Synchronous Machines – Review Sheet

Principles of a Synchronous Machine:

        The stator of a synchronous machine consists of a series of windings though which AC current is passed. This sets up a rotating magnetic field inside the motor. The rotor on the machine is either a permanent magnet or a DC electromagnet. The magnetic field of the rotor follows that of the stator. This causes the rotor to rotate in phase with the stator field and produce torque.

        The rotational speed (in RPM) is given by: $N = \dfrac{120f}{P}$ where P is the number of poles and *f* is the electrical frequency. The number of poles is an even number based on the windings of the stator and is constant for a given machine. Thus the only way to change the speed of a synchronous motor is by changing the electrical frequency.

*Motor V-curves and Power Factor:*

        The motor v-curves describe the relationships among field current, armature current, load and power factor.
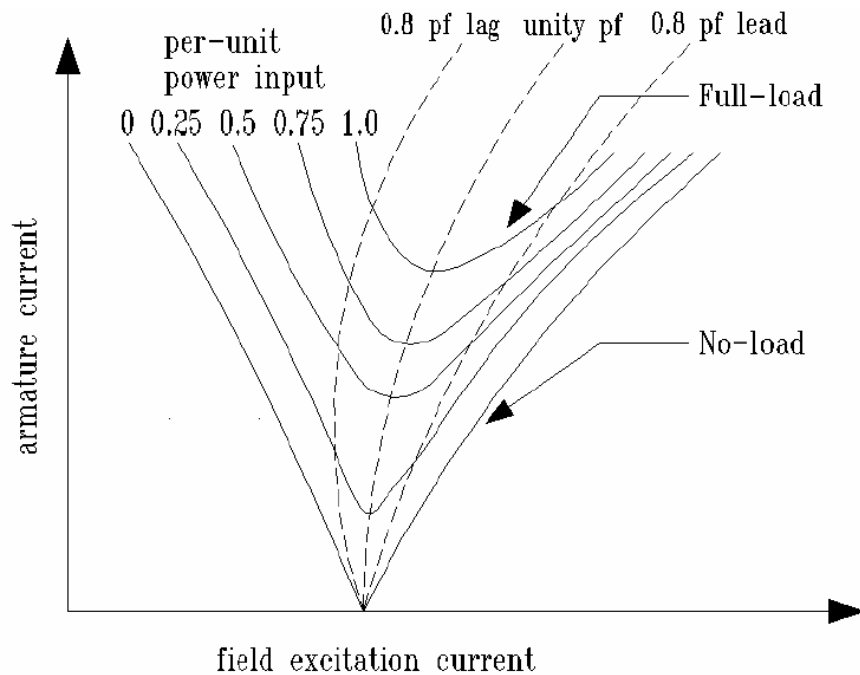

        The loading of the machine determines which of the v-curves the machine is operating on. Each individual v-curve gives the armature and field current relationship for that operating regime. The line through the minimums of the v-curves corresponds to an operating power factor of unity. As you move left or right of this centerline the power factor lags or leads respectively. The major point to notice here is that a synchronous machine has a variable power factor that is controlled by the magnitude of its field excitation current. In the first part of the lab you will be using this principle to balance the lagging power factor of an induction motor (which is an inductive element as the name implies).

Determination of Motor Equivalent Circuit:

In the final sections of the procedure you will be determining the equivalent circuit of the synchronous machine. This is done using the open circuit characteristic (OCC) and short circuit characteristic (SCC) curves along with the armature resistance. The equivalent circuit of a synchronous motor is as follows:
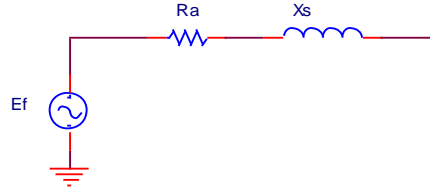
From the OCC and SCC data you should obtain plots of the following sort:
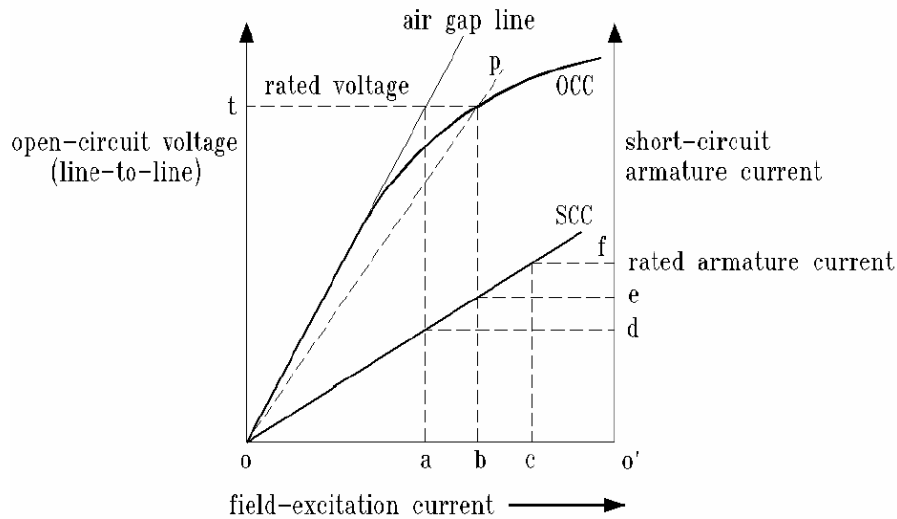
From here you find the rated line-to-line open circuit voltage (point t). From the OCC find the field excitation current that gives the open circuit voltage (point b). Using the SCC find the short circuit armature current that corresponds to the field excitation current (point e). Using the open circuit line-to-line voltage and short circuit armature current the impedance can be calculated as follows:

$$Z = \frac{Voc}{Isc\sqrt{3}} = \frac{t}{e\sqrt{3}}$$

In the final section of the lab Ra is determined which you can use with Z to find Xs as follows:

$$X_S = \sqrt{\left(Z^2\right) - \left(R_A\right)^2}$$

One note about determining Ra, in the lab a fluke was used to measure resistance of the windings, this gives a DC resistance value. The DC resistance value needs to be multiplied by a correction factor called the "skin effect" to convert it to an AC resistance. The skin effect describes the tendency for an AC current signal to travel along the surface of a conductor instead of the center. Since the current is flowing in a smaller area the resistance goes up. In general as frequency increases resistance increases as well. For 60Hz we will assume the skin effect is 1.2, give the following relationship:

$$R_{60Hz} = 1.2 * R_{DC}$$