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

Objectives

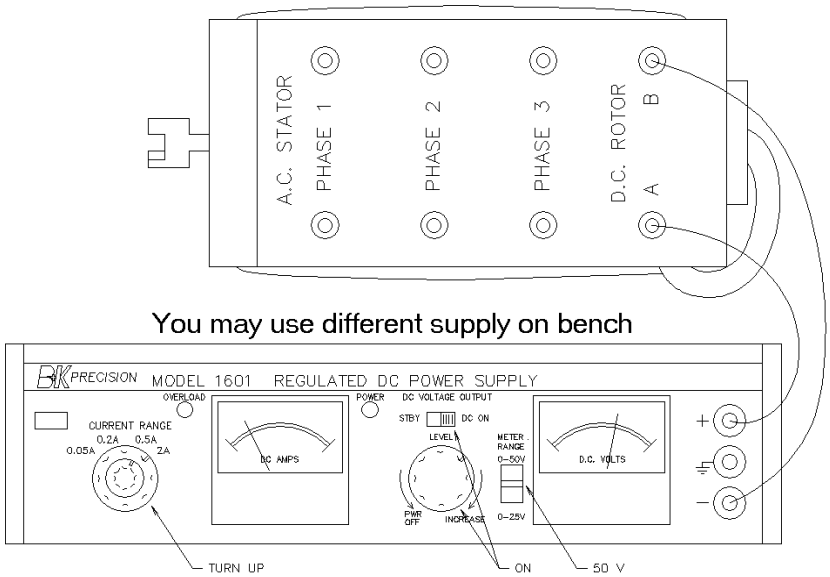
1. Hook up the synchronous machine as a motor (Δ) and observe the effects of varying the field current.
2. Hook up the synchronous machine as a generator (Y) and drive it with a DC motor.
3. Synchronize the generator to the 3-phase line and bring it "on line".
4. Observe the effects of adding torque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

Equipment and materials to be checked out from stockroom:

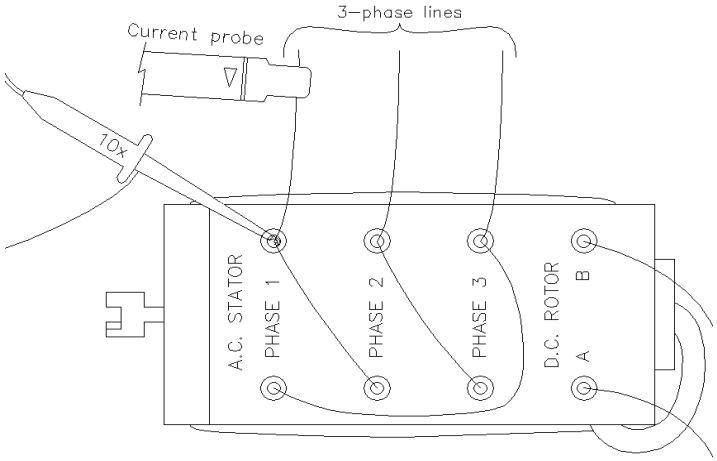
See the last page of this lab.
Ask TA for pre-printed check-out list. Check out those items.

Motor

Mount the 3-phase synchronous motor on the motor rack in such a position that you can later add the DC motor to drive it. 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.



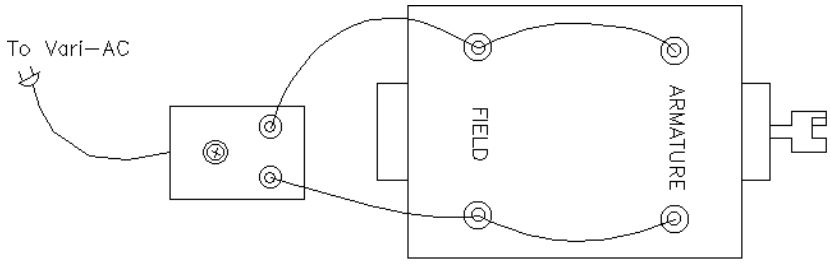
Hook Ch1 of the scope up to observe one of the line-to neutral voltages. Connect the scope ground to the 3-phase neutral (white). **(Note: never-ever-ever... hook a scope ground to anything other than ground or neutral.)** If you have an HP current probe, place the probe around the same line, with the arrow pointing to the motor. Plug in the probe box and hook its output to Ch2 of the scope (use a BNC-to-clip lead). As always, make a drawing and comments in your notebook. If you don't have a current probe, find a group

who does and observe the actions of the next paragraph.

Turn the DC power supply on and 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 is normal for our particular motors. 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, verify that neither scope channel is inverted.) 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.

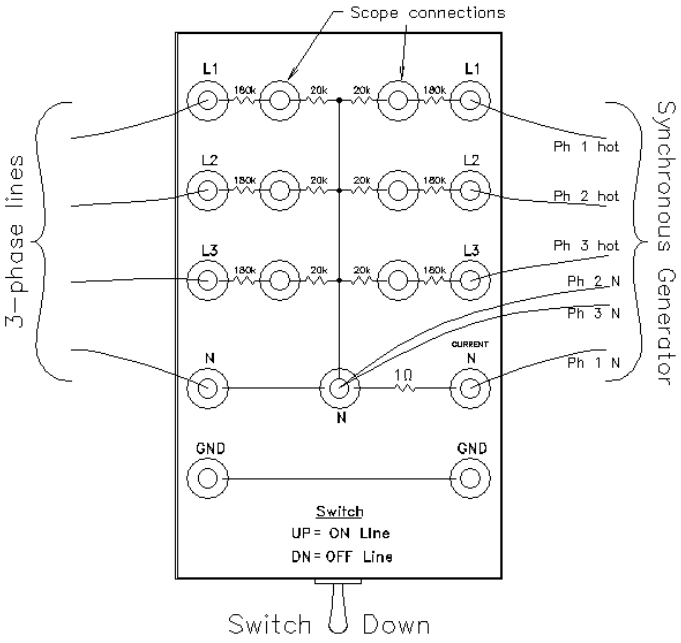
Switch off the 3-phase breaker and the DC power supply. Leave the DC supply-to-field connections in place, but remove all the 3-phase wires. Clear away the current probe and the scope probes you've been using. From here on you'll use the BNC-to-banana plug leads as scope probes.

Generator

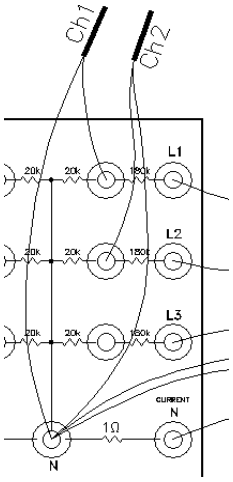


Mount the DC motor on the motor rack to drive 3-phase synchronous machine. Give the motors plenty of slack at the coupling. You may need to use a shim under the DC motor to make the two line up well. Turn off the Vari-AC and plug it in. Plug the Rectifier box into the Vari-AC and hook the output to the 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.

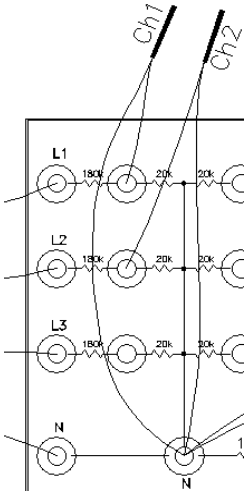
Wire the 3-phase lines to the left-most connections of the synchronizing box. Wire the AC motor in Y to the right side connections of the box. Hook two of the neutrals to the center neutral of the box and one to the "CURRENT N" connection. This will be your current measurement position, you will later hook it to Ch3 of the scope. Make sure the switch is in the down (off line) position. Turn on the 3-phase breaker. The motor should not move or make noise.



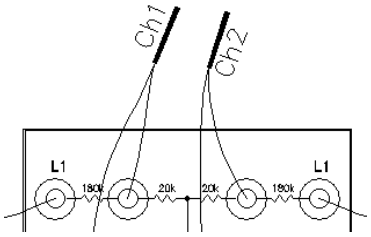
Turn on the B&K (or DC) power supply. Turn up the Vari-AC and spin up the generator with the DC motor.



Your box should contain 3 BNC to Banana cables for the scope. Set the scope to trigger on Ch1 and hook it to the L1, low voltage, "Scope connection" (the inner connection of the synchronizing box). These inner connections are just for the scope. Hook Ch2 to the L2 scope connection and check the relative phase of the two lines. Hook Ch3 to the L3 scope connection. If L1, L2 and L3 don't make an ABC sequence, change generator connections or the DC motor rotation direction as necessary to get an ABC sequence. (If you aren't sure what I mean or what you should look for, ask your TA.)



In the same way, check that the 3-phase lines at left side of the box are also in an ABC sequence. (Use the low voltage, "Scope connections" of the synchronizing box.) Make sure they match the sequence of the generator. If you have any doubts about what you just did, **ask the TA 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 speed of the DC motor so that the generated frequency is 60Hz. Set the field current so that the phase voltage magnitudes you see on the scope are the same. Try to ignore the higher-frequency "noise" 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.

Move Ch 3 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 CH3 button and find the"invert" button to the right of the screen.) Sketch the current waveform. Note the harmonics. What is the dominant harmonic.

Determine which phase current you are measuring and make sure Ch 1 is connected to the same phase. Note the setting of the Vari-AC that controls the speed of the DC motor. Now turn it up to start pushing mechanical power into the generator. The generator is now converting this mechanical power into electrical power which it is pushing onto the line. Turn up the Vari-AC far enough to "pull-out" the generator (or to max) and then turn it half way back to where you started.

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 V and I values.

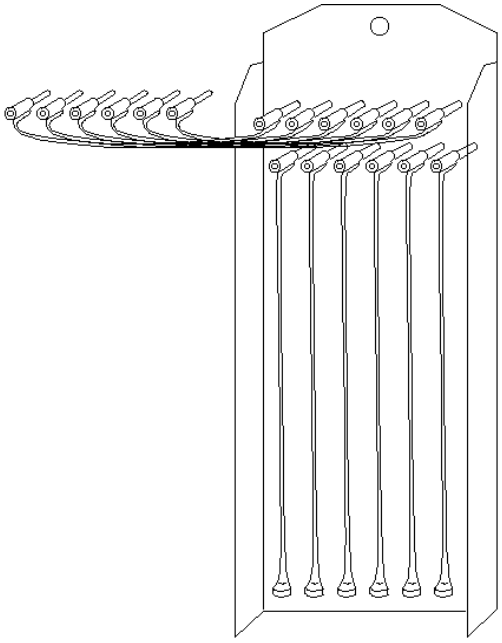
Turn up DC motor voltage far enough to “pull-out” the generator (or to max) and then vary the excitation. Describe the effect of excitation on the pull-out” behavior. Set the excitation so that the generator is operating normally.

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.

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.

As you put the wires back on the 2 power wire kits, please put a male-to-male of each color wire on the top row of each metal holder and a a male-to-female of each color wire on the bottom row of each.



NAME	
DATE	
CLASS	ECE 3600 SECTION
QUANTITY	DESCRIPTION
2	Power wire kits
1	Box with an HP current probe and
	AC to DC rectifier box and
	Synchronizing box
1	Vari-AC (Auto-transformer)
1	Power strip
1	B&K 1601 Power supply
1	Motor rack
1	BOB (bucket of bolts)
1	NSH-34 DC motor
1	NNP34 3-phase synchronous motor

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