Indian Institute of Technology Hyderabad (IITH)

Electrical Machines Laboratory, Department of Electrical Engineering

Experiment-4:

Determination of Voltage Regulation of a Synchronous Generator Using EMF Method

1. Objective

The aim of this experiment is to get the value of X_s and R_s for a given synchronous generator and to find the voltage regulation of it using EMF method.

2. About Synchronous Reactance

The single-phase equivalent circuit of an alternator for a balanced operation is shown as follows.

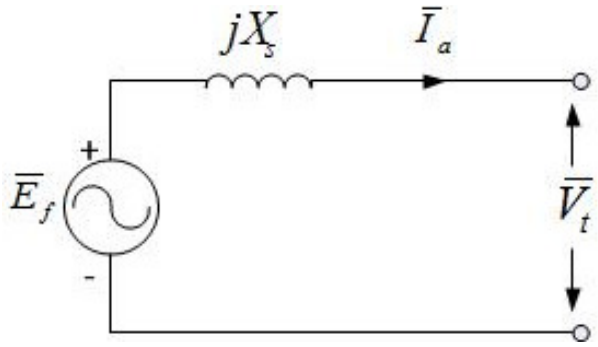

FIGURE 1

Here, $\bar{E}_f$ is the voltage that is induced in the armature winding by the field excitation and, hence, is called as the excitation voltage. Apart from the excitation voltage, there will be a voltage drop in the armature circuit because of the armature current $\bar{I}_a$ itself. By assuming a linear magnetization and by ignoring the armature resistance, it can be shown that the respective voltage drop is proportional to the armature current with a phase lead of 90^0. Thus, the voltage drop caused by the armature current can in effect be modeled through an inductive reactance X_s, which is finally called as the synchronous reactance.

3. Circuit Arrangement

The circuits arrangement to conduct the experiment is shown in Figures 2, 3 and 4. Here, three different tests are to be performed. The first test is called as the open circuit test and is to be conducted by employing the circuit configuration shown in Figure 2. Subsequently, a short circuit test and voltmeter ammeter method is used to calculate the per phase resistance of the stator by employing the circuit configurations shown in Figures 3 and 4, respectively.

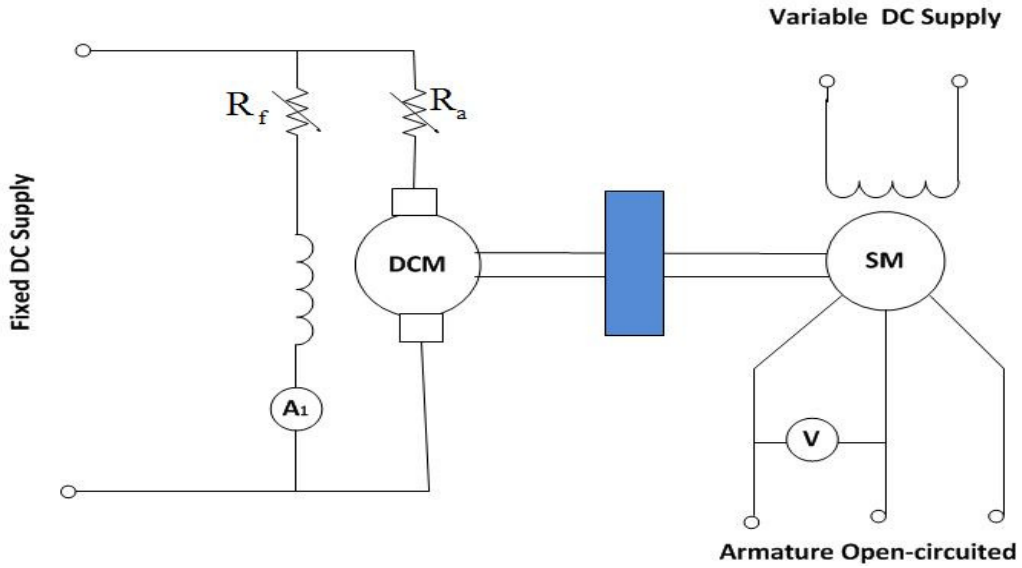

FIGURE 2

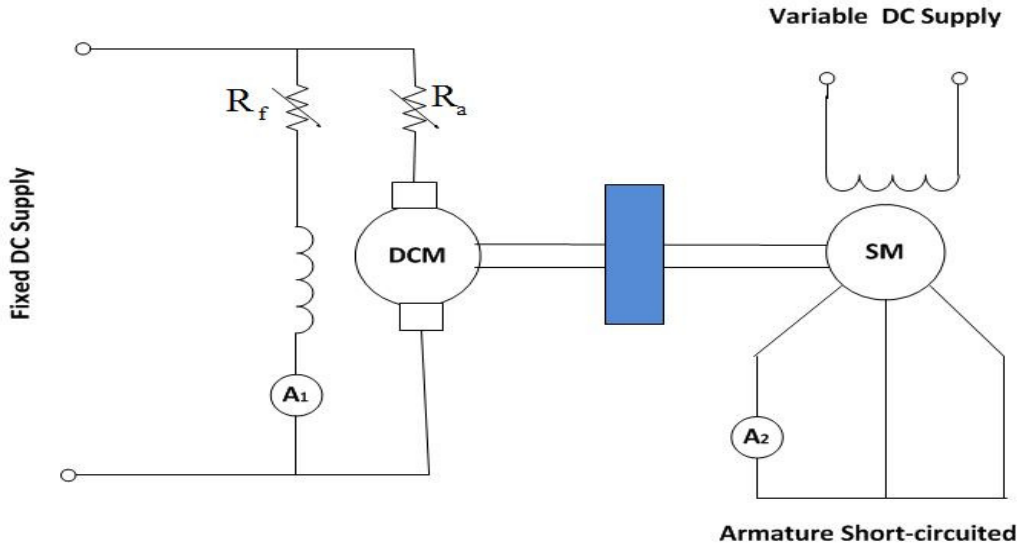

FIGURE 3

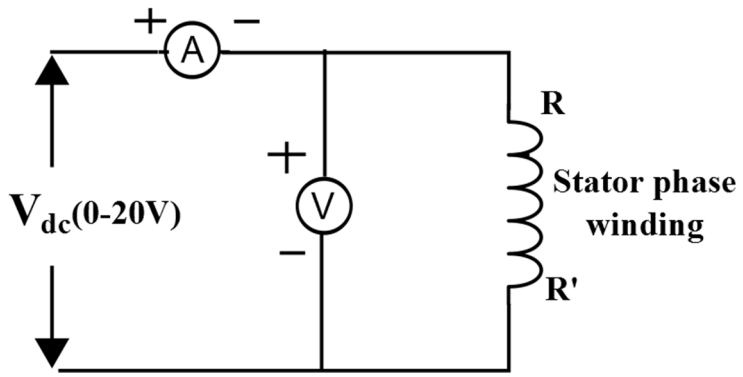

FIGURE 4

4. Procedure

1. To perform a test, the speed of the DC shunt motor should initially be set close to 1500 r.p.m. by adjusting its armature and field resistances.

2. For the open circuit test, the current in the alternator field is to be gradually increased (by adjusting the variable DC voltage) and the corresponding armature voltages are to be noted down.

3. Similarly, for the short circuit test, the armature currents are to be noted down for different values of field currents. Although the open circuit test should be continued up to a voltage higher than the rated voltage, exceeding the armature rated current is strictly prohibited in the short circuit test.

   Based upon the observations from open circuit and short circuit tests, the synchronous reactance of the alternator can be calculated as follows.

   $$X_s = \frac{V_{OC}}{\sqrt{3} I_{SC}}$$

   Here, V_{OC} and I_{SC} are the open circuit line-to-line voltage and short circuit line current, respectively, for the same value of field current. The value of X_s should be calculated for all the different values of the alternator field current.

4. Per phase stator resistance of the synchronous machine is calculated using voltmeter and ammeter method but the value obtained here is a DC resistance of the machine winding. AC resistance should be calculated by multiplying the DC resistance with factor of 1.1 (to account for skin effect)

$$R_s = 1.1 * R_{dc}$$

Now the voltage regulation of the machine is calculated using the values of X_s and R_s as given by the following formulae.

$$\% \text{ voltage regulation} = \frac{(V_{nl} - V_{fl})}{V_{fl}} * 100$$

Where V_{nl} (no load) voltage is

$$V_{nl} = \sqrt{\left(V_{fl} * \cos\theta + I * R_s\right)^2 + \left(V_{fl} * \sin\theta + I * X_s\right)^2}$$

V_{fl} is full load voltage

And θ is the power factor angle

5. Results

I. Open Circuit and Short Circuit Tests' Observations:

S. No.	Open Circuit Test		Short Circuit Test		Synchronous reactance (X_s)
	Field current (I_f)	Open circuit voltage (V_{OC})	Field current (I_f)	Short circuit current (I_{SC})	
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					

II. Voltmeter Ammeter Method for Stator Resistance Measurement:

S. No.	Current (amps)	Voltage (volts)	DC resistance $R_{dc} = V/I$	Per phase stator resistance $R_s = 1.1 * R_{dc}$
1.				
2.				
3.				
4.				

6. Conclusions

1 Draw the open circuit characteristics (OCC) and short circuit characteristics (SCC).

2 Calculate the voltage regulation from OCC and SCC plots and compare it with the voltage regulation value that is obtained from the section.4 mentioned above.

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