Chapter 6: Synchronous Motor

In general, a synchronous motor is very similar to a synchronous generator with a difference of function only.

Steady State Operations

A synchronous motor are usually applied to instances where the load would require a constant speed. Hence for a synchronous motor, its torque speed characteristic is constant speed as the induced torque increases. Hence SR = 0%.

Since,

$$\tau_{ind} = kB_R B_{net} \sin\delta$$

$$\tau_{ind} = \frac{3V_\phi E_A \sin\delta}{\omega_m X_s}$$

Maximum torque (pullout torque) is achieved when sin δ = 1. If load exceeds the pullout torque, the rotor will slow down. Due to the interaction between the stator and rotor magnetic field, there would be a torque surge produced as such there would be a loss of synchronism which is known as **slipping poles**.

Also based upon the above equation, maximum induced torque can be achieved by increasing E_a hence increasing the field current.

Effect of load changes

Assumption:

> *A synchronous generator operating with a load connected to it. The field current setting are unchanged.*

Varying load would in fact slow the machine down a bit hence increasing the torque angle. Due to an increase to the torque angle, more torque is induced hence spinning the synchronous machine to synchronous speed again.

The overall effect is that the synchronous motor phasor diagram would have a bigger torque angle δ. In terms of the term E_a, since I_f is set not to change, hence the magnitude of E_a should not change as shown in the phasor diagram (fig.6-6). Since the angle of d changes, the armature current magnitude and angle would also change to compensate to the increase of power as shown in the phasor diagram (fig. 6-6).

Effect of field current changes on a synchronous motor

Assumption:

> *The synchronous generator is rotating at synchronous speed with a load connected to it. The load remains unchanged.*

As the field current is increased, E_a should increase. Unfortunately, there are constraints set to the machine as such that the power requirement is unchanged. Therefore since P is has to remain constant, it imposes a limit at which I_a and jX_sI_a as such that E_a tends to slide across a horizontal limit as shown in figure 6-8. I_a will react to the changes in E_a as such that its angle changes from a leading power factor to a lagging power factor or vice versa.

This gives a possibility to utilise the synchronous motor as a power factor correction tool since varying magnetic field would change the motor from leading to lagging or vice versa.

This characteristic can also be represented in the V curves as shown in figure 6-10.

Synchronous motor as a power factor correction

Varying the field current would change to amount of reactive power injected or absorbed by the motor. Hence if a synchronous motor is incorporated nearby a load which require reactive power, the synchronous motor may be operated to inject reactive power hence maintaining stability and lowering high current flow in the transmission line.

Starting Synchronous Motors

Problem with starting a synchronous motor is the initial production of torque which would vary as the stator magnetic field sweeps the rotor. As a result, the motor will vibrate and could overheat (refer to figure 6-16 for diagram explanations).

There are 3 different starting methods available:

a) Reduced speed of stator magnetic field – the aim is to reduce it slow enough as such that the stator will have time to follow the stator magnetic field.
b) External prime mover to accelerate the synchronous motor.
c) Damper windings or amortisseur windings.

Stator magnetic field speed reduction

The idea is to let the stator magnetic field to rotate slow enough as such that the rotor has time to lock on to the stator magnetic field. This method used to be impractical due to problems in reducing stator magnetic field.

Now, due to power electronics technology, frequency reduction is possible hence makes it a more viable solution.

Using a prime mover

This is a very straightforward method.

Motor Starting using Amortisseur windings

This is the most popular way to start an induction motor. Amortisseur windings are a special kind of windings which is shorted at each ends. Its concept is near similar to an induction motor hence in depth explanation can be obtained in the text book (page 345-348).

The final effect of this starting method is that the rotor will spin at near synchronous speed. Note that the rotor will never reach synchronous speed unless during that time, the field windings are switched on hence will enable the rotor to lock on to the stator magnetic field.

Effect of Amortisseur windings

The advantage of this starting method is that it acts as a damper as such that during transient cases at which the system frequency would vary significantly (varying frequency would affect the synchronous speed) hence the amortisseur windings may act as a dampening effect to slow down a fast machines and to speed up slow machines,