Power Angle Characteristics of a Cylindrical Rotor Synchronous Machine:

The armature resistance r_a of an alternator is very small compared to synchronous reactance. So, neglecting r_a the phasor diagram of the machine is as shown in fig.1(a)

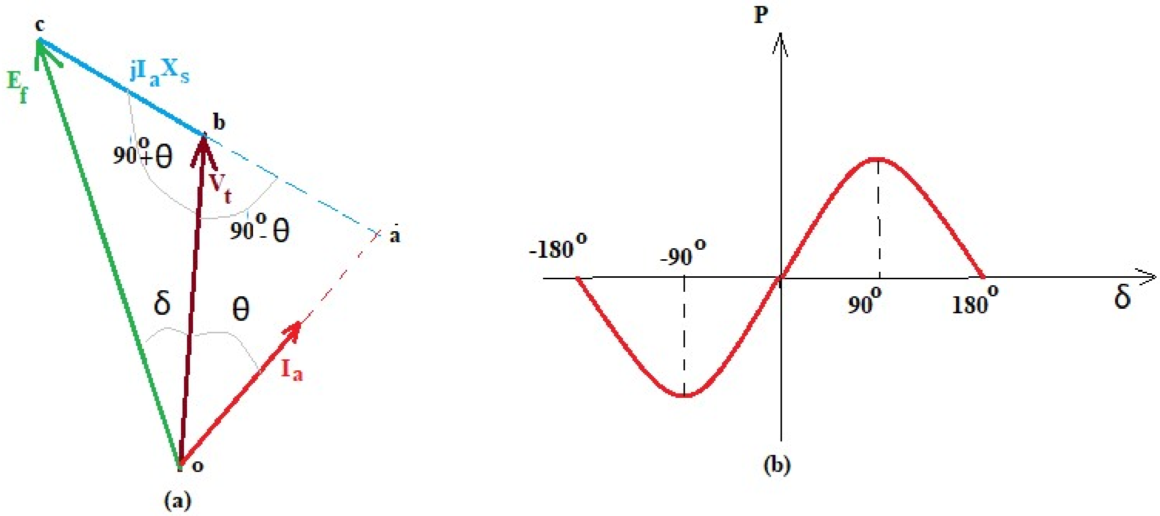


Fig. 1

$$\frac{bc}{\sin boc} = \frac{oc}{\sin obc}$$

$$\frac{I_a X_s}{\sin\delta} = \frac{E_f}{\sin(90° + \theta)}$$

$$I_a X_s \sin(90° + \theta) = E_f \sin\delta$$

$$I_a X_s \cos\theta = E_f \sin\delta$$

$$I_a \cos\theta = \frac{E_f \sin\delta}{X_s}$$

Per phase power developed by the machine is $P = V_t\, I_a \cos\theta$. So,

$$P = \frac{E_f V_t}{X_s} \sin\delta$$

Plot between per phase power P and angle δ is shown in fig. 1 Ib). The angle δ is called the load angle. The plot between per phase power P and angle δ shown is the **Power Angle Characteristics** of a cylindrical rotor machine.

Synchronizing Power and Synchronizing Torque:

The variation of synchronous power associated with small change in load angle δ, is called synchronizing power. Synchronizing power coefficient P_{sy}, given by:

$$P_{sy} = \frac{dP}{d\delta} = \frac{E_f V_t}{X_s} \cos\delta$$

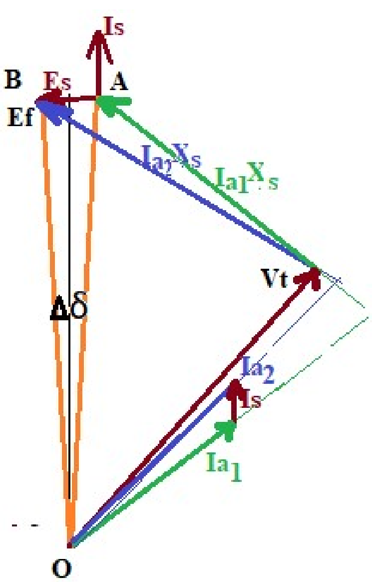
So for small change in load angle synchronizing power is given by :

$$P_s = \frac{dP}{d\delta}\Delta\delta = \frac{E_f V_t}{X_s} \cos\delta \ \Delta\delta$$

Synchronizing torque is given by $T_s = \frac{mP_s}{\omega_s}$; $or, T_s = \frac{1}{\omega_s} m \frac{dP}{d\delta}\Delta\delta;$

$$or\ T_s = m\frac{1}{\omega_s}\frac{E_f V_t}{X_s} \cos\delta \ \Delta\delta$$

Physical concept of Synchronizing Power:



The machine is running on infinite bus bar with constant terminal voltage V_t,and constant induced emf E_f with a load current of I_a.

Due to some transient disturbance, the rotor speed momentarily decreases from synchronous speed and rotor falls back by a small angle, and E_s called the synchronizing voltage appears. Magnitude of V_t and E_f can not change but the equation $\overline{E_f} = \overline{V_t} + j\overline{I_a}X_s$should hold good, so current I_s called the synchronizing current develops $I_s = \frac{E_s}{X_s}$. Now , from the phasor diagram,

$$E_s = BA = 2\, E_f \sin\frac{\Delta\delta}{2}$$

$$\frac{E_s}{X_x} = I_s = 2\, \frac{E_f}{X_s}\sin\frac{\Delta\delta}{2}$$

So the synchronizing power P_s associated with I_s is given by

$$V_t \times 2\, \frac{E_f}{X_s}\sin\frac{\Delta\delta}{2}\cos(\delta + \Delta\delta) = \frac{V_t E_f}{X_s}.\Delta\delta \quad \cos\delta = P_{sy}\Delta\delta$$