Electrical Machines & Power Systems
Practical 3 - Synchronous Machines
ENG224

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1 Objective

Using a dc motor as a prime mover, synchronous machine will be operated as an alternator. Equivalent circuit parameters will be obtained using open circuit and short circuit tests. Phasor diagrams will be drawn for each testing scenario to aid analysis.

2 Procedure and Results

2.1 Open circuit test

The open circuit test is carried out with the terminals of the synchronous machine disconnected, as shown in the equivalent circuit model of the synchronous machine in Figure 1. In this test, there is no armature current the measured terminal voltage, V_t, is the induced voltage, E_f.

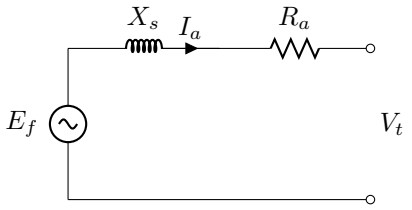

Figure 1: Synchronous generator equivalent circuit

The synchronous machine was connected in a star, and the DC motor was engaged to run the synchronous machine at rated speed of 1500 rpm. Readings

of the field current and the open circuit line to neutral voltage were recorded. The experimental results can be seen in Table 1.

I_f (A)	E_f (V)
0.000	5.50
0.210	23.50
0.037	40.00
0.073	81.00
0.110	120.50
0.157	160.00
0.212	200.00
0.246	220.00
0.324	254.00

Table 1: Experimental results of open circuit test

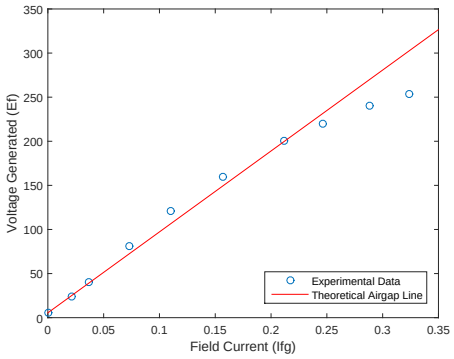

Figure 2: Open circuit characteristic plot

The open circuit characteristic plot can be seen in Figure 2. We note that the field current for which the rated voltage (240V) is generated is:

$$\boxed{I_{f0} = 0.288\text{A}}$$

To find an equation of the theoretical air gap line, shown in Figure 2, two I_f and E_f tuples were used to find the equation:

$$E_f = 917.45 \cdot I_f + 5.5 \tag{1}$$

2.2 Short circuit test

The short circuit test is carried out with the terminals of the machine short circuited. Figure 3 shows the equivalent circuit for the test. The field current was set to zero, and the synchronous generator was driven by the DC machine at synchronous speed. The field winding current was slowly increased until the short circuit armature current reached the rated current.

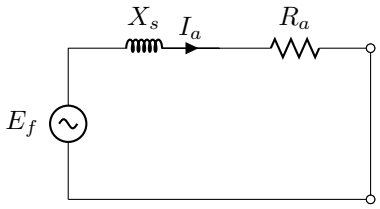

Figure 3: Synchronous generator equivalent circuit

The short circuit current, I_{sc0}, at the rated voltage of 240V was found to be:

$$\boxed{I_{sc0} = 0.318\text{A}}$$

This point was plotted on the against the rated armature current, I_a, and can be seen in Figure 3 with the short circuit characteristic curve (SCC).

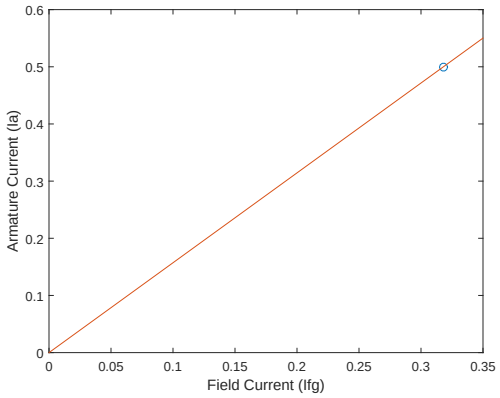

Figure 4: The short circuit characteristic plot.

The equation of the SCC, was found using simple coordinate geometry and is reported as:

$$I_a = 1.572 \cdot I_f \tag{2}$$

The field current at the rated voltage, I_f, found in the open circuit test is used in conjunction with equation (1) and equation (2) to find the synchronous impedence, Z_s.

$$Z_s = \frac{917.45 \cdot 0.288 + 5.5}{1.572 \cdot 0.288} = 595.76\Omega$$

The saturated synchronous impedence, is:

$$\boxed{Z_s = 595.76\Omega}$$

2.3 Stator resistance

The stator resistance was found by passing a current of 0.5A through the stator windings and recording a voltage of 23.75V. The stator winding resistance was measured as:

$$\boxed{R_a = 49\Omega}$$

We can find the saturated synchronous reactance, X_s, since $Z_s = R_a + jX_s$:

$$X_s = \sqrt{Z_s^2 - R_a^2} = 593.74\Omega$$

Hence, the saturated synchronous reactance is given by:

$$\boxed{X_s = 593.74\Omega}$$

2.4 Phasor diagrams

Phasor diagrams for both the open circuit test and the short circuit test can be seen in Figures 5 and 6.

Figure 5: Phasor diagram for open circuit test

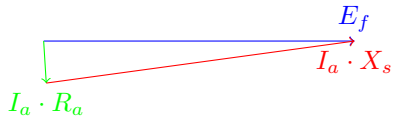

Figure 6: Phasor diagram for short circuit test

We see that in Figure 5 V_t is the same as E_f due to the fact that there is no current I_a since the circuit is open. Similarly, we note that since there is no load attached to the generator, the is no terminal voltage (because it's shorted).

3 Conclusion

Using a dc motor as a prime mover, synchronous machine was operated as an alternator. The following equivalent circuit parameters were obtained using open circuit and short circuit tests:

$$R_a = 49\Omega$$
$$Z_s = 593.74\Omega$$