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ELECTRICAL ELECTRONICS ENGINEERING

ELECTRICAL MACHINES (EEE 326)

POWER FACTOR CORRECTION.

SOLUTION:

1) How is Power factor correction done by using a synchronous motor?

When a synchronous motor is used for the purpose of power factor correction it is called a Synchronous Compensator/Condenser/Capacitor. It is a Synchronous Motor, whose shaft spins freely without any torque on it except its weight.

How it is done:

A Synchronous Motor when used for power factor correction has two circuits, A Stator Circuit which is connected to the grid and a rotor circuit which is called Field winding/Excitation Winding. The field winding is controlled by a solid-state voltage and frequency regulator. Increasing the device's field winding excitation results in its furnishing reactive power (vars) to the system and decreasing the field winding excitation causes absorption of reactive power from the system (vars). Hence, it acts as a capacitor in over excited mode and an as inductor in under-excited mode. synchronous motors can be set to operate in a “leading” mode that enables them to perform essentially the same function as capacitor banks, creating capacitive energy to counteract system kVARs and permit more efficient kW usage. For the production facility with less power factor problems. Using synchronous motors approach is an excellent method.

2) What is meant by power factor when it comes to synchronous motor?

This means that the three-phase current entering the stator winding has an angle difference (theta) with the voltage. The purpose of using synchronous motor is to use it in leading power factor by controlling the field current in rotor. Synchronous motors are designed to operate at unity (1.0) power factor or 0.8 leading power factor. By varying the DC excitation of the motor, the power factor of the motor can be varied widely. Over-excited synchronous motors work at the leading power factor and have kVAR-like reactive condensers. It results in an increased power-supply balance for the machine.

3) **How do synchronous motors improve power factors?**

Synchronous motors are used with other induction motors and operated in an overexcited mode so that they draw leading current to compensate the lagging current drawn by the induction motors, thereby improving the power factor.

Fig.1 below shows the power factor improvement by synchronous motor method. The three-phase load takes current I_L at low lagging power factor cos φ_l. The synchronous condenser takes a current I_m which leads the voltage by an angle φ_m. The resultant current I is the phasor sum of I_m and I_l and lags behind the voltage by an angle φ. It is clear that φ is less than φ_l so that cos φ is greater than cos φ_l. thus the power factor is increased from cos φ_l to cos φ.

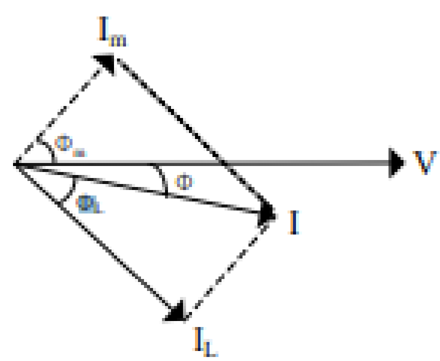

Figure 1

4) **Why there is better power factor in synchronous motor as compared to that of an equivalent induction motor?**

A synchronous motor has better power factor as compared to that of an equivalent induction motor. This is mainly because stator supply is not required to produce magnetic field. Also, Higher PF implies low energy transfer requirement of MMF, thus low demand for magnetizing current. The synchronous machine has separate DC excitation which reduces the arousal dependency of the system on the main supply and hence better PF.

5) **How can a power factor be controlled in synchronous motors?**

In a synchronous motor, if the rotor field winding provides just the necessary excitation, the stator will draw no reactive current; that is, the motor will operate at a unity power factor. If the rotor excitation current is decreased, lagging reactive current will be drawn from the ac source to aid magnetization by the rotor field current, and the machine will operate at a lagging power factor. If the rotor field current is increased, leading reactive current will be drawn from the ac source to oppose magnetization by the rotor field current, and the machine will operate at a leading power factor. Thus, by changing the field current, the power factor of the synchronous motor can be controlled.

6) **What happens when synchronous motor operates on no load?**

A synchronous machine with no load is called a synchronous condenser. When the motor is not loaded, but is simply floating on the ac supply system, it will thus behave as a variable inductor or capacitor as its rotor field current is changed. Since the motor is not really a no-load operation, though it is acting as a condenser which actually feeds a part of the reactive load of the device it is attached to. Depending on the system voltage, the same motor will draw a reactive current from the battery when operating with lagging power factor at no-load. Furthermore, at no-load it draws a very small current from the mains to meet the internal losses of the motor. With the increase in load torque, the torque angle δ increases and the motor draws more current from the mains. After the input current reaches maximum (at torque angle δ nearly equal to 90^o) no further increase in the load is possible. If the motor is further loaded it goes out of synchronism and stops.

7) **Why is a synchronous motor not used for developing power factors?**

This is because there are considerable losses in the motor, synchronous motors require dc excitation which must be supplied from external sources, synchronous motors are inherently not self-starting motors and needs some arrangement for its starting and synchronizing. The maintenance cost is high, it produces noise. Except in sizes above 500 kva, the cost is greater than that of static capacitors of the same rating. Also, as a synchronous motor has no self-starting torque, therefore, an auxiliary equipment has to be provided for this purpose. A synchronous motor is used to develop power factor by varying the excitation. When it is under excited the power factor lags, when it is normally excited the power factor is unity (i.e its equal to 1), when it is over excited the power factor leads.

8) **Why is the efficiency of the synchronous motor greater than the induction motor?**

In an induction motor, some part of the power is spent to generate the magnetic field in the motor. The synchronous motors have a fixed magnetic field due to the presence of permanent magnets. So, their efficiency is higher. Also, the of a synchronous motor output is higher than an induction motor with the same output and voltage level, since there are no slip-related losses or additional magnetizing current losses. There's no difference in speed for synchronous motors between air gap spinning magnetic field and rotor.

9) Why is a fixed power factor used in a motor?

Fixed Power factors are used in motor for less expense on reactive/wasted power. Because fixed amount of reactive power needs to be generated to support the voltage or correct for constant inductive loads like the magnetizing inductance. Also, because they are fixed, the capacitor banks are be made larger and placed strategically such that the voltage regulation on the feeder will meet certain limits. Usually such motors huge and therefore their reactive power causes huge losses.

10) If a synchronous motor has a leading power factor, does this motor consume or supply reactive power?

Since the synchronous machine is being operated at leading power factor (PF), it always eliminates its leading Reactive VARs (volta-ampere reactive). When such machine which is deficient with leading VARs (operating at lagging PF) thus the VARs deficient machine will absorb that leading VARs supplied and tend to improve its lagging PF to unity. With that being said when a synchronous motor is being operated at leading PF it will supply the reactive power

11) We use multiple MV synchronous AC motors from 350hp to 2000hp. What is a ballpark efficiency of these motors?

The maximum efficiency of Large synchronous motors having adjustable power factor even leading power factor of motors is generally quite high. The ballpark efficiency would be about 0.85 to 0.9, the efficiency is dependent on the having the right mechanical load attached, meaning a load that uses a major amount of the available mechanical power output of the motor.

12) Why is the efficiency of a synchronous motor greater?

This is because:

- In an induction motor, some part of the power is spent to generate the magnetic field in the motor. The synchronous motors have a fixed magnetic field due to the presence of permanent magnets. So, their efficiency is higher.
- Also, the efficiency is higher than that of an induction motor of the same output and voltage rating because there are neither losses related to slip nor the additional losses due to magnetizing current.
- Furthermore, in synchronous motors, there is no difference of speed between air gap rotating magnetic field and rotor. But with induction motors, rotating magnetic field and rotor are not at the same speed, so eddy losses are present and those losses introduced by the slip are mainly responsible for reduced efficiency.

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13)Which motor can operate at a high-power factor?

The Capacitor run motor can operate at high power factor.

14)How is the power factor considered in an induction motor?

The power factor of induction motors varies with load, typically from around 0.85 or 0.90 at full load to as low as about 0.20 at no-load. As we know, in an inductive load current lags the voltage by a certain angle. Higher the lag, lesser will be the power factor. In case of DC current, voltage and current are in phase but in case of AC, at a given instant the current lags the voltage. As a result, the actual or active power to the machine is product of Voltage and cosine component of current. cosine of the angle between Voltage and Current is called power factor.

15)How does a synchronous motor work as a power factor corrector?

When a Synchronous Motor is used as a power factor corrector it is called a synchronous condenser, whose shaft spins freely without any torque on it except its weight. A Synchronous Machine when used for power factor correction has two circuits; A Stator Circuit which is connected to the grid and A Rotor Circuit which is called Field winding/Excitation Winding. The field winding is controlled by a solid-state voltage and frequency regulator. Increasing the device's field winding excitation results in its furnishing reactive power (VARs) to the system and decreasing the field winding excitation causes absorption of reactive power from the system (VARs). Its principal advantage is the ease with which the amount of correction can be adjusted. Also, it makes use of a three-phase load phasor diagram whereby, the three-phase load takes current I_L at low lagging power factor cos φ_l. The synchronous condenser takes a current I_m which leads the voltage by an angle φ_m. The resultant current I is the phasor sum of I_m and I_l and lags behind the voltage by an angle φ. It is clear that φ is less than φ_l so that cos φ is greater than cos φ_l. thus the power factor is increased from cos φ_l to cos φ.