1 Experiment No. 2

2 Experiment Title

Observation of Characteristics of a Synchronous Generator.

3 Objective

The objectives of this lab are as follows:

- To analysis terminal voltage and field current.
- To analysis terminal voltage and rotation.
- To understand the generator's excitation and performance behavior.

4 Theory

A synchronous generator converts mechanical energy into electrical energy at a constant frequency. It operates based on the principle that the generated electrical frequency is synchronized with the mechanical speed of the rotor.
The induced electromotive force (EMF) depends on the rotor speed (S) and the magnetic flux per pole (Φ), and is expressed as:

$$E \propto S \cdot \Phi$$

Since the flux Φ is directly proportional to the field current (I_f), increasing the field current enhances the magnetic field strength and thus increases the terminal voltage:

$$I_f \propto \Phi$$

$$E \propto \Phi$$

Thus

$$E \propto I_f$$

The synchronous speed (S) of the generator is related to the electrical frequency (f) and the number of poles (P) as:

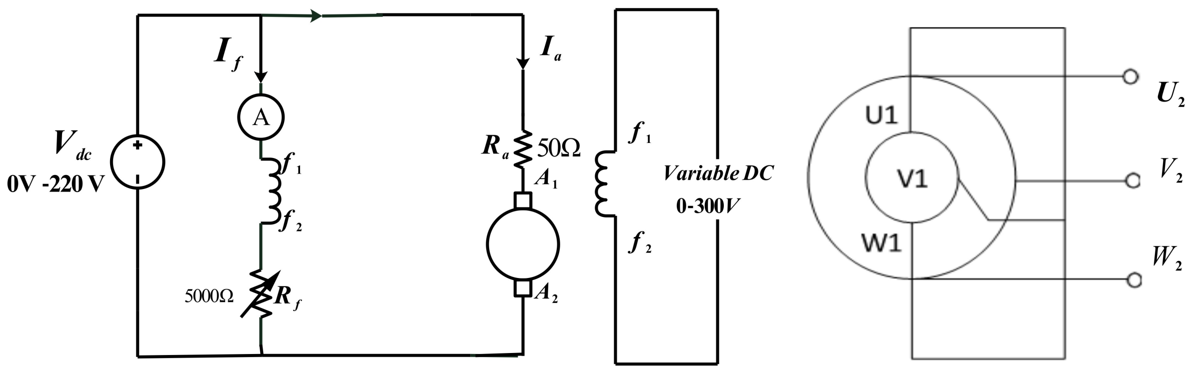
$$S = \frac{120f}{P}$$

where S is in revolutions per minute (rpm), and f is in hertz (Hz).
In operation, the rotor is excited with a direct current (DC) to produce a magnetic field. This rotating field induces an alternating voltage in the stator windings due to Faraday's law of electromagnetic induction. Under no-load conditions, the induced EMF per phase is given by:

$$E = 4.44 f N \Phi$$

where E is the RMS value of the induced EMF, f is the frequency, N is the number of turns per phase, and Φ is the flux per pole.
The relationship between terminal voltage and field current under no-load is illustrated by the Characteristic curve. As field current increases, the terminal voltage also increases, provided the speed remains constant. Additionally, increasing the speed of the prime mover raises the EMF and hence the terminal voltage.

5 Circuit Diagram



(a) Circuit Diagram of Synchronus Generator.

6 Required Apparatus

1. **DC Motor**
   (a) Power: 300W , Speed: 3000 rpm
   (b) Voltage: 220V
   (c) **Excitation (Series)**: D1-D2, Current: 1.9A, **Excitation (Separate)**: F1-F2, Current: 1.8A, Excitation Voltage: 220V, Excitation Current: 0.1A
2. **Synchronous Generator**
   (a) Power: 350W ,Power Factor: $\cos\phi = 1$,Speed: 3000 rpm
   (b) Voltage: 400V (star) / 230V (delta) ,Current: 0.7A (star) / 1.2A (delta)
   (c) Excitation Voltage: 220V ,Excitation Current: 0.45A
3. **Resistors**
   (a) 50Ω: Power = 500W, Current = 3.16A
   (b) 200Ω: Power = 500W, Current = 1.58A
   (c) 5000Ω: Power = 500W, Current = 0.31A
4. **Tachometer**
   (a) For 0.6V/rev: 300V at 5000 RPM , For 2mV/rev: 10V at 5000 RPM
   (b) Maximum Current: 0.07A
   (c) Maximum Speed: 5000 RPM
5. **AC Multimeter**
   (a) 500V AC RMS
   (b) 5A

7 Data Table

Table 1: Readings of Terminal Voltage V_T , Field Current I_f and Speed S

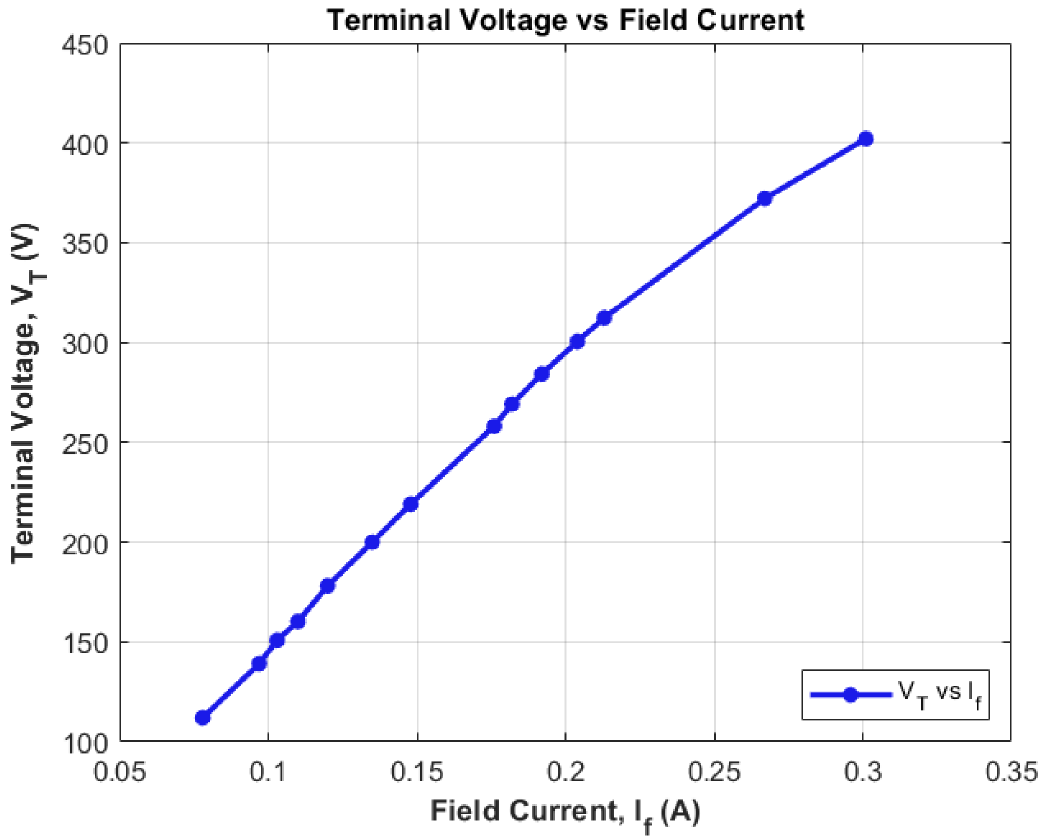
SI No.	**Terminal voltage** $V_g(V)$	**Field current** $I_f(A)$	**Speed (rpm)**
1	112.0	0.078	3000
2	139.1	0.097	
3	150.8	0.103	
4	160.2	0.110	
5	178.1	0.120	
6	200.0	0.135	
7	219.1	0.148	
8	258.1	0.176	
9	269.2	0.182	
10	284.2	0.192	
11	300.5	0.204	
12	312.3	0.213	
13	372.1	0.267	
14	402.1	0.301	

(a) Readings of V_T and I_f

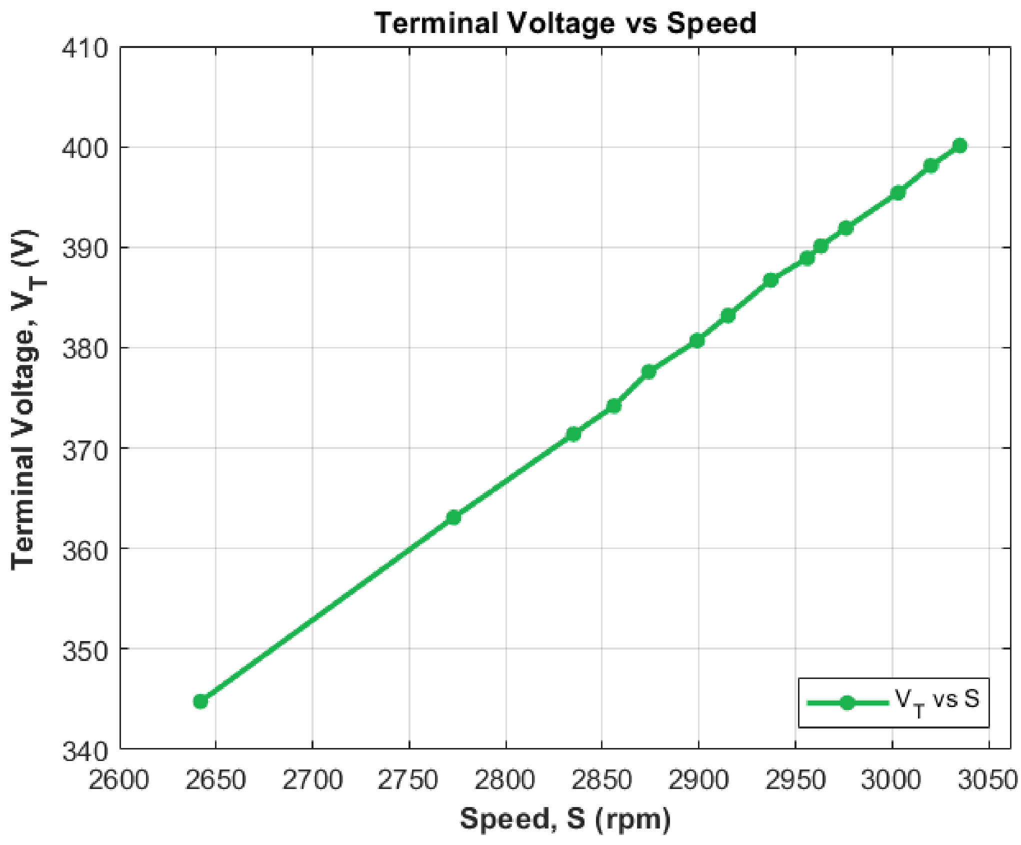
SI No.	**Terminal voltage,** $V_g(V)$	**Speed S (rpm)**
1	400.1	3035
2	398.1	3020
3	395.4	3003
4	391.9	2976
5	390.1	2963
6	388.9	2956
7	386.7	2937
8	383.2	2915
9	380.7	2899
10	377.6	2874
11	374.2	2856
12	371.4	2835
13	363.1	2773
14	344.8	2642

(b) Readings of V_T and S

8 Graph



(a) V_T vs I_f Graph



(b) V_T vs S Graph

9 Discussion

The synchronous reactance of the synchronous generator was determined through Open Circuit and Short Circuit tests by varying the field current. During the Open Circuit Test, the terminal voltage increased with increasing field current, exhibiting an approximately linear relationship in the unsaturated region of the magnetic core. This behavior follows the theoretical Open Circuit Characteristic (OCC) of a synchronous generator, confirming that:

$$E_{oc} \propto I_f$$

In the Short Circuit Test, the short circuit current also increased linearly with the field current, as there is minimal magnetic saturation due to the low voltage during the test.
By taking the ratio of the open-circuit voltage to the short-circuit current for corresponding field currents, the synchronous reactance (X_s) was estimated using the relation:

$$X_s = \frac{V_{oc}}{I_{sc}}$$

This value provides a measure of the internal impedance due to armature reaction and leakage reactance in the generator. The experimental data followed the expected theoretical trend, validating the method used and highlighting the dependence of X_s on both excitation and the magnetic characteristics of the generator.
Overall, the experiment successfully demonstrated the process for determining synchronous reactance, an essential parameter for performance analysis and design of synchronous machines.