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FACULTY OF ENGINEERING & TECHNOLOGY

Electrical Machine-ii

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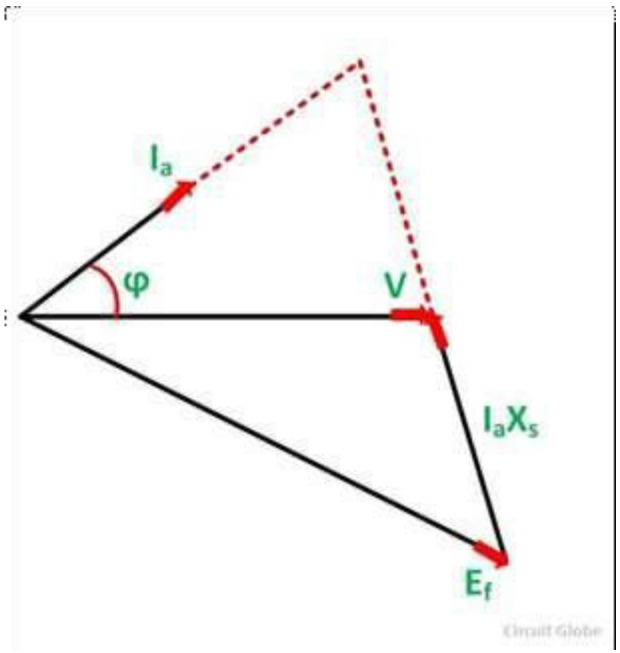
EFFECT OF LOAD ON A SYNCHRONOUS MOTOR

A synchronous motor runs at constant synchronous speed, regardless of the load. Let us see the effect of the load change on the motor.

If the load on a synchronous motor is increased the following points are considered which are given below.

1. The motor continues to run at synchronous speed.
2. The torque angle δ increases.
3. The excitation voltage E_f remains constant
4. The armature current I_a drawn from the supply increases.
5. The phase angle ϕ increases in the lagging direction.



❖ Consider a synchronous motor operating initially with a leading power factor. The phasor diagram for leading power factor is shown below.

❖The load on the shaft is increased. the rotor slows down momentarily, as it required some time to take increased power from the line. In another word, it can be said that even if the rotor is rotating at synchronous speed, the rotor slips back in space because of the increase in the load. In this process, the torque angle δ becomes larger and, as a result, the induced torque increases.

The induced torque equation is given as

$$T_{ind} = \frac{V\, E_f \sin\delta}{\omega\, X_s}$$

Then increased torque increases the rotor speed, and the motor again regains the synchronous speed, but with the larger torque angle. The excitation voltage E_f is proportional to ϕω, it depends upon the field current and the speed of the motor. Since the motor is moving at a synchronous speed, and the field current is also constant. Hence, the magnitude of the Voltage **$|E_f|$** remains constant. We have,

$$P = \frac{V\,E_f \sin\delta}{X_s} = V\,I_a \cos\varphi$$

Therefore,

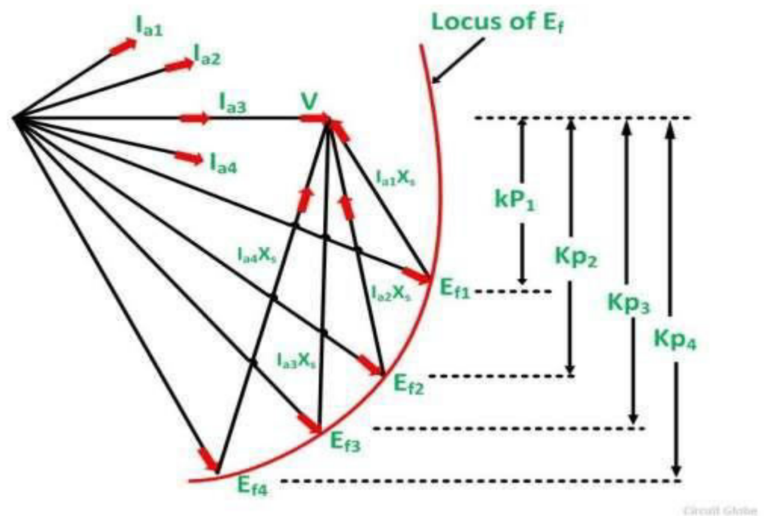
$$E_f \sin\delta = \frac{X_s}{V} P = KP \quad \text{where} \quad K = \frac{X_s}{V} = \text{constant}$$

From the above equations, it is clear, that if P is increased the value of $E_f \sin\delta$ and $I_a \cos\phi$ also increases.

It is seen from the above figure that with the increase in load, the quantity jI_aX_s goes on increasing and the relation $V = E_f + jI_aX_s$ is satisfied. The armature current is also increased. The power factor angle also changes with the change in load. It becomes less and less leading and then becomes more and more lagging as shown in the figure above.

There is a limit to the mechanical load that can be applied to a synchronous motor. As the load is increased, the torque angle δ also increases until the condition arises when the rotor is pulled out of synchronism and the motor is stopped.

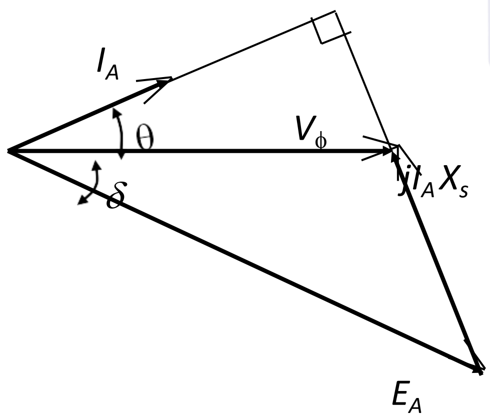
Pull-out torque is defined as the maximum value of the torque which a synchronous motor can develop at rated voltage and frequency without losing synchronism. It values varies from **1.5** to **3.5** times the full load torque.



The figure below shows the Effect of increase in load on the operation of a synchronous motor.

VECTOR DIAGRAM OF SYNCHRONOUS MOTOR

- The equivalent circuit of a synchronous motor is exactly same as the equivalent circuit of a synchronous generator, except that the reference direction of I_A is reversed.
- The basic difference between motor and generator operation in synchronous machines can be seen either in the magnetic field diagram or in the phasor diagram.
- n generator, E_A lies ahead of $V_{\square}$, and B_R lies ahead of B_{net}. In a motor, E_A lies behind $V_{\square}$, and B_R lies behind B_{net}.
- In a motor the induced torque is in the direction of motion, and in a generator the induced torque is a countertorque opposing the direction of motion



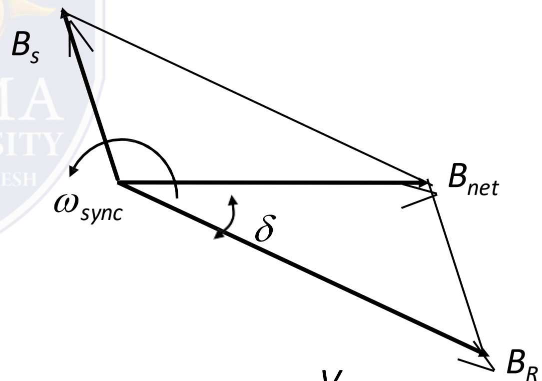


Fig. The phasor diagram (leading PF: overexcited and $|V_t|<|E_A|$) and the corresponding magnetic field diagram of a synchronous motor.

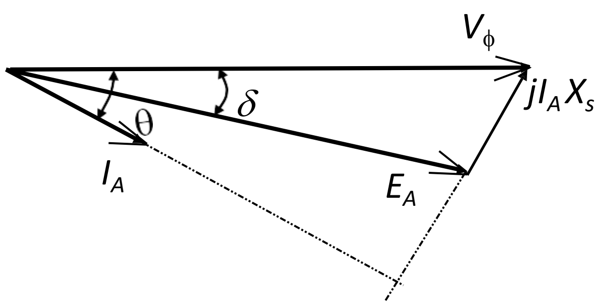


Fig. The phasor diagram of an underexcited synchronous motor (lagging PF and $|V_t|>|E_A|$).

PHASOR DIAGRAM

- **(a) Unity power factor**
- In this unity power factor, the excitation of the synchronous motor is 100% or in normal excitation.
- **(b) Lagging power factor**
- In this unity power factor, the excitation of the synchronous motor is less than 100%.
- **(c) Leading power factor**
- In this unity power factor, the excitation of the synchronous motor is greater than 100%.