3- Synchronous Motors

3-1 Introduction:

A synchronous motor is electrically identical with an alternator or A.C generator. in fact, a given synchronous machine may be used, at least theoretically, as an alternator, when driven mechanically or as a motor then driven electrically just as in the case of D.C machines. Must synchronous motor be rated between 150 Kw to 15 μw and run at speeds ranging from 150 to 1800 r.p.m.

Some characteristic features of a syn. Motor

Are worth noting:

1-It runs either at syn. Speed or not at all, While running it maintains constant speed.

The only way to change speed is to vary the supply frequency, $N_s = 60\frac{f}{P}$

2-It is not inherently self-starting. It has to be run up to sync. Speed or near it, by some means, before it can be synchronized to the supply

3-Mainly salient-pole motors, for low and medium rang speed.

- Single- phase and 3-phase motor ʎ or △

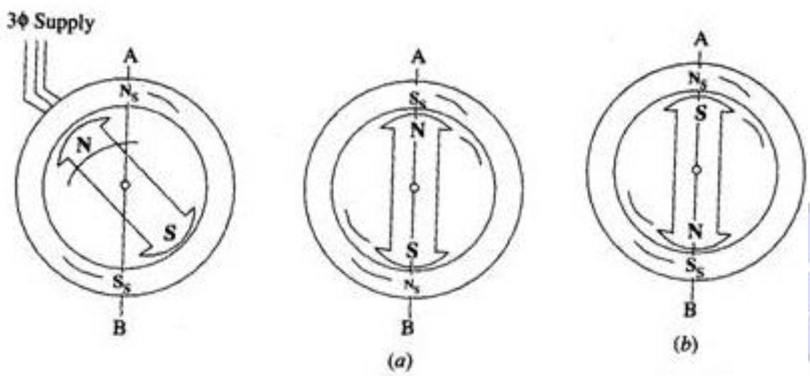
Conn. Arm. Winding

4-Damper or starting winding. Air gap length is lower SG

$\frac{I_s}{I_r} = 4 - 5$, $\frac{T_s}{T_r} = 2 - 3$ lagging reaction P.F

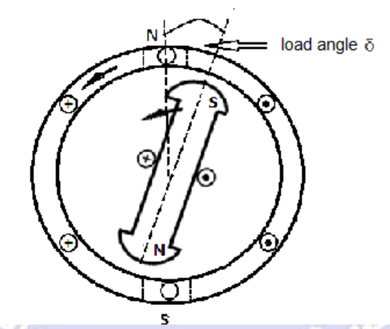
3-2 Motor Operation:

When a 3-Ø winding is fed by a 3-Ø supply, then magnetic flux of constant magnitude but rating at syn. speed, is produced. Consider a two-pole stator of fig. below. In which are shown two poles at stator. Marked N_s and S_s rotating at syn. speed, say in clockwise direction. With the rotor position as shown, suppose. The stator poles are at that instant situated at points A and B. The two similar poles N (of rotor) and N_s of stator as well as S and S_s will repel each other, with the result that the rotor tends to rotate in the anticlockwise direction, but half a period later, stator poles, having rotated around. Interchange their position, it will be rotate with clockwise.



Load angle (pole axis E_o logging relative to the flux axis v)

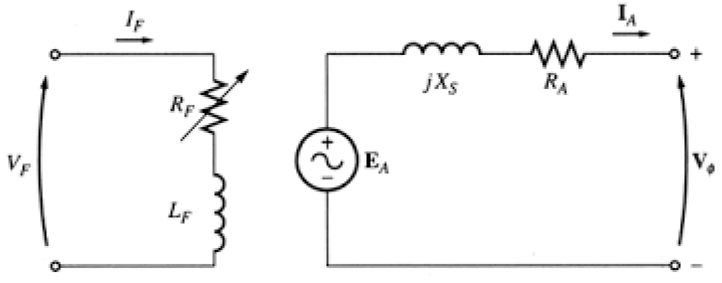
load↑ → δ ↑ , In generator $+\delta$, in motor $\delta -$



3-3 Equivalent circuit of syn. motor

The equivalent circuit model for one armature phase of a cylindrical rotor syn. motor is shown in fig.1, it is seen that the phase applied voltage(v) is the vector sum of reversed back emf E_o and the impedance drop I_1 , Z_s . In other words,

$V = (-E_o + I_1 Z_s)$. The angle δ between the phase for (V) and (E_o) is called the load angle of syn. motor.

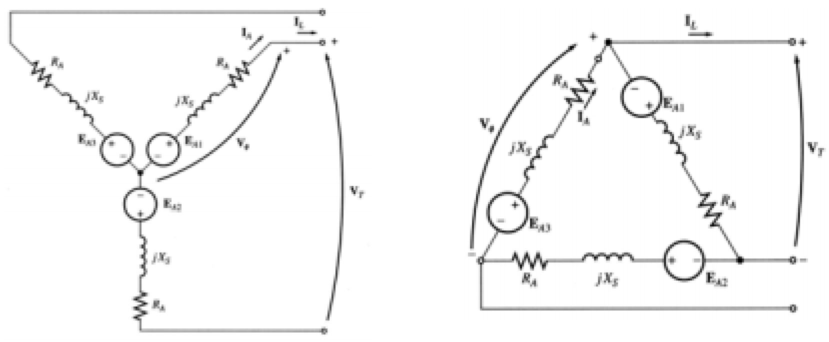


When $R_a = 0$

$$E_o = V - j\, I_a\, X_s$$

$$\delta = \sin^{-1}\left(\frac{X_s\, P}{3\, V E_o}\right)$$

A synchronous generator can be Y- or Δ-connected:



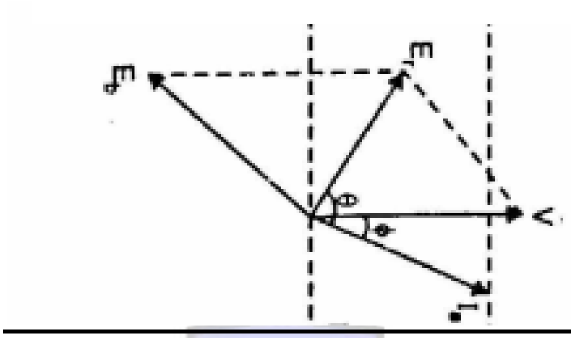
The terminal voltage will be

$$V_T = \sqrt{3} V_\phi \quad - \text{ for } Y \qquad (7.19.1) \qquad V_T = V_\phi \quad - \text{ for } \Delta$$

3-4 Phasor Diagrams:

In the syn. motor, a back e.m.f is set up the armature (stator) by the rotor flux which opposes the applied voltage(v).This back e.m.f depends on rotor excitation only .The net voltage in armature (stator) is the vector difference of V and E_o. Armature current is obtained by dividing the vector difference of voltage by armature impedance. The simplified phaser diagram is represented as follow: a-for lagging power factor b-for leading power factor

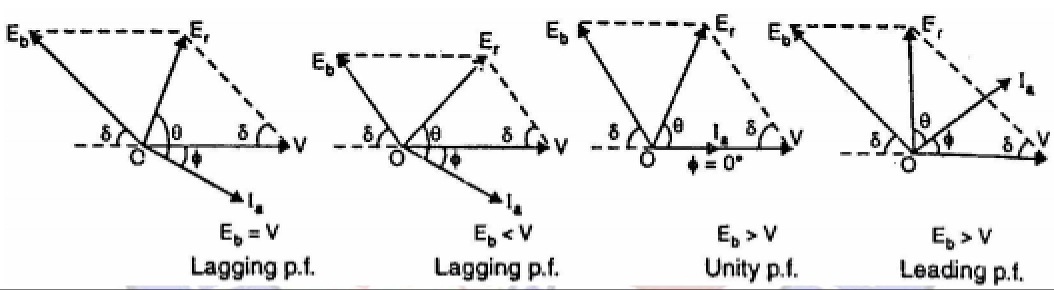
a-For lagging power factor:



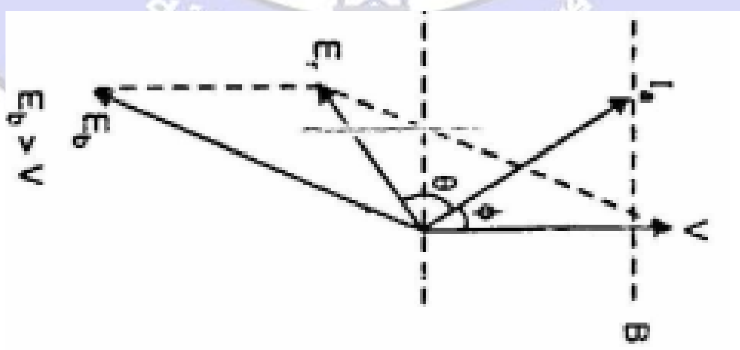
$$E_o^2 = (V + E_r \sin\varphi)^2 + (E_r \cos\varphi)^2$$

$$E_o^2 = V^2 + E_r^2 - 2VE_r \cos\gamma$$

$$\gamma = \theta - \varphi$$



b-for leading power factor:



$$E_o^2 = (V + E_r \sin\varphi)^2 + (E_r \cos\varphi)^2$$

$$E_o^2 = V^2 + E_r^2 - 2VE_r \cos\gamma \qquad , \gamma = \theta + \varphi$$

Note:: If $R_a = 0$, $Z_s = X_s$, $E_r = I_1 X_s$

The power supplied to the motor is:

$$P_1 = \sqrt{3}\, V_s\, I_1 \cos\varphi_1$$

The electromagnetic power supplied to the rotor is:

$$P_{em} = P_1 - P_{cu1}$$

$$= \sqrt{3}\, V_s\, I_1 \cos\varphi_1 - 3\, I_1^2\, R_1$$

$$E_r = \sqrt{(V - E_o \cos\delta)^2 + (E_o \sin\delta)^2}$$

$$\gamma = \tan^{-1} \frac{E_o \sin\delta}{V - E_o \cos\delta} \qquad , \quad \delta = \sin^{-1}\left(\frac{X_s\, P}{3VE_o}\right)$$

$$P = \frac{3VE_o}{X_s} \times \sin\delta$$