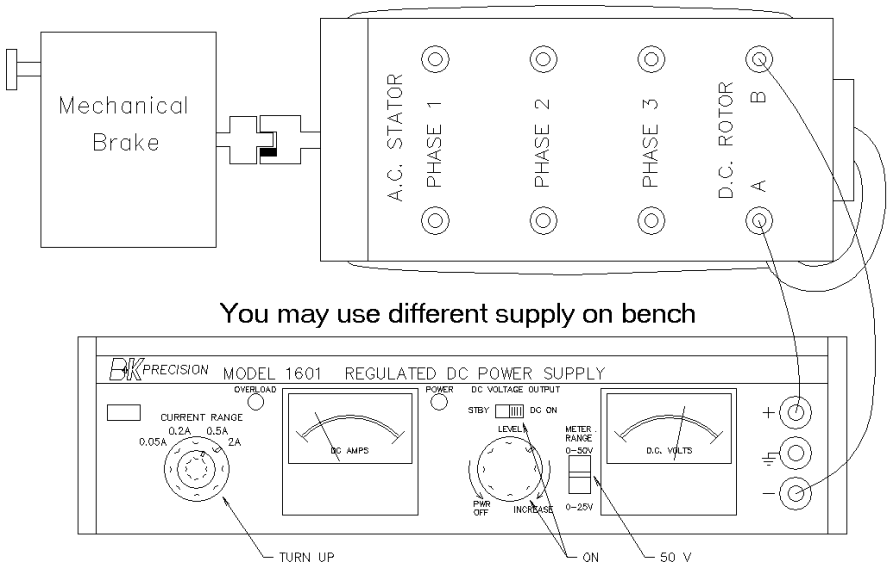
Based on a lab by: D. K. Gehmlich
A. Stolp, 11/11/08, rev, 10/24/12, 10/24/19, 10/4/22

Objectives

1. Hook up the synchronous machine as a motor (Δ) and observe the effects of varying the field current.
2. Hook up the synchronous machine as a generator (Y) and drive it with a DC motor.
3. Synchronize the generator to the 3-phase line and bring it "on line".
4. Observe the effects of adding torque with the DC motor and of varying the field current of the synchronous generator.

Equipment and materials to be checked out from stockroom:

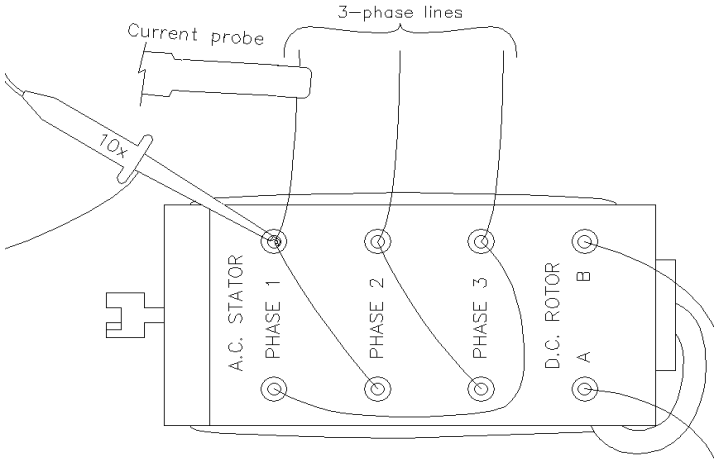
See the last page of this lab.
Ask TA for pre-printed check-out list. Check out those items.



Motor

Turn the knob on the mechanical brake counter-clockwise to loosen up the brake. Mount the 3-phase synchronous motor and the mechanical brake on the motor rack. Give them plenty of slack at the coupling. Hook a power supply to the D.C. ROTOR (A B) connections. Polarity is not important. These connections will not change throughout this lab.

Turn off the 3-phase line breaker and hook up the 3-phase synchronous motor to the 3-phase lines (black, red, & blue) in Δ. Pay no attention to the connector colors of the motor.

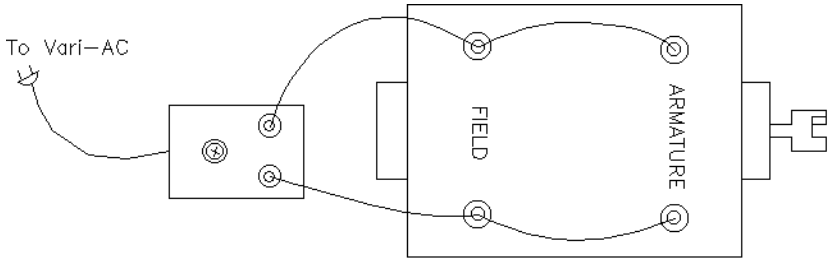


Hook Ch1 of the scope up to observe one of the line-to neutral voltages (a bare banana plug may be helpful here). Connect the scope ground to the 3-phase neutral (white). **(Note: never-ever-ever... hook a scope ground to anything other than ground or neutral.)** Clamp the Hantek current probe around the same line, with the trigger at the bottom. Turn on the current probe to the middle position and hook it to Ch4 of the scope. As always, make a

drawing and comments in your notebook.

Turn the DC power supply on and turn it up to 20 V. (Note: If the current knob isn't turned up enough, the voltage knob won't work.) Switch on the 3-phase breaker and run the motor. Observe the voltage and current on the scope. Note that there is a large 6th harmonic on the current waveform, this is normal for our particular motors. Apply some load to the motor with the brake, that will make the current go up. Back off if the current gets "squirrely" or the motor sounds weird. Try to smooth out the current wave to its fundamental wave in your mind or on paper to estimate the phase relationship between the voltage and current. (If the two waveforms are not close to being in phase, first verify that neither scope channel is inverted. Turn over the current probe if there's still a problem.) Make a sketch of the voltage and current in your notebook. Vary the excitation (field) voltage (B&K or other DC supply) and observe the effect on this phase relationship. Do this for under-excitation and over-excitation. Sketch the waveforms and find the approximate phase angle (I relative to V) for each case. Draw an approximate phasor diagram for each case. Do your best to find the excitation voltage (and current) to get a power factor of 1. Record the DC V and I values.

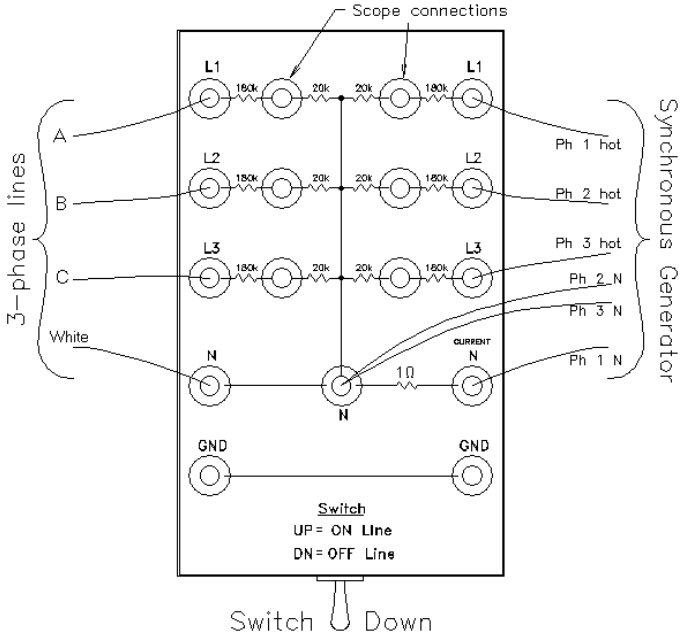
Switch off the 3-phase breaker and the DC power supply. Leave the DC supply-to-field connections in place, but remove all the 3-phase wires. Clear away the current probe (**switch it OFF**) and the scope probes you've been using. From here on you'll use the BNC-to-banana plug (or clip leads) leads as scope probes.



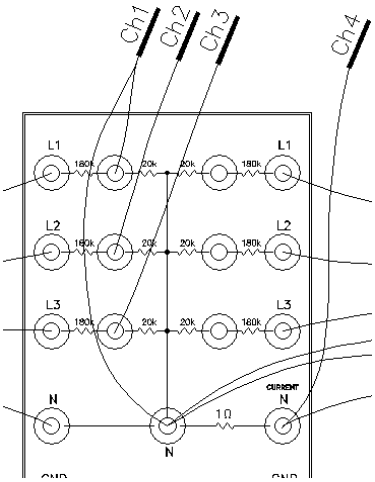
Generator

Mount the DC motor on the motor rack to drive 3-phase synchronous machine. Give the motors plenty of slack at the coupling. You may need to use a shim under the DC motor to make the two line up well. Turn off the Vari-AC and plug it in. Plug the Rectifier box into the Vari-AC and hook the output to the DC motor. Polarity is not important. Switch on the Vari-AC and turn it up to make sure that you can drive the AC motor smoothly. Turn it back down.

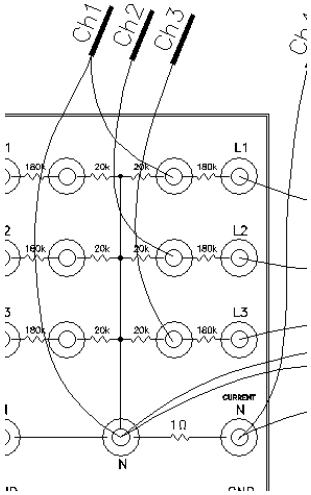
Wire the 3-phase lines to the left-most connections of the synchronizing box. Wire the AC motor in Y to the right side connections of the box. Hook two of the neutrals to the center neutral of the box and one to the "CURRENT N" connection. This will be your current measurement position, you will later hook it to Ch4 of the scope. Make sure the switch is in the down (off line) position.



Turn on the DC power supply. Turn on the 3-phase breaker. The motor should not move or make noise. Turn up the Vari-AC and spin up the generator with the DC motor.

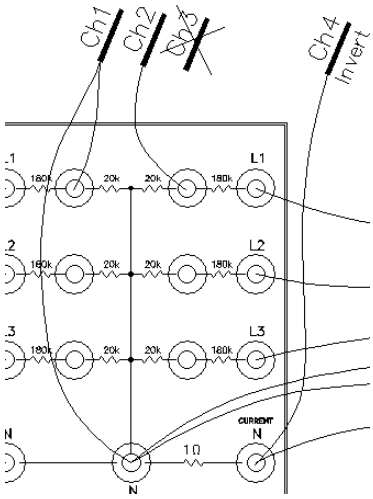


Your box should contain 3 BNC-to-Banana cables for the scope. (If not, use BNC-to-clip leads with some bare banana plugs.) Hook up the scope channels as shown (only one neutral connection is needed). Set the scope to trigger on Ch1 and view channels 1-3. All 3 channels should be set up the same way (volts/div & probe setting). Turn on the 3-phase breaker. L1, L2 and L3 should make an ABC sequence (yellow, blue, red on the scope). Note the color sequence if it's different.



Move the scope channels as shown at right. (Note that there is a large 12th harmonic on the waveforms, this is normal for our particular machines.) You should see the same color sequence as before

Change generator connections or the DC motor rotation direction as necessary to get the same sequence. This is **VERY Important**. Go back to the earlier scope connections to double-check. If you have any doubts about what you just did, **ask the TA to check your sequences before proceeding**. If they are wrong, you **could destroy the synchronous machine**. 3-phase synchronous machines of this size are not used in the field, these were specially wound for the University of Utah many years ago. We only have 4 left and they would be **very expensive** to replace.



Move Ch1 & Ch2 so as to display a line phase and a generator phase on the scope at the same time. Set the scope to trigger on Ch2 and view channels 1 & 2. Set the speed of the DC motor so that the generated frequency is 60Hz and closely matches the line waveform. Set the field current so that the phase voltage magnitudes you see on the scope are the same. Try to ignore the higher-frequency harmonics on the generator voltage. Note the generator's field current (or voltage). Wait for the two waveforms on the scope to line up and then switch the generator on line at just the right instant. In your notebook, describe the steps to bring a generator on line. Note the setting of the Vari-AC that controls the speed of the DC motor.

View Ch 4 to observe a phase current at the "CURRENT N" connection. Because of where and how this current is measured, you will need to Invert this waveform at the scope. (Hit the CH4 button and find the"invert" button to the right of the screen.) There should be very little current. Try to increase the speed of the DC motor. (Back off if the current gets "squirrely" or the motor sounds weird.) The motor will not increase the speed, but it will apply a torque to the AC generator and the current to the grid will increase. The generator is now converting this mechanical power into electrical power which it is pushing onto the line. Sketch the current waveform. Note the harmonics. What is the dominant harmonic?

Check to make sure you are measuring the current and voltage of the same phase. Look at the voltage and current on the scope. Do they make sense? Explain in your notebook. Try to smooth out the current wave to its fundamental wave in your mind or on paper to estimate the phase relationship between the voltage and current. Vary the excitation (field) voltage (B&K) and observe the effect on this phase relationship. Do this for under-excitation and over-excitation. Sketch the waveforms and find the approximate phase angle (I relative to V) for each case. Draw an approximate phasor diagram for each case. Do your best to find the excitation voltage (and current) to get a power factor of 1. Record the DC field V and I values.

Turn up the Vari-AC far enough to "pull-out" the generator and then back off enough that the phase current settles back down. Increase the field current to bring the phase current back in phase with the voltage waveform. Repeat this paragraph 1 or 2 more times. Estimate the power you are generating from the scope waveforms.

Describe the effect of excitation on the pull-out" behavior.

Switch the generator off line and note how much the system speeds up. What does this say about the torque between the two machines when the generator was on line?

Turn off the 3-phase line breaker, the DC power supply and the Vari-AC.

NAME	
DATE	
CLASS	ECE 3600 SECTION
QUANTITY	DESCRIPTION
2	Power wire kits
1?	Power strip (may be in power wire kit)
1	SG Box with Hantek current probe and AC to DC rectifier box and Synchronizing box
1	Vari-AC (Auto-transformer)
1	Motor rack
1	BOB (bucket of bolts)
1	NSH-34 DC motor
1	NNP34 3-phase synchronous motor
1?	B&K 1601 Power supply (or use power supply on bench, hooked in series configuration)

Check off, Conclude and Clean Up

Check off and conclude as always. Be sure to compare what you found in the lab to what you expect to see from theory.

TURN OFF THE CURRENT PROBE before returning it !!

<------ A pre-printed ckeckout slip like this should be available from your TA