EXPERIMENT NO. 6

Objective

1.
   (a) To perform open and short circuit tests on a synchronous generator and determine its synchronous impedance (i) neglecting saturation and (ii) considering saturation.
   (b) To write an equivalent circuit of the generator using the synchronous impedance values determined in 1(a)(i) and (ii).
   (c) To determine and draw the terminal voltage versus load current characteristics of the generator for unity power factor load using the equivalent circuit determined in (b). Also to determine voltage regulation of the generator for unity power factor load.

2. To perform a load test on the generator for unity power factor load. To draw the terminal voltage versus load current characteristic and to compare it with the results in 1 (c). Also to determine voltage regulation and compare it with results in 1 (c).

Theory

Synchronous impedance Z_S can be determined by open and short circuit tests on the generator. The generator is run at its rated speed. Open circuit characteristic (OCC) of generator is the plot of its terminal voltage against field current. This is also called the magnetization characteristic of the machine. Short circuit characteristic (SCC) is the plot of generator short circuit current versus field current. See Fig. 6.1. The synchronous impedance magnitude, Z_S neglecting saturation is

$$Z_S(unsaturated) = \frac{Rated\ voltage\ on\ Air-gap\ line}{S.C. current on SCC}\Big|_{I_f\ for\ rated\ voltage}$$

$$Z_S(unsaturated) = \frac{O.C. Voltage\ corresponding\ to\ AD}{S.C.\ correspoding\ to\ AB}\Big|_{for\ the\ same\ field\ current\ OA} \tag{1}$$

where AB is the short circuit current corresponding to the field current OA. The generator impedance adjusted for saturation is

$$Z_S(adjusted\ \ for\ saturation) = \frac{Rated\ voltage\ on\ OCC}{S.C.\ current\ on\ SCC}\Big|_{I_f\ \ saturated}$$

$$Z_S(adjusted\ \ for\ saturation) = \frac{O.C.\ Voltage\ corrosponding\ to\ AC}{S.C.\ Current\ corresponding\ to\ AB}\Big|_{for\ the\ same\ field\ current\ OA} \tag{2}$$

where, AB is the short circuit current corresponding to the field current OA.

Note that the values as determined above are approximate because to consider exactly the effect of armature reaction mmf, it is necessary to determine the orientation of armature reaction mmf in the machine (the reactance of the magnetic path depends on the orientation of the resultant mmf due to main field and armature reaction in machines with salient poles), and magnitude of the mmf (since this decides the level of saturation in the magnetic circuit).

These are not accurately taken into account in the two ways mentioned for finding synchronous impedance. Synchronous reactance is given by

$$X_S = \sqrt{(Z_S^2 - R_a^2)} \tag{3}$$

where R_a is the effective resistance of the armature. R_a can be measured for d.c. conditions (using voltmeter-ammeter method, say) and the result multiplied by a factor of 1.6 to get a good estimate of the effective value of the ac resistance. (See the discussion about this point in Chapter 14 ‘Alternating-Current Machine’ by Puchtein, Lloyd and Conrad).

We can now write an equivalent circuit for the generator in terms of a constant voltage behind the synchronous impedance. Per unit voltage regulation is defined as

$$p.u.\ voltage\ regulation = \frac{|\overline{E}_{ph}| - |\overline{V}_{ph}|}{|\overline{V}_{ph}|} \tag{4}$$

where, $\overline{E}_{ph}$ and $\overline{V}_{ph}$ denote, respectively, the phase values of no-load and full-load terminal voltages, for constant field excitation, rated speed and with $|\overline{V}_{ph}|$ = rated voltage of the machine.

Laboratory Work

1. Note the nameplate details of the machines (alternator and prime mover) for the experiment. Use only half of the panel board (dc motor and alternator terminals) for this experiment.

Open Circuit Test

2. Make suitable connections as shown in Fig. 6.1 and get them checked.

3. Keep the armature rheostat of dc motor to maximum position.

4. Switch on the dc supply of prime mover and start the prime mover. Bring the speed to the rated value (1500 rpm) of alternator by reducing the resistance of armature rheostat. If the rated speed is not attained by armature rheostat then reduce the field current of prime mover and maintain the speed constant at this value during the experiment.

5. Keep the resistance of field rheostat of alternator at maximum and switch on the dc supply of field of alternator.

6. Switch on the output of alternator and set the rated voltage by changing the field current of

alternator by filed rheostat.

7. Take the reading of all the meters.

8. Switch off output supply of alternator and bring back the field rheostat at maximum position. Do not stop the prime mover.

Short Circuit Test

9. Draw a circuit diagram of the test setup, including the prime mover circuit and show all the meters and their ranges.

10. Make suitable connections and get them checked.

11. Switch on the output supply of alternator.

12. Now switch on the dc supply of field circuit of alternator but before switching on the field supply make sure that the field rheostat should be at maximum position. Maintain the rated speed of alternator throughout the experiment.

13. Increase the field current of alternator so that the rated current of alternator will flow through the stator. Note down the reading of all the meters. Do not go beyond the full load current of alternator.

14. Switch off output supply of alternator and bring back the field rheostat at maximum position. Do not stop the prime mover.

Load Test at unity Power Factor (See Fig. 6.1A)

15. Draw the circuit diagram for the load test. Show all the meters and their ranges.

16. Make suitable connections as per Fig. 6.1A and get them checked.

17. Switch on the output supply of alternator and loading of alternator is done by a 3-phase resistive load.

18. Adjust the load and alternator field current to give full load current and rated voltage at the terminals of the alternator.

19. Keeping the field excitation of the alternator constant, gradually reduce the load current and note down the current and terminal voltage of the alternator.

20. Make sure that throughout the experiment the speed of the alternator remains constant at 1500 rpm by adjustment of dc motor field excitation or armature rheostat.

21. After taking all the required readings stop the prime mover.

Measurement of d.c. Resistance of Alternator Armature

Measurement of resistance is to be done by LCR Bridge.

Report

Draw a circuit diagram of the test setup and show all the meters and their ranges. This should include circuit for prime mover (which is d.c. shunt motor).

The report should contain all the things required to done as stipulated in the section 'Objective'.

1. Plot OCC and SCC on the same axes (as shown in Fig. 6.2).
2. Determine Z_S, R_a, and X_S as explained in 'Notes'.
3. Write equivalent circuit of alternator with values of circuit parameters shown.
4. Determine the voltage regulation of alternator at unity power factor using the equivalent circuit of item 3.
5. Determine and draw the load characteristics, i.e. plot of terminal voltage against load current of alternator at unity power factor using the equivalent circuit of item 3.
6. On the same axes as for item 5 above, draw the load characteristics as determined experimentally.
7. Discuss the results obtained in items 5 and 6.
8. Compare the regulation as calculated in item 4 and as determined from the characteristic in item 6.

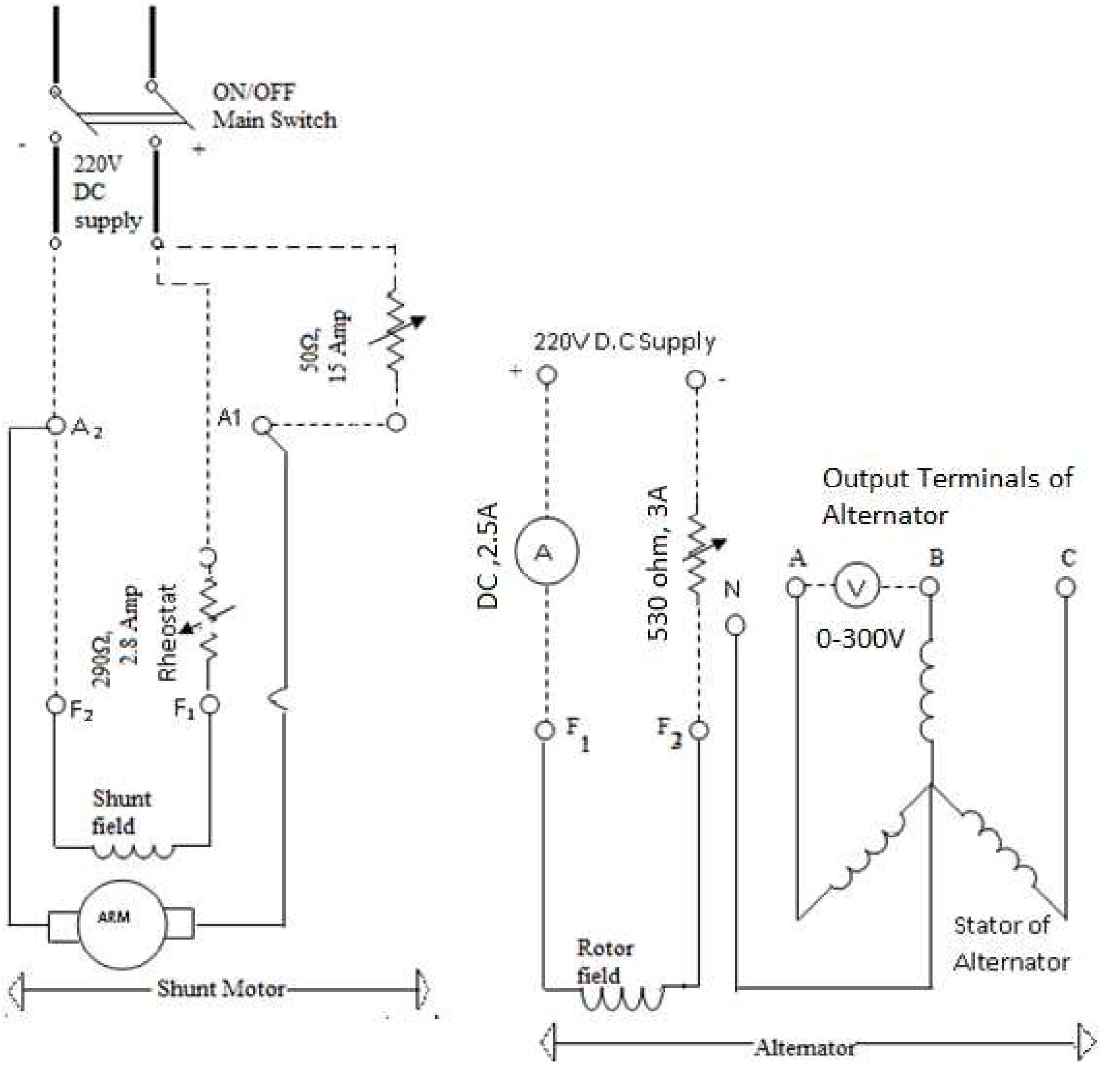
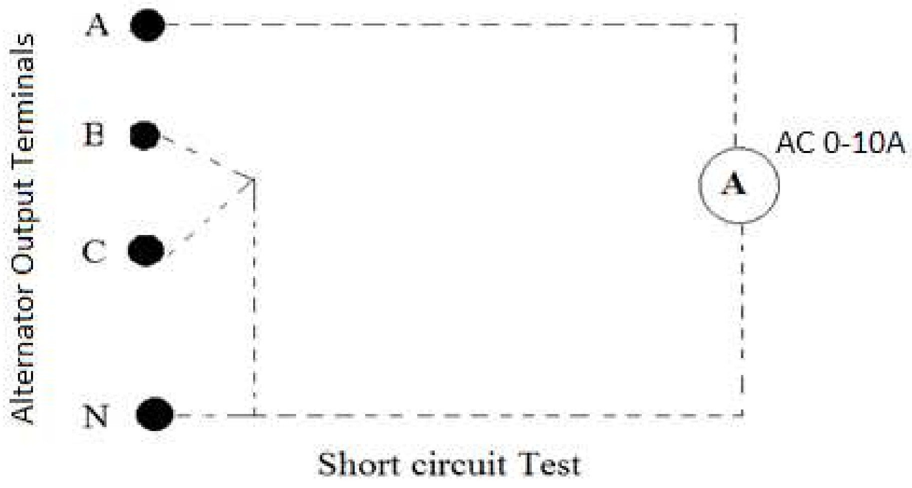


FIG 6.1 Circuit diagram of an alternator coupled with DC Shunt motor
(Panel board diagram)


Alternator Output Terminals
A
B
C
N
AC 0-10A
A
Short circuit Test

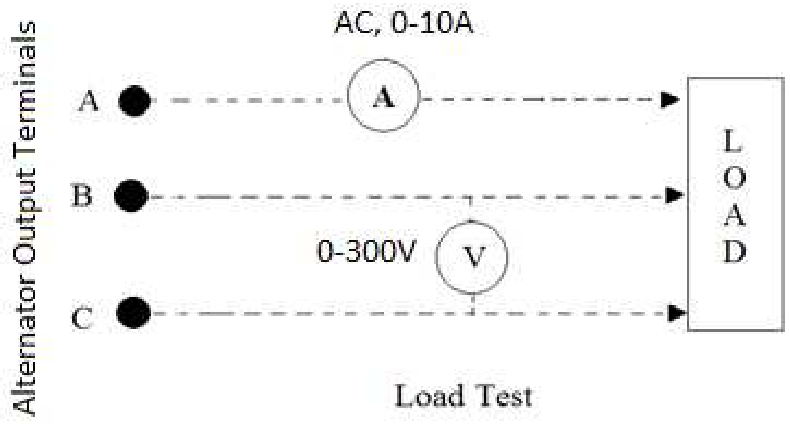

Alternator Output Terminals
AC, 0-10A
A
B
C
A
0-300V
V
LOAD
Load Test

Fig. 6.1A

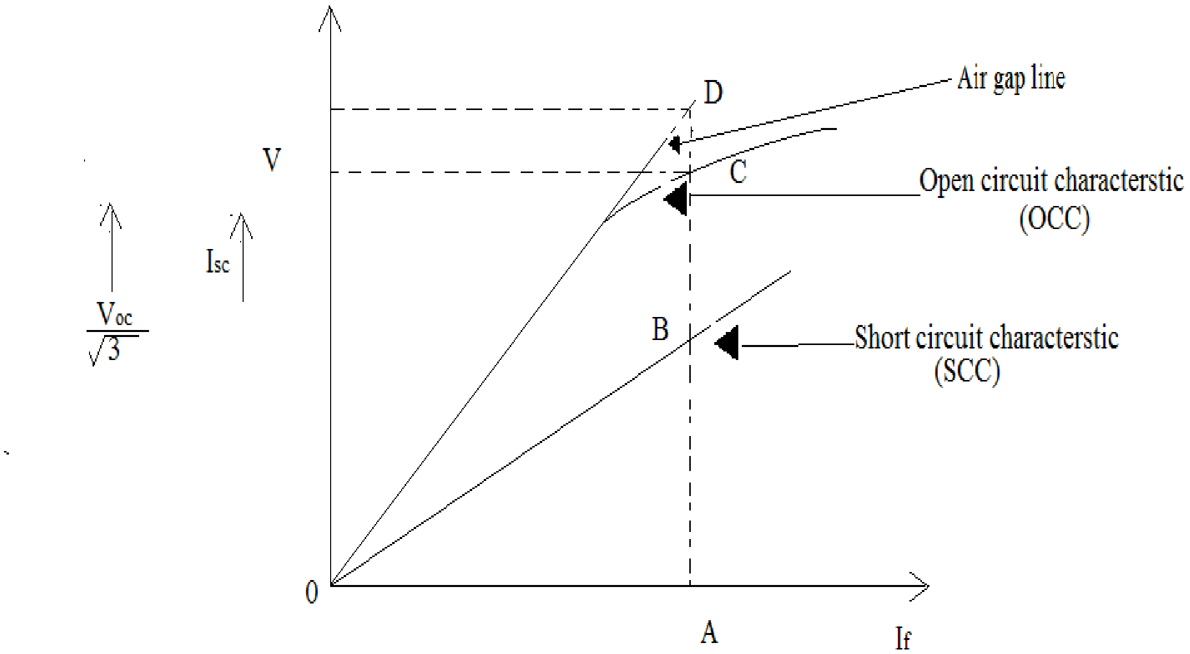


FIG 6.2 : Open and short circuit characterstics