EE 340L – Experiment 6: Synchronous Generator - Stand-Alone Operation

The synchronous machine (see Fig. 1) is mechanically coupled to the Four-Quadrant Dynamometer/Power Supply (see Fig. 2) using a timing belt. This second machine is used as a prime mover to provide mechanical power to the first electric generator.

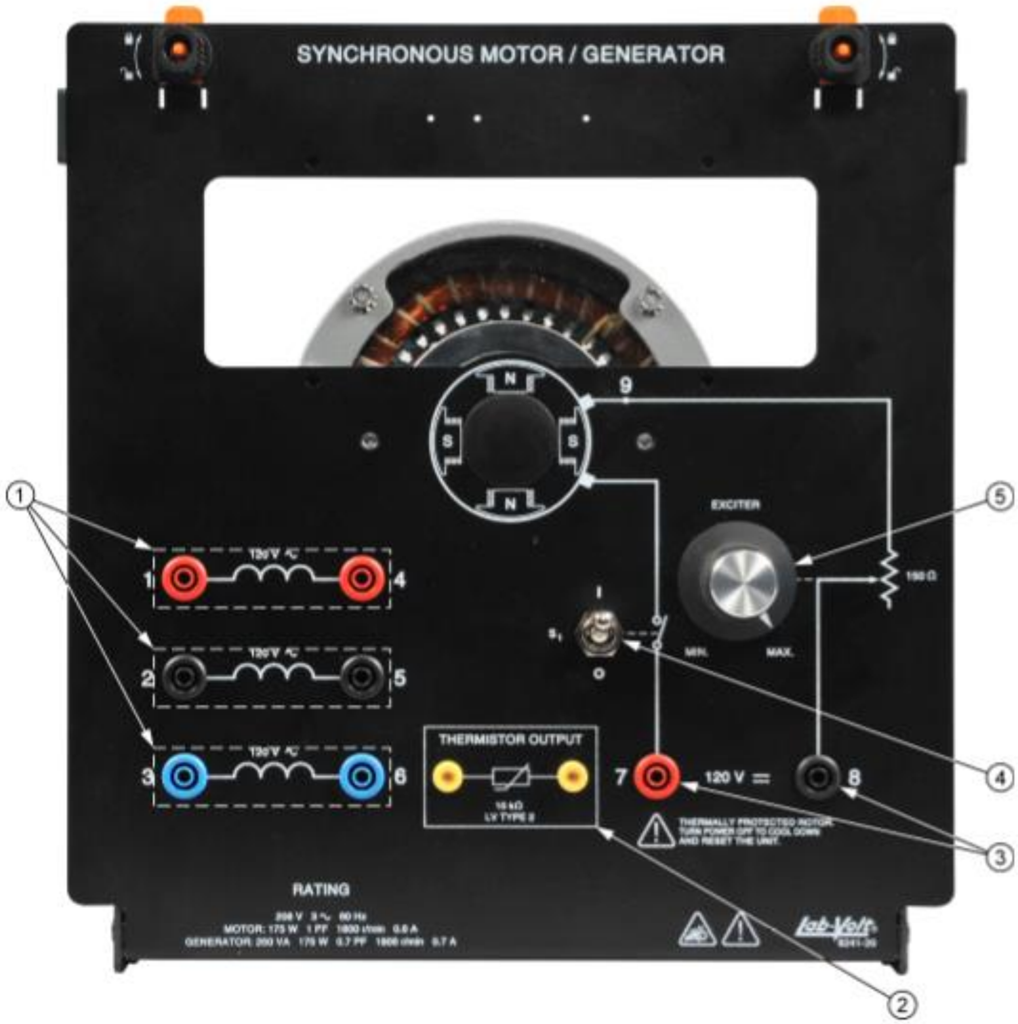

Fig. 1: Synchronous Machine

1. Stator winding terminals:
2. Thermistor Output.
3. Exciter input terminals:
4. Exciter switch.
5. Exciter knob:

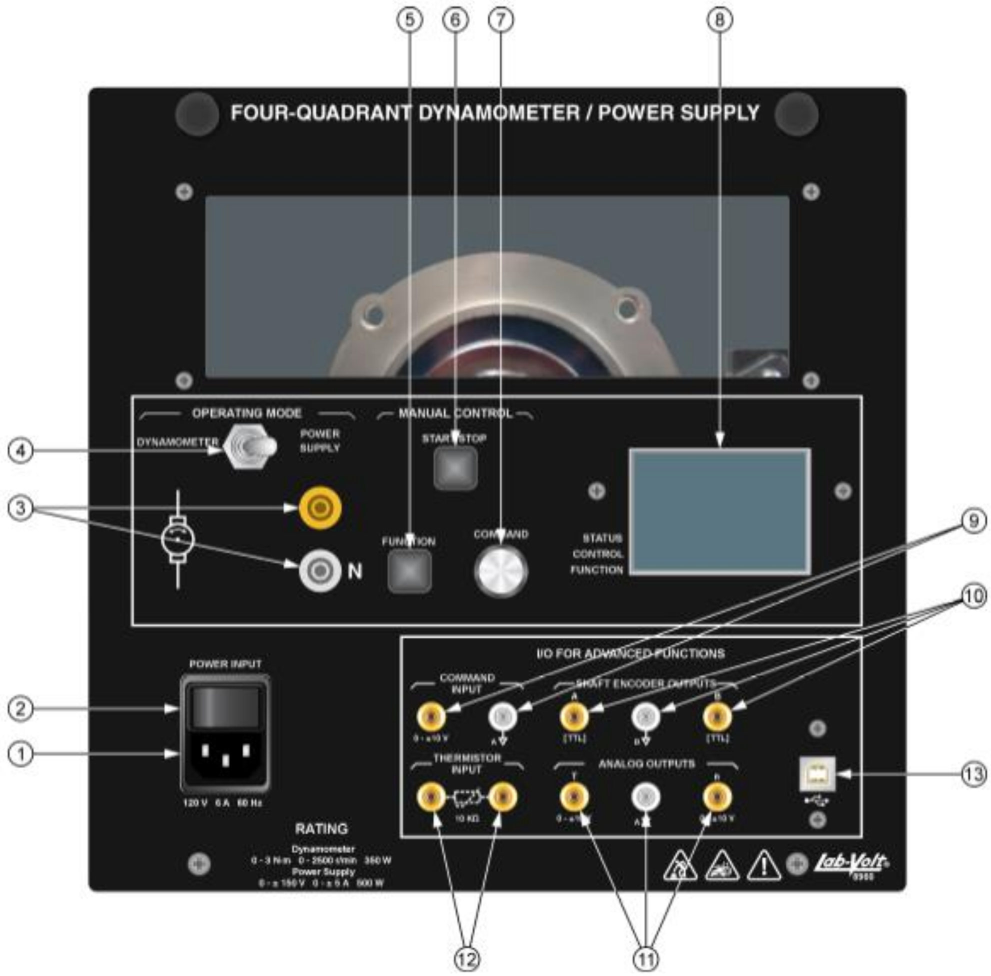

Fig. 2: Four-Quadrant Dynamometer/Power Supply

1. Power Input:
2. Main power switch:
3. Power Supply terminals
4. Operating Mode switch:
5. Function push-button:
6. Start/Stop push-button:
7. Command knob:
8. Liquid crystal display (LCD):
9. Command Input:
10. Shaft Encoder Outputs:
11. Analog Outputs
12. Thermistor Input:
13. USB port connector:

1) Stator winding resistance.

Use a multi-meter to measure the resistance of the stator windings. These windings are identical; hence, their resistance value should be the same. Record the value of this resistance below

Rs = …………..Ω

2) No-load Test

a) Connect the stator windings in a Y-connection (by shorting out terminals 4-5-6). Make sure the exciter switch is in the OFF position, and the exciter knob is in the minimum position. Then install volt-meters (using the Data acquisition and Control interface which should be powered by a 24 V supply) across each phase and neutral as shown in Fig. 3. Furthermore, connect a variable 120 V DC supply across the field winding and an amp-meter to read the field current – also illustrated in Fig. 3. *As a precaution, always set the variable DC supply to a minimum value to turning the control knob CCW to the limit.*

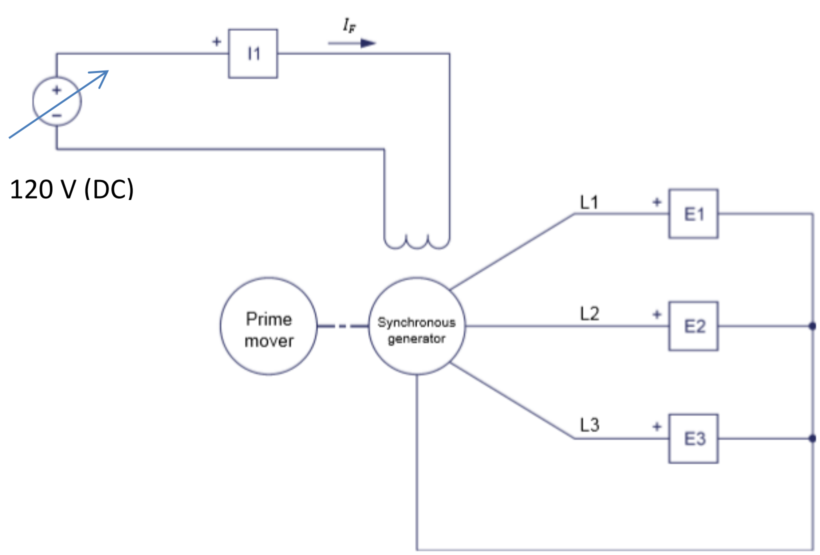

Fig. 3: No- Load Test.

b) Make sure that the main power switch on the Four-Quadrant Dynamometer/ Power Supply is set to the O (off) position, then connect its Power Input to an ac power outlet. Turn the Four-Quadrant Dynamometer/Power Supply on, then set the Operating Mode switch to Dynamometer.

   a. Set the Function parameter to CW Constant-Speed Prime Mover/ Brake.
   b. Set the Speed parameter to the synchronous speed of the Synchronous Generator (1800 rpm).

c. Start the prime mover and note the speed of the shaft. *This speed must be kept contant at 1800 rpm at all times throught this experiment.*

c) On the Synchronous Generator, set the Exciter switch to the closed position. Turn on the variable DC supply, and slowly increase the voltage till the fiels crrent reaches 0.1 A. field current by turning the exciter knob clockwise till it reaches 0.1 A, then record the induced stator voltage in the table below. Repeat this procedure by increasing the fied current in increments of 0.1 A. If you reach the maximum DC supply voltag, you can keep increasing the field current by slowly turning the exciter knob clockwise.

Field current I_f (A)	**Induced phase voltage E_a (V)**
0.1	
0.2	
0.3	
0.4	
0.5	
0.6	
0.7	
0.8	
0.9	

d) Once finished, reduce the variable DC supply back to its minimum vaule, the exciter knob back to minumum position, turn off the DC power source of the exciter, then stop the prime mover.

e) Plot the the no-load curve of the generatori.e., E_a versus I_f. (home assignment).

3. Short circuit Test

a) Replace volt-meters in Fig. 3 with amp-meters as shown in Fig. 4.

b) Start the prime mover, and bring the speed to 1800 rpm.

c) On the Synchronous Generator, set the Exciter switch to the closed position. Turn on the Variable DC supply, slowly increase the applied DC voltage till the field current reaches 0.05 A, then record the resulting armature (or generator) short circuit current in the table below.

d) Keep incresing the field current in increments of 0.05 A while recording the resulting short circuit current. Make sure the rotor speed is kept at 1800 rpm at all time.

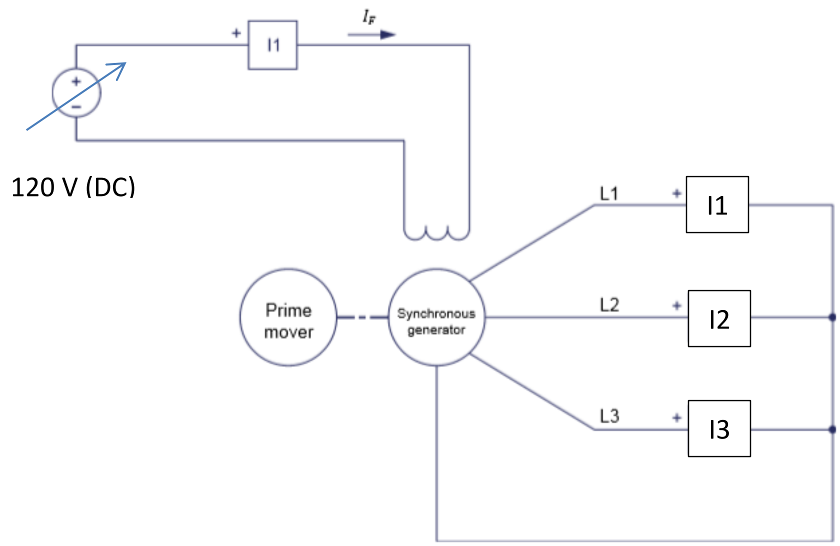

Fig. 4: Short Circuit Test

Field current I_f (A)	**Short Circuit Current I_a (A)**
0.05	
0.1	
0.15	
0.2	
0.25	

f) Once finished, reduce the variable DC supply back to its minimum vaule, turn off the DC power source of the exciter, then stop the prime mover.

g) Plot the the short-circuit curve of the generatori.e., I_a versus I_f. (home assignment).

3) Load Test

Figure 5 shows the voltage regulation characteristics (i.e., curves of the output voltage as a function of the output current) of a three-phase synchronous generator for resistive, inductive, and capacitive loads. The curves show that when the load is either resistive or inductive, the generator output voltage decreases when the generator output current increases. Conversely, when the load is capacitive, the generator output voltage increases when the generator output current increases. In this experiment, we will consider only the resistive load.

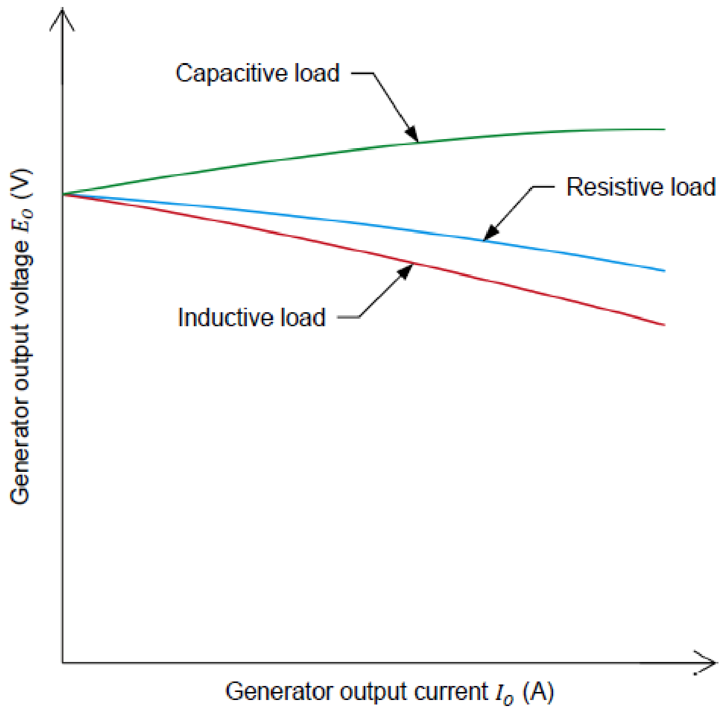

Fig. 5: Generator Voltage as a Function of Load Current.

a) Connect a resistive load bank at the generator terminals as shown in Fig. 6 below. Initially start with all resistances switched off (i.e., open circuit). Connect the meters as shown. Start the prime mover and run the shaft at 1800 rpm. Then turn on the DC power supply and adjust the exciter current till the line-to-line voltage of the generator reaches 208 V (which is corresponds to a phase voltage of 120V). Record the metered values in the first row of the table below.

b) Increase the generator current by decreasing the load resistance in increments as shown in the table below. For each load, record the generator line voltage and current. Make sure the speed is kept constant at 1800 rpm. The field current should remain fairly constant.

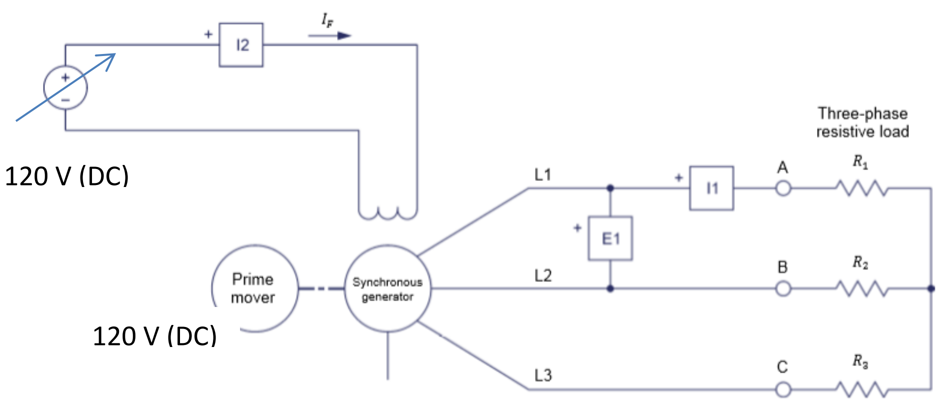

Fig. 6: Resistive Load Test.

Field Current I_f (A)	**Load Resistance (Ω)**	**Generator current I_a (A)**	**Generator Line Voltage Ea (V)**
	∞	0	208
	1200		
	600		
	400		
	300		
	200		
	171		

h) Once finished, reduce the variable DC supply back to its minimum vaule, turn off the DC power source of the exciter, then stop the prime mover.

i) Plot the the generator load curve, i.e., E_a versus I_a. (home assignment).

Real generators have automatic voltage regulators (AVR) that maintain the terminal voltage constant by increasing the field current every time the AVR senses a drop in voltage. You may mimic this feature by adjusting the field current manually in order to keep the voltage constant at 120/208 V under any load condition.

j) Start the procedure above by switching off the entire resistive load, then for each added load, increase the field current till the voltage regains its no-load value of 208 V. At each step, record the field current and generator current.

k) Once finished, reduce the variable DC supply back to its minimum vaule, turn off the DC power source of the exciter, then stop the prime mover.

Field Current I_f (A)	Load Resistance (Ω)	Generator current I_a (A)	Generator Line Voltage Ea (V)
	∞	0	208
	1200		208
	600		208
	300		208
	200		208

Table C-1. Impedance table for the load modules.

Impedance (Ω)			Position of the switches								
120 V 60 Hz	220/230 V 50 Hz/60 Hz	240 V 50 Hz	1	2	3	4	5	6	7	8	9
1200	4400	4800	I								
600	2200	2400		I							
300	1100	1200			I						
400	1467	1600	I	I							
240	880	960	I		I						
200	733	800		I	I						
171	629	686	I	I	I						
150	550	600	I			I	I	I			
133	489	533		I		I	I	I			
120	440	480			I		I	I			
109	400	436			I	I	I	I			
100	367	400	I		I	I	I	I			
92	338	369		I	I	I	I	I			
86	314	343	I	I	I	I	I	I			
80	293	320	I			I	I	I	I	I	I
75	275	300		I		I	I	I	I	I	I
71	259	282			I		I	I	I	I	I
67	244	267			I	I	I	I	I	I	I
63	232	253	I		I	I	I	I	I	I	I
60	220	240		I	I	I	I	I	I	I	I
57	210	229	I	I	I	I	I	I	I	I	I