1 Experiment No. 3

2 Experiment Title

Determination of synchronous reactance of a synchronous generator.

3 Objective

The objectives of this lab are as follows:

- To determine the synchronous reactance of a synchronous generator through open circuit and short circuit tests.
- To investigate the linearity of the open circuit voltage and short circuit current versus field current, and analyze the implications for estimating synchronous reactance

4 Theory

Synchronous generators operate at synchronous speed to generate alternating current (AC) power at a desired frequency. An important parameter in analyzing their performance is the **synchronous reactance** (X_s), which represents the imaginary component of impedance that accounts for the voltage drop due to inductance in the generator.
To determine X_s, two essential tests are performed:

- **Open Circuit Test (OCT)** – The generator is run at synchronous speed with no load connected. The terminal voltage (E_{oc} or V_{oc}) is measured at different values of field current (I_f).
- **Short Circuit Test (SCT)** – The terminals are short-circuited and the short circuit current (I_{sc}) is measured for the same values of field current (I_f).

From the test data, the synchronous reactance can be determined using the ratio of open-circuit voltage to short-circuit current, assuming linear behavior and negligible armature resistance.

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

The phasor equation for a synchronous generator is:

$$V_\phi = E_a - jX_sI_a - I_aR_a$$

Where:

- V_ϕ = Phase voltage at the terminals
- E_a = Induced EMF
- I_a = Armature current
- X_s = Synchronous reactance
- R_a = Armature resistance

If the armature resistance R_a is negligible, then:

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

This estimation aids in modeling and efficient operation of synchronous generators in power systems.

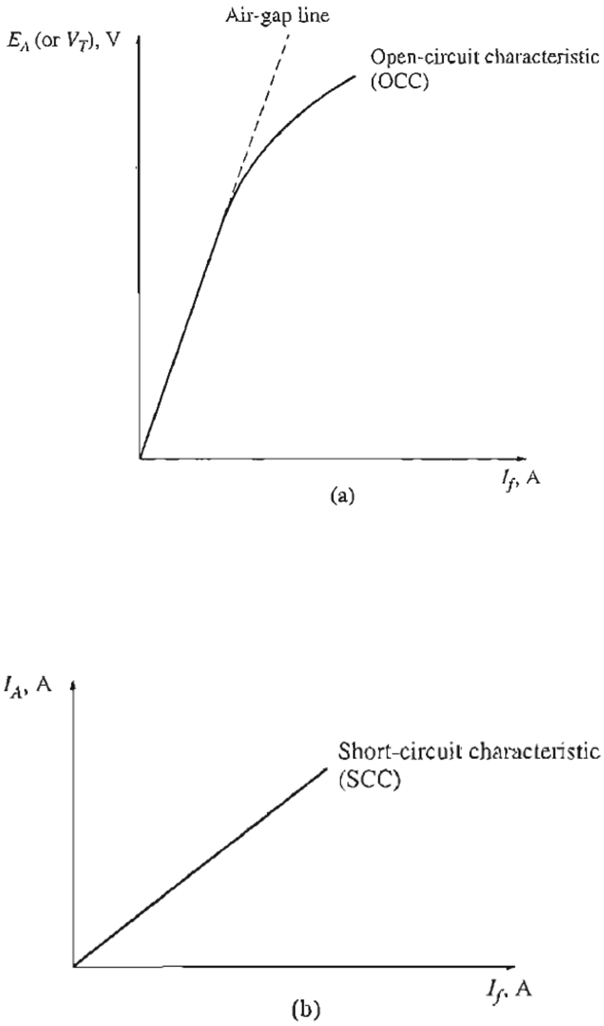
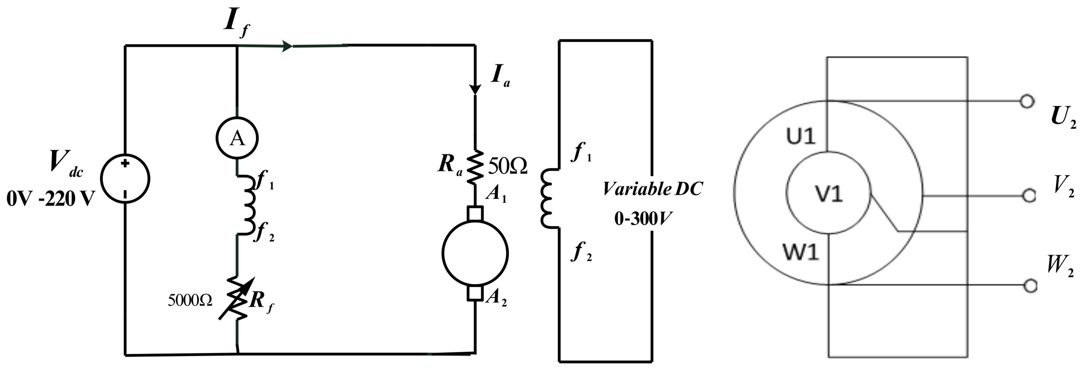
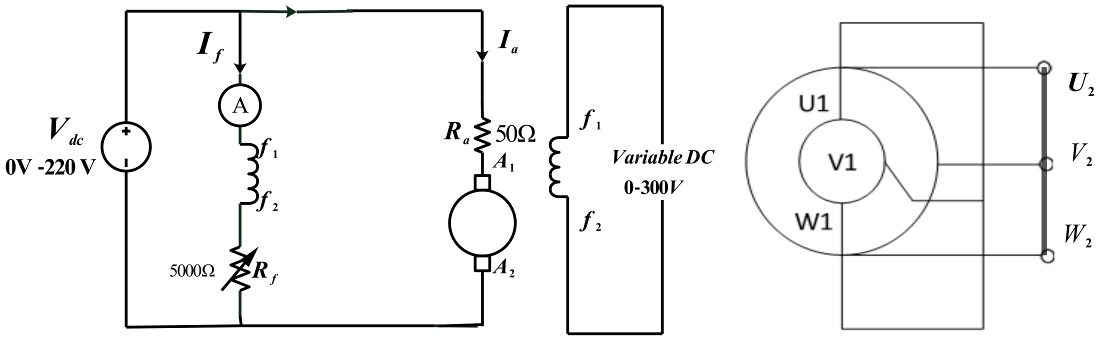


Figure 1: Open Circuit Characteristic curve & Short Circuit Characteristic Curve [Electric Machinery Fundamentals_Chapman_5ed]

5 Circuit Diagram



(a) Circuit Diagram of Open Circuit Test.



(b) Circuit Diagram of Short Circuit Test.

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

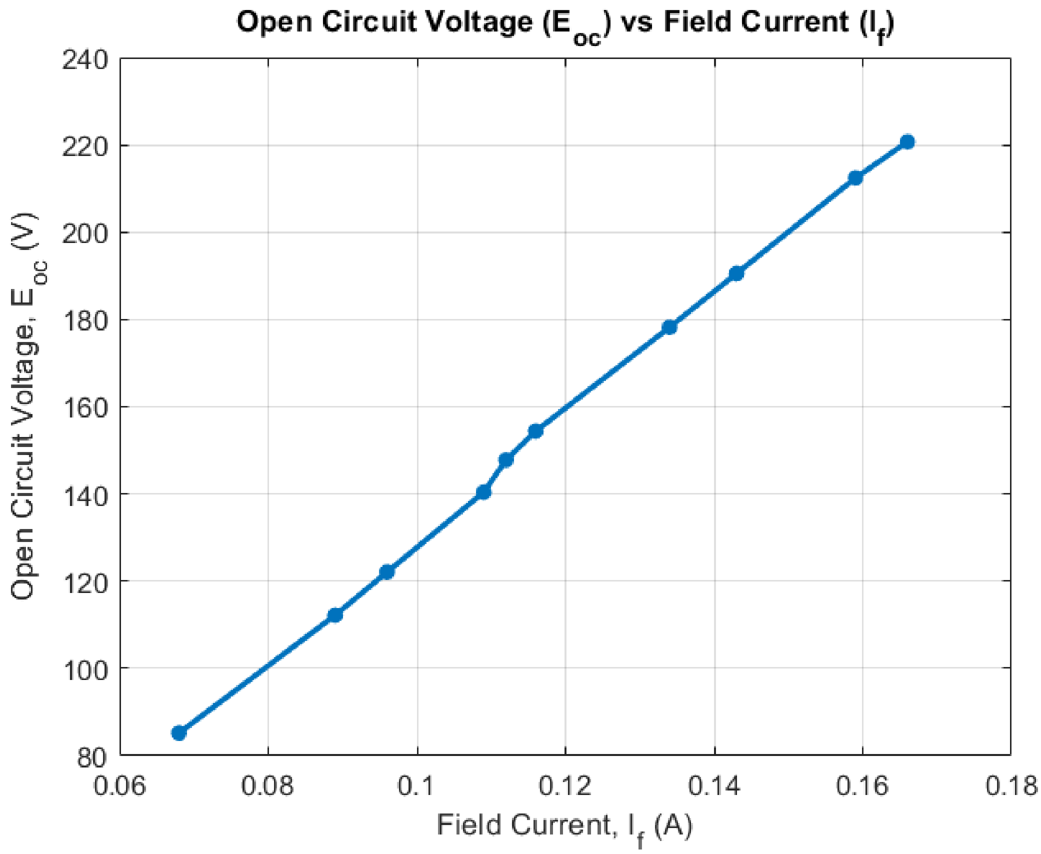
(b) 5A

7 Data Table

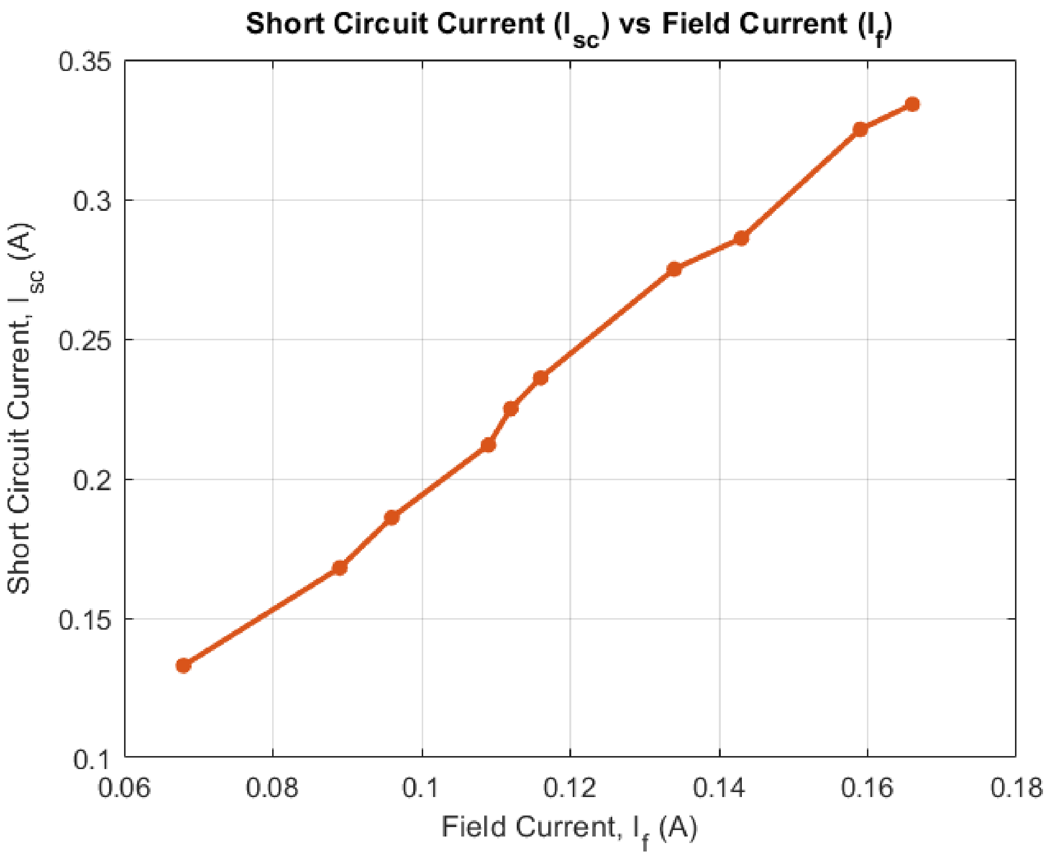
Table 1: Readings of OCC & SCC test

SI No.	V_f	I_f	I_{sc}	E_{oc}	$Z_s = \frac{E_{oc}}{I_{sc}}$	R_{eff}	$X_s = \sqrt{Z^2 - R_{eff}^2}$
1	37.2	0.068	0.133	85.2	640.600	1.05	640.599
2	48.10	0.089	0.168	112.2	667.857		667.856
3	52.80	0.096	0.186	122.1	656.450		656.446
4	60.58	0.109	0.212	140.4	662.264		662.263
5	63.80	0.112	0.225	147.8	656.870		656.888
6	66.10	0.116	0.236	154.4	654.237		654.236
7	76.61	0.134	0.275	178.2	648.000		647.999
8	80.70	0.143	0.286	190.5	666.084		666.083
9	91.81	0.159	0.325	212.4	653.538		653.537
10	96.10	0.166	0.334	220.7	660.778		660.777

8 Graph



(a) E_{oc} vs I_f Graph



(b) I_{sc} vs I_f Graph

9 Discussion

The synchronous reactance of the generator was found by performing Open Circuit and Short Circuit tests with different field currents. In the Open Circuit Test, the terminal voltage was seen to increase almost linearly with the field current in the unsaturated region, following the Open Circuit Characteristic (OCC):

$$E_{oc} \propto I_f$$

In the Short Circuit Test, the short-circuit current also rose linearly with the field current, as magnetic saturation was minimal.

The synchronous reactance (X_s) was calculated by taking the ratio of the open-circuit voltage to the short-circuit current:

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

The results matched the expected result, confirming the method and showing the dependence of X_s on excitation and magnetic properties. Overall, the experiment was completed successfully, and synchronous reactance was determined.