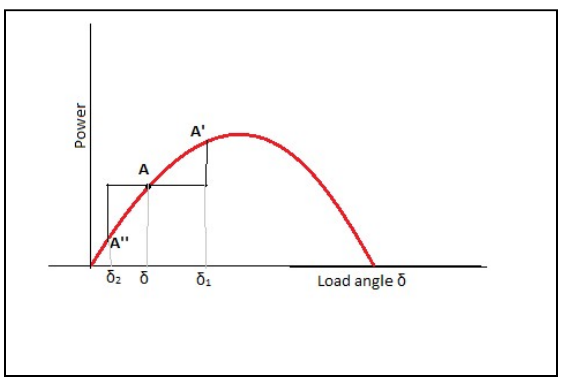
Period of phase swing or Hunting:

If two synchronous generators are operating in parallel, then if the angular velocity of one momentarily changes due do some disturbance, synchronizing power appears, which tries to restore the proper phase relations. The generator which swings ahead (δ increases to δ_1); more load is put on it and the other generator is relived of load. But the amount of power they receive from their prime mover cannot change instantaneously. This will cause slowing down of the first generator and speed up of the second. While generator '1' is slowing down the excess load is supplied by the kinetic energy of the moving parts. At the instant when the load angle equals the operating value δ, the power input equals the power output plus the loss. But due to inertia the generator swings past the position of no synchronizing action and the load angle reduces to δ_2. The synchronizing action then reverses and tends to pull the generators together again. This is hunting of synchronous generator. It would continue indefinitely if the system is un-damped. But there will be eddy currents induced in the solid rotor body of the cylindrical rotor machine and in the damper bars in the pole faces of a salient pole machine, which will damp out the oscillation. Since, the change in load on a synchronous generator must be accompanied by a change in load angle δ, such a machine is also subjected to hunting. With a properly designed synchronous generator, the oscillation about the phase position corresponding to a load is small and of little importance. Only when the oscillations become extremely large due to periodic change in load, in terminal voltage or in the frequency of the system, the hunting is likely to become serious and causes violent current surges and the machine may drop out of synchronism. Violent hunting may be caused by the periodic variations of the driving torque of a synchronous generator driven by a reciprocating engine, specially a gas engine. So sufficient fly wheel effect must be there to limit the variation of angular velocity to a small value.



Swing Equation:

The dynamic torque equation is:

Accelerating torque= Inertia torque + Damping torque + Stiffness torque

Accelerating torque: The machine receives mechanical power P_{in} and develops electromagnetic power P_e, the difference of these two is the accelerating power P_a. Thus, $P_a = P_{in} - P_e$ Watts. The corresponding accelerating torque is

$$T_a = \frac{P_a}{\omega_m} = \frac{P}{2}\frac{1}{\omega_e} P_a \; N-m; \text{ where P = no. of poles; } \omega_m = \text{mechanical angular velocity;}$$

$$\omega_e = \text{electrical angular velicity} = 2\pi f \, {}^{\text{rad}}/_{\text{sec}}$$

Inertia torque:

Inertia torque $T_i = J\frac{d\omega_m}{dt} = \frac{2}{P} J \frac{d\omega_e}{dt}$; where J is polar moment of inertia.

$$\text{Now, } \theta = \omega t + \delta \quad \therefore \omega_e = \frac{d\theta}{dt} = \omega + \frac{d\delta}{dt} \ \ and \ \frac{d\omega_e}{dt} = \frac{d^2\delta}{dt^2}$$

$$\therefore T_i = J\frac{d\omega_m}{dt} = \frac{2}{P} J \frac{d\omega_e}{dt} = \frac{2}{P} J \frac{d^2\delta}{dt^2}$$

Damping Torque:

Damping torque is generated due to interaction of eddy current induced in the rotor body of in the damper windings and the air gap flux. As it is an induction torque, is proportional to the slip speed $\omega_e - \omega$. Therefore is given by $T_d = D \frac{d\delta}{dt}\ Nm$, where D is the damping coefficient. Therefore we get

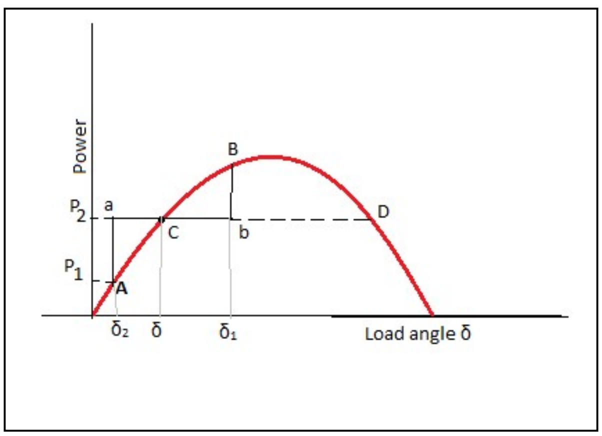
$$\frac{P}{2}\frac{1}{\omega_e} P_a(\delta) = \frac{2}{P} J \frac{d^2\delta}{dt^2} + D\frac{d\delta}{dt}$$

$$\therefore P_a(\delta) = \frac{4\omega_e}{P^2} J \frac{d^2\delta}{dt^2} + \frac{2\omega_e}{P} D \frac{d\delta}{dt}$$

$$\therefore P_a(\delta) = J'\frac{d^2\delta}{dt^2} + D'\frac{d\delta}{dt}$$

Equal Area Criteria:

Neglecting the damping torque, the above equation can be written as $P_a(\delta) = J'\frac{d^2\delta}{dt^2}$



The Equal area Criteria states that the area ACaA=CBbC. The maximum possible area above the power input line P_2 is CBDC and if area ACaA>area CBDC, the machine losses stability. For stable operation δ_1 should be less than the critical power angle δ_c determined by point D, the point of intersection of the power angle curve and the power input line P_2. If δ_2 exceeds δ_c the machine will loose synchronism. $\delta_c = \pi - \delta$.