Date:____________________

Name: __________________

ID: __________________

LABORATORY EXPERIMENT NO. 7

SYNCHRONOUS GENERATOR

OBJECT

1. To understand the basic operation of a synchronous generator.
2. To measure the synchronous reactance of a synchronous generator by measured values of open circuit voltage and short circuit current.
2. To measure the voltage regulation of a synchronous generator under different loads.

DISCUSSION

Electric power is produced in large generating stations which contain one or more alternating current (AC) generators, or synchronous generators, and a mechanical means of driving them. The mechanical power is usually provided by steam turbines which, in turn, derive their energy from the heat given off by burning oil, gas or coal or from the heat of nuclear reaction. In areas where water power is plentiful, hydraulic turbines provide the mechanical power to drive the synchronous generators.

The voltage E_0 generated by the synchronous generator depends on the flux per pole which, in turn, depends on the DC current which flows in the pole windings. The generator voltage per phase can therefore be varied by adjusting the DC excitation. At no load, the voltage E_T measured at the generator terminals is the same as the generated voltage E_0.

If the Synchronous generator is loaded, its terminal voltage will change, even though the DC excitation is kept constant. This is because of the synchronous generator has an internal impedance, composed of the resistance and reactance of the stator windings. A synchronous generator can, therefore, be represented by a circuit such as shown in Fig 7-1, in which *X* is the stator reactance, *R* the winding resistance, and E_0 the stator voltage generated as the poles sweep past the stator conductors.

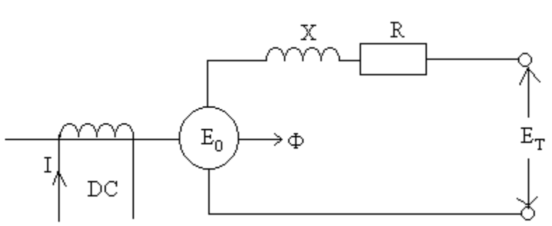

Fig 7-1

The resistance R is always much smaller than the reactance X, so we can simplify the circuit to that shown in Fig 7-2 without introducing a significant error. The terminal voltage of the generator (per phase) is E_T and X is its so-called *synchronous reactance*.

The equivalent circuit of a synchronous generator is very simple and with it we can explain all the major properties of this machine. For example, we would expect that if a resistive or an inductive load is connected to the terminals, the terminal voltage E_T will drop. On the other hand, if a capacitive load is connected to the terminals, a voltage rise is to be expected.

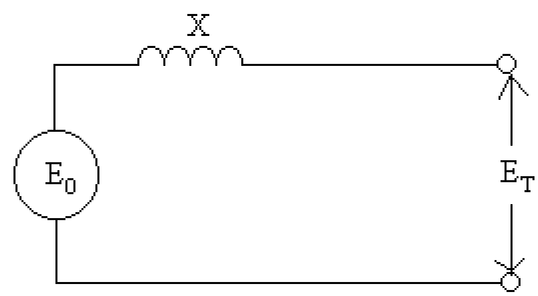

Fig 7-2

The value of the synchronous reactance can be found by measuring the voltage E_T on open circuit and then measuring the current when the terminals are placed in short-circuit. (Similar to Thevenin Equivalent Circuit?

Then X can be drawn with $X=E_0/I_{sc}$

The synchronous reactance of a synchronous generator is always very large, so that even under short-circuit conditions, the current rarely exceeds 1.5 times the normal full-load current. However, for the first few cycles following a short-circuit, the current can be much higher owing to the transient properties of the machine.

In the experiment, a Prime Mover/Dynamometer module will be used to drive the 3-phase synchronous generator, replacing the steam turbine which usually be employed in a real generating station.

INSTRUMENTS AND COMPONENTS:
Power Supply
Prime Mover/Dynamometer
Synchronous Motor/Generator Module
Resistance Module
Inductance Module
Capacitance Module
Fluke DMM
AC Metering Module
3-Phase Watt-Var Module
Timing Belt
Connection Leads.

EXPERIMENTS

<u>Synchronous Generator Open-Circuit Test</u>

Caution: High voltages are present in this experiment. Do not make any connections with the power on. The power should be turned off after completing each individual measurement.

7-1. Please make sure your power supply is working properly. Specifically your power supply should be able to generate variable DC voltage between terminals 7 - N and fixed 120V DC at 8 - N.

7-2. In this experiment we determine the variation of the generated voltage as the DC exciting current is increased. Set up the circuit as shown in Fig 7-3. Couple the Prime Mover to Synchronous Generator using a timing belt. Connect AC voltmeter from line to neutral of one phase of the synchronous generator to measure the generator voltage E_0. Connect a DC ammeter to measure the exciting current I_F.

7-3. Apply power and adjust the speed of the Prime Mover to 1800 *rpm* exactly. This speed must be kept for the remainder of the experiment.

7-4. Vary the current I_F using the knob on the Synchronous Generator and note the effect upon the generated voltage E_0 and record your results in Table I.

7-5. Turn off the power supply

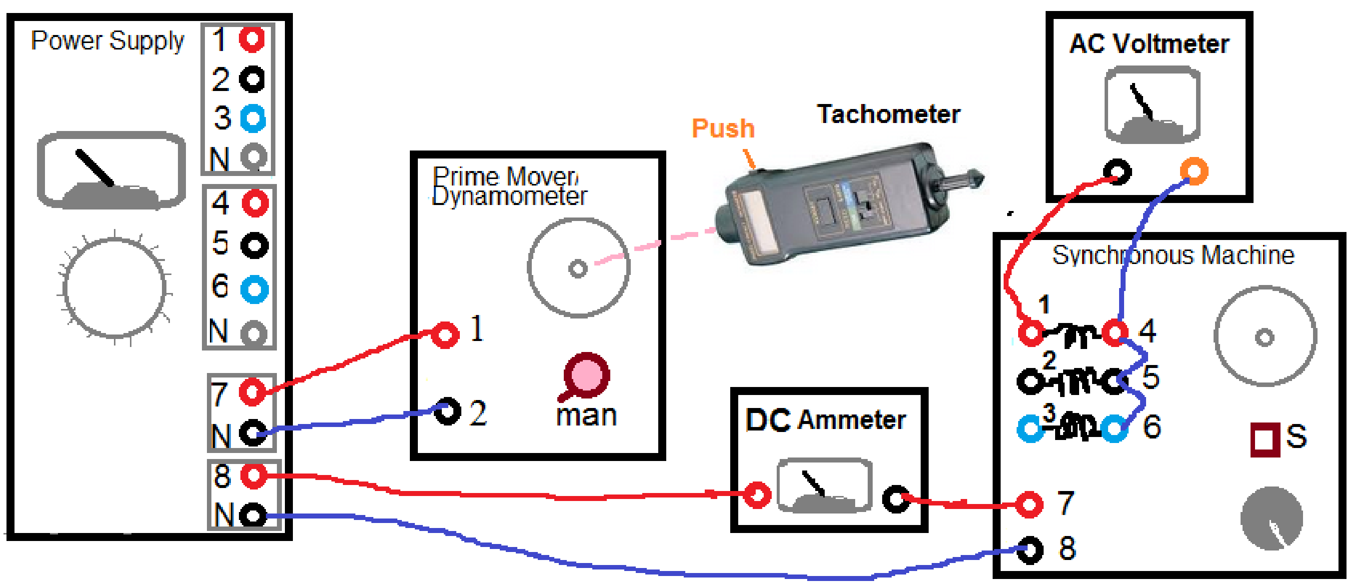

Fig 7-3

Table I

I_F [A]	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
E_0[V]									

Synchronous Generator Short-Circuit Test

(Read and proceed very carefully)

7-6. Using the same set-up as in Fig 7-3, Adjust the open-circuit voltage E_0 to 120 volts.

7-7 Turn off the power supply.

7-8. Short circuit the stator terminals through three AC ammeters as shown in Fig 7-4.

7-9. Turn on power and take the reading of the currents. Get the average current I.

7-10. Calculate the value of the synchronous reactance from the formula: $X=E_0/I$

7-11. Do above procedures (1 - 5) for E_0=140V and E_0=100V.

7-12. Fill the Table II.

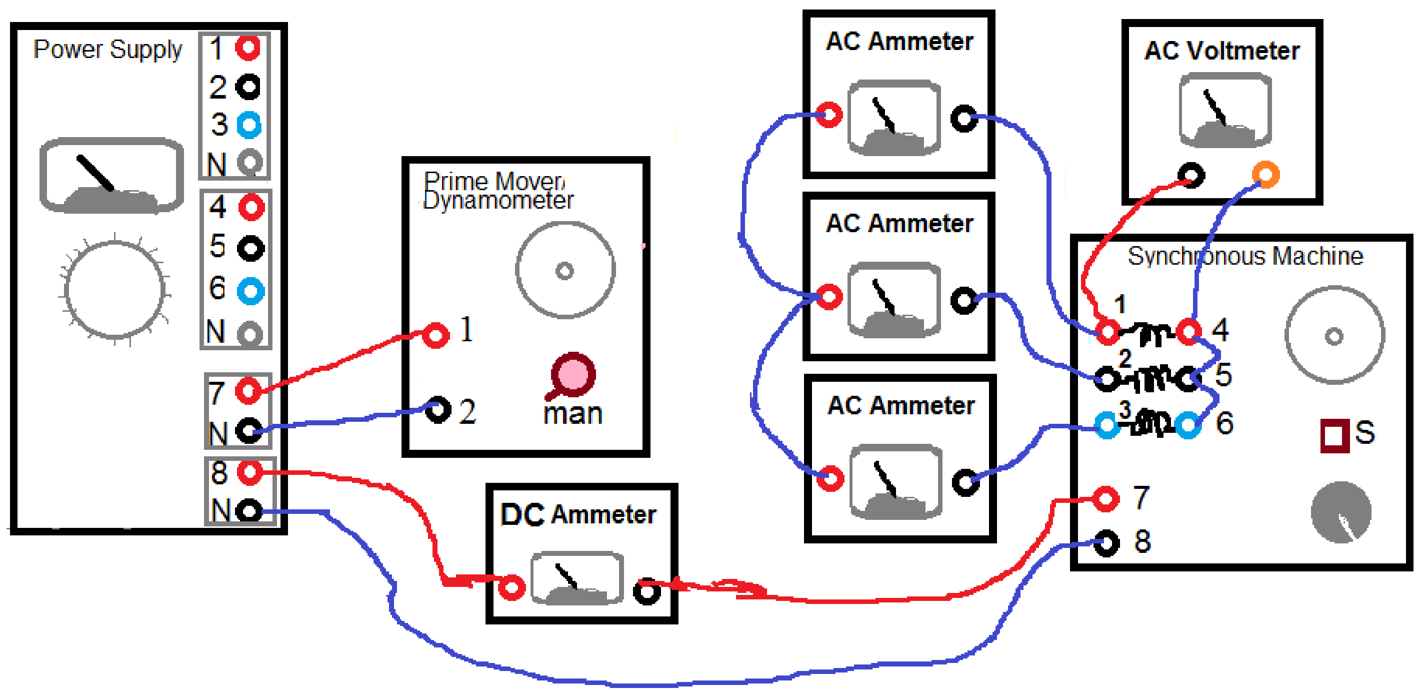

Fig. 7-4

Table II.

E_0	I_a	I_b	I_c	I(average)	X
100 V					
120 V					
140 V					

7-13. In this section, you will find the effect of various loads upon the terminal voltage of the synchronous generator. Connect a resistive load to the generator terminals and introduce a watt-var meter and a voltmeter as shown in Fig 7-5.

7-14. Adjust the exciting current I_F of the synchronous generator so that the open-circuit voltage E_0=120V. (Note: this E_0 is not the same as the Line-to-Line voltage (E_L) between the terminals 1 and 2 indicated in Fig. 7-5. E_0 is the Phase voltage between terminal 1 and 4 as in Fig. 7-3.)

7-15. While keeping the speed and the current I_F constant, vary the resistive load and record your results. Be sure to keep the load resistance balanced so that all phases are equally loaded. Complete Table III.

7-16. Repeat the above procedure using an inductive load in place of the resistance, and record the results and complete Table III.

7-17. Repeat the above procedure using a capacitive load in place of the resistance, and record the results and complete Table III.

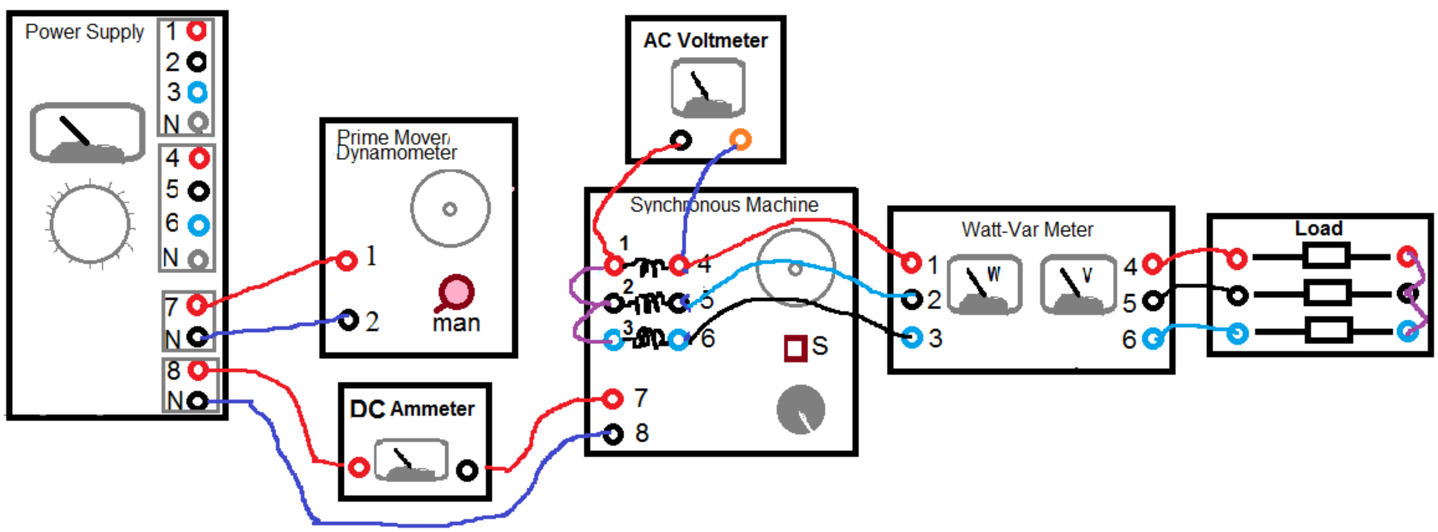

Fig 7-5

TABLE III

LOADS	R/Phase (Ω)	I_F (A)	E_L(V)	W	VAR	VA
Resistive Load	∞					
	1200					
	600					
	300					
Inductive Load	∞					
	1200					
	600					
	300					
Capacitive Load	∞					
	1200					
	600					
	300					

KNOWLEDGE PROBLEM

1. A 150MW synchronous generator generates an open-circuit line-to-line voltage of 12kV at nominal DC excitation. When the terminals are placed in short-circuit the resulting current per phase is 8000A. (i) Calculate the approximate value of the synchronous reactance per phase, and (ii) draw the equivalent circuit of the Synchronous Generator per phase under the DC field excitation conditions given above.

Calculation:

Equivalent Circuit Diagram: