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Department: Electrical/Electronics Engineering
Course Title: Electric Machines II
Course Code: EEE 326
Assignment: 2
Due date: 17th April, 2020.

Questions:

1. How is Power factor correction done by using a synchronous motor?
2. What is meant by power factor when it come to synchronous motor?
3. How do synchronous motors improve power factors?
4. Why there is better power factor in synchronous motor as compared to that of an equivalent induction motor?
5. How can a power factor be controlled in synchronous motors?
6. What happens when synchronous motor operates on no load?
7. Why is a synchronous motor not used for developing power factors?
8. Why is the efficiency of the synchronous motor greater than the induction motor?
9. Why is a fixed power factor used in a motor?
10. If a synchronous motor has a leading power factor, does this motor consume or supply reactive power? Does this motor consume or supply real po...
11. We use multiple MV synchronous AC motors from 350hp to 2000hp. What is a ballpark efficiency of these motors? I'm trying to estimate operation...
12. Why is the efficiency of a synchronous motor greater?
13. Which motor can operate at a high power factor?
14. How is the power factor considered in an induction motor?

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

Answers:

1) A Synchronous motor which is over excited is referred to as a **Synchronous condenser**.
   Over exciting means giving more current to its field winding(winding which produces the magnetic field).
   A synchronous condenser acts like a capacitor in terms that it decreases lagging power factor.
   A synchronous condenser produces reactive power as opposed to consuming in case of ordinary motor. Both transformers and induction motors draw lagging currents from the line. On light loads, the power drawn by induction motor has a large reactive component and the power factor has a low value.
   The added current flowing to supply reactive power creates additional losses in the power system. Synchronous motors can be used to supply some of the reactive power required by induction motors. This improves the plant power factor and reduces the reactive current required from the grid.
2) 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.
3) There are two types of 'power' in an electric network. One is called "Active Power", which does actual work like heating a filament, lifting a weight etc. Then there is so called "Reactive Power", which can only create a magnetic field. For example, an old fluorescent lamp (tube light) fitted with a magnetic choke uses reactive power for starting the operation of lamp. An induction motor or even an induction generator (used in old wind power generators) also consume this reactive power.

   Some people use an analogy where active power is represented by the beer in a mug while the reactive power is represented by the froth. If you have too much froth, the amount of beer that can be held in the mug decreases. (That's why people pour beer along the wall of the mug, not to the centre!)

Similarly, if more reactive power flows in an electric network, then the amount of active power that can be sent through a given conductor decreases. Also you need a higher current for getting the same amount of active power. “Power factor” is the ratio between these two powers. (Actually Active/SQRT(Active squared+ Reactive squared). In a synchronous machine (motor or generator) you have magnetic poles on the rotor. If the strength of the rotor magnets can be changed (ie. they are electromagnets, not permanent magnets) you can have three regions of the strength of the magnetic field.

- Rotor magnetic field is not sufficient to generate an e.m.f (say voltage) equal to the voltage applied to the motor - This is called ‘under exited’ state.
- Rotor magnetic field is just sufficient to generate an e.m.f equal to the voltage applied to the motor - I don’t remember a name for this state (is it “properly excited”?).
- Rotor magnetic field is higher than needed to generate an e.m.f equal to the voltage applied to the motor - This is called ‘over exited’ state.

Like an induction machine, an under excited synchronous machine too will consume reactive power; a properly excited synchronous machine neither consumes nor produces reactive power; An over excited synchronous machine can produce reactive power.

4) Higher Power Factor means low requirement of MMF for energy transfer , hence low magnetizing current requirement. synchronous machine have separate DC excitation which reduces machine's excitation dependency on main supply, hence better PF. where as IM have no such provisions, hence low Power Factor .

5) Synchronous motors are doubly fed motors. AC supply is given to the stator terminals whereas dc excitation is given to rotor terminals.

Note:The power factor is governed by the proportion of active or reactive power to the apparent power drawn from the supply.

Now, since the set up of the magnetic flux (which can be considered as the reactive power component) inside the motor is done by the dc excitation provided on the rotor terminals, the power factor can also be controlled by controlling this dc excitation.

Synchronous motors are used for the power factor correction as well. They offer smoother and wider control of power factor compared to the capacitor banks.

Overexcited synchronous motor on no load condition or light load condition is known as synchronous condenser and used as a power factor corrective device.

In general, synchronous motors offer better power factor than induction motors because in case of induction motors, both the excitation (stator and flux setup) are drawn from the main supply itself whereas in case of synchronous motors, main supply does not contribute in setting up the flux.

6) A synchronous motor running on no-load with leading power factor will act as a synchronous condenser. This is not truly a no-load operation since the motor, while behaving as a condenser is actually feeding a part of reactive load of the system to which it is connected.

The same motor when operated with lagging power factor on no-load will draw a reactive current from the system depending upon the system voltage.

However, this does not mean that the motor can be operated on no-load regardless of the armature current that flows in the motor. The capacity of the motor to run as synchronous condenser or as synchronous motor, whether on load or no-load is dictated by its V-curve (Armature current vs. field current).

*8)* Synchronous motor always rotates with synchronous speed, irrespective of the loading conditions. So, the effective output is not reduced, compared to induction motor. So, more efficiency is observed in this case. Also, the operating power factor is constant in synchronous motors. It is also a doubly excited machine, unlike induction motor.

9) Power factor of induction motor depend on load and speed.

Power factor of synchronous motors might be fixed. Usually such motors r huge and therefore their reactive power causes huge losses. It's a question of efficiency and economic reasons probably.

10) When ever a synchronous machine( either motor or generator) is being operated at leading power factor(PF), it always shed out its leading Reactive VARs( Volta-ampere reactives) for such machine which is

deficient with leading VARs( operating at lagging PF) and thus the VARs deficient machine will absorb that leading VARs supplied and tend to improve its lagging PF to unity.

Now, when this machine is done with improvement of its PF from lagging to unity and still being fed with Leading VARs in excess, it will eventually start acting like a source of Leading VARs for some other Leading VARs deficient machines connected in the power system.

Synchronous condensers( phase modifiers) are the best examples for this kind of practices. Phase modifier is nothing but an unloaded synchronous motor operated at leading PF and without load.

By this practise, the power factor is improved and the overall performance of the entire power system gets improved.

Further, to answer the question, since the question is about the synchronous motor, always remember that any kind of **motor** (either synchronous or induction or DC)require active power to do the mechanical work. Now, if it is being operated at leading PF(only in case of AC motors, as described above) it will supply the reactive power (+Q) and if it is operating at lagging PF, it will absorb the reactive power(-Q), where symbols have their usual meanings .

11) Large synchronous motors have adjustable power factor. They can even have leading power factor. They are often set this way to compensate for all the other induction motors. This can affect the efficiency of the motor depending on the load. With the system tuned to near unity the entire distribution system benefits. There is not just one type of synchronous motor but they most often do better than standard induction motors.

12) 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.

13) The Motor that can operate at a high power factor is the capacitor run motor reason being that the starting torque is lower at about 50% of full load torque. Therefore, Power factor is improved. It may be about unity. Efficiency is improved to about 75%.

The **capacitor run motor** is used in fans, room coolers, portable tools and other domestic and commercial electrical appliances.

14) In a three-phase induction motor, there is a large component of magnetizing current. It is required to make the motor operate, but it is large because the magnetic circuit for each stator phase looks like an inductor with rather a large air gap in it. Typically the magnitude of this magnetizing current is around 50% of the full load current of the motor. This current is inductive, that is, the phase current lags behind the phase voltage by 90 degrees.

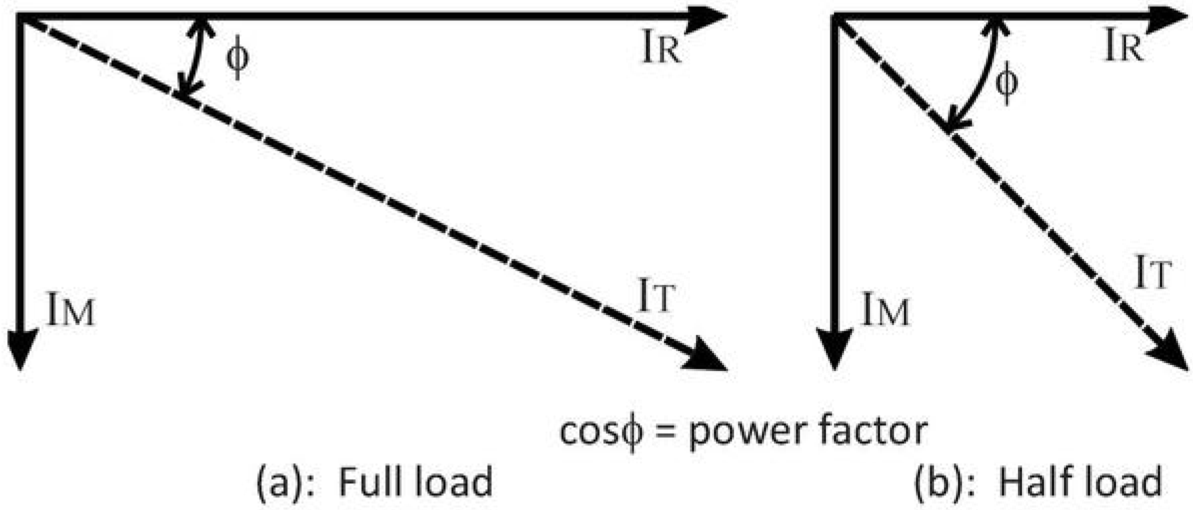


*Figure 1: Phase current components in 3-phase induction motor*

Referring to Figure 1. As the load increases, the real current increases. The real (load) component of current is in phase with the applied voltage. There will be three sets of such currents in the motor - each displaced 120 degrees from the other. The power factor cos(phi) varies form zero at no load to around 0.86 at full load. Cos(phi) of 0.86 implies phi = 30 degrees, that is, the magnitude of IM is 50% of IT as previously stated.

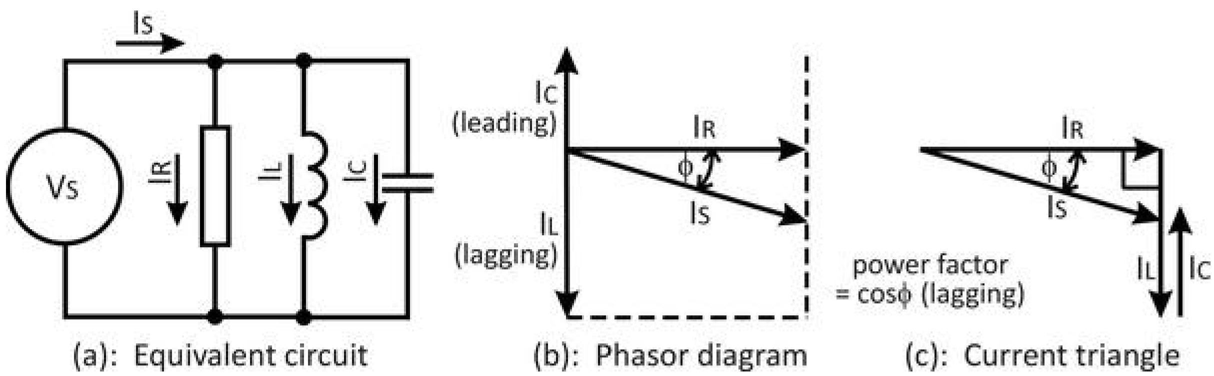


*Figure 2: Parallel R-C-L circuit*

Figure 2 shows how the power factor may be improved by adding a judicious amount of capacitance in parallel with each phase. The capacitor draws current that leads the phase voltage by 90 degrees. So the capacitor current directly subtracts from the magnetising current. Typically the amount of capacitance used corrects the power factor cos(phi) to around 0.95 which reduces the net magnetising current enough to satisfy the electrical distribution authorities.

15) A synchronous motor has an adjustable field winding on the rotor. When the excitation current is increased, the magnetic field is strengthened; when it is decreased, the field is weakened. This changes both the power factor as well as the amount of reactive power absorbed by the motor.

When the field is overexcited, the magnitude of the back emf voltage EmEm will be greater than the terminal voltage VtVt and the power factor angle $\theta$θ will be leading. In this condition, the motor will generate reactive power and the system (grid) will absorb it.

When the field is under-excited, the the magnitude of EmEm will be less than the terminal voltage and the power factor angle will be lagging. In this condition, the motor will absorb reactive power provided (generated) by the system.

Thus, in addition to performing mechanical work, a synchronous motor can generate and absorb reactive power by adjusting the excitation of the field winding. This can be used to adjust the system power factor as well as regulate the system voltage at the location of the motor.

For the discussion above, it helps to know what reactive power actually is. Apparent power is defined to be

S=P+jQ=VI∗ .S=P+jQ=VI∗ .

*Reactive power* is simply the imaginary component QQ of the apparent power. It has units *volt-amp-reactive* or *vars*. *Active power* is what turns the motor shaft and does ‘real’ work. It is the real component PP of apparent power and has units of *watts*. Apparent power SS is a complex number with real and imaginary components. It has units of *volt-amps* and can be calculated by multiplying the voltage phasor VV with the complex conjugate of the current phasor I∗ I∗ .