

SAARC Training Workshop 'Power System Studies for Synchronization of Multiple Systems'

Review of Basic Power System Stability Concepts

Day-3-A

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What is Transient Stability ?

- The ability of power system to maintain synchronism when subjected to a severe transient disturbance such as:
 - Fault on transmission facilities
 - Loss of generation
 - Loss of a large load
- The system response to such disturbances involves large excursions of
 - Generator rotor angles
 - Power flow on lines/transformers
 - Bus voltages
 - Other system variables
- Stability is influenced by the non-linear characteristics of power system
- If the resulting angular separation between machines remains within certain bounds, the system maintains synchronism i.e. system is Stable
- Loss of synchronism i.e. system Unstable, if it occurs, will usually be evident within 2 to 3 seconds of the initial disturbance

Power Swing Equation

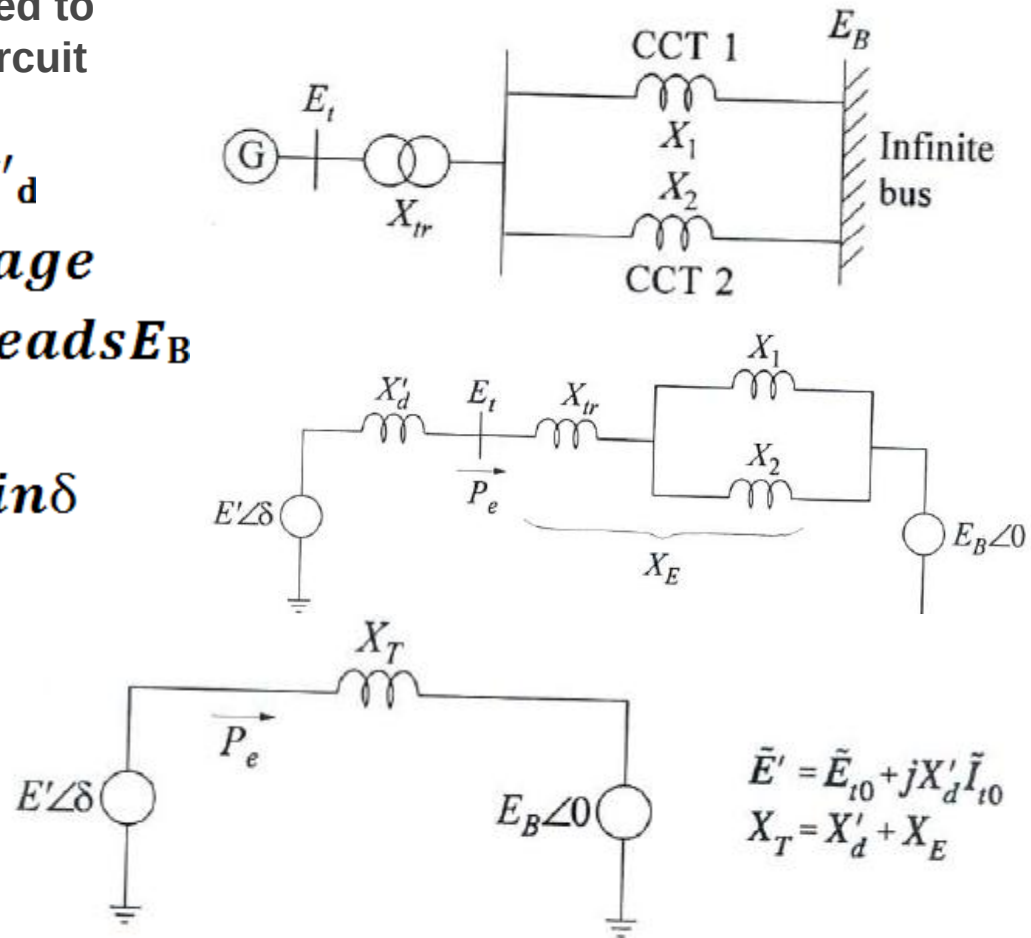
A generating station is connected to infinite bus through a double circuit

E' = Voltage behind X'_d

E_B = Infinite bus voltage

δ = Angle by which E' leads E_B

$$P_e = \frac{E' E_B}{X_T} \sin \delta = P_{\max} \sin \delta$$

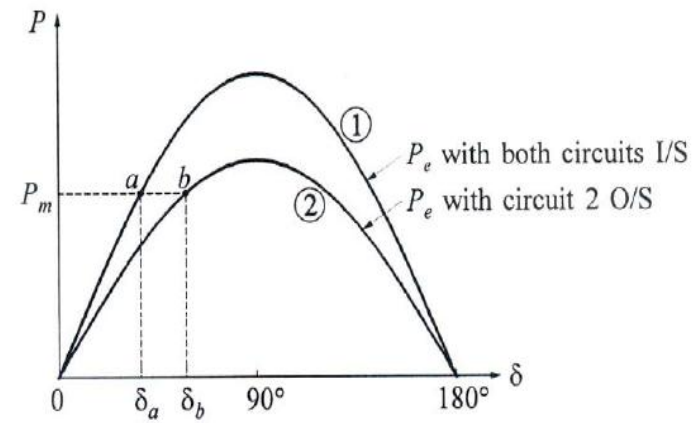


(b) Reduced equivalent circuit

Swing equation under disturbed condition

- When one circuit is out of service, operating point shifts from a to b and rotor angle increases from δ_a to δ_b to transmit the same power
- Swing equation will be

$$\frac{2H}{\omega_0} \frac{d^2\delta}{dt^2} = P_m - P_{\max} \sin\delta$$



When

P_m = mechanical power input

$P_{\max}$ = maximum electrical power input

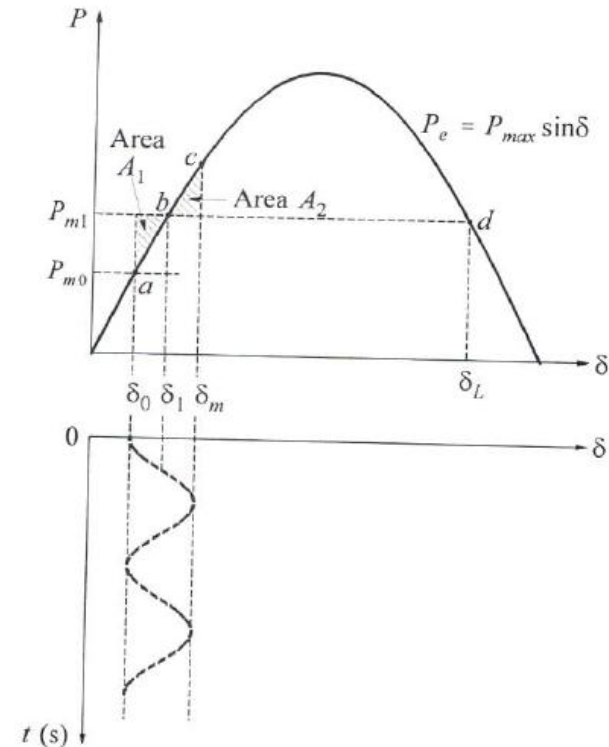
H = inertia constant in MWs / MVA

δ = rotor angle in elec. Rad

T = time in seconds

Response to step change in P_m

- Rotor angle cannot change instantly from δ_0 to δ_1 corresponding to new equilibrium point b at which $P_e = P_{m1}$
- Mechanical power is now in excess of the electrical power
- Resulting accelerating torque causes the rotor to accelerate from initial point a to b
- Accelerating power = $P_{m1} - P_e$
- When point b is reached the accelerating power is zero, but rotor speed is higher than synchronous speed ω_0 . Hence the rotor angle continues to increase
- For values of δ greater than δ_1 , P_e is greater than P_{m1} and rotor decelerates
- At δ_m rotor speed recovers to synchronous value ω_0 but P_e is higher than P_{m1}
- The rotor continues to decelerate with speed dropping below ω_0 .
- The operating point retraces $P_e - \delta$ curve from c to b and then to a.
- Rotor angle oscillates indefinitely about the new equilibrium angle δ_1 with a constant amplitude.
- Area $A_1 = \text{Area } A_2$



Equal Area Criterion

- For stable case**

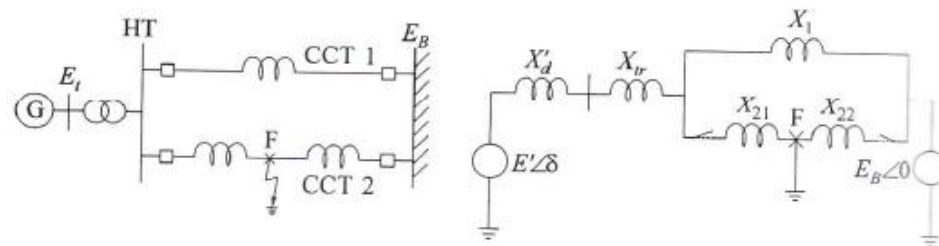
Decelerating area should at least be equal or more than accelerating area

$$\text{Area } A_2 \geq \text{Area } A_1$$

- For unstable case**

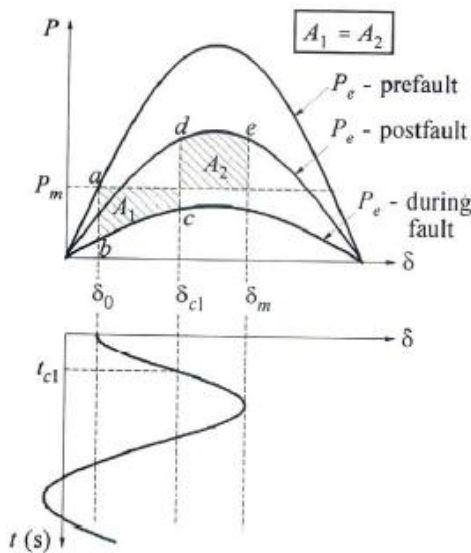
Accelerating area would be more than decelerating area

$$\text{Area } A_2 < \text{Area } A_1$$

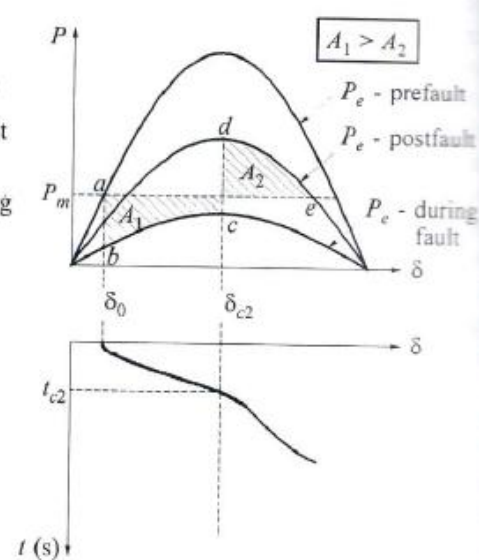


(a) Single-line diagram

(b) Equivalent circuit



(c) Response to a fault cleared in t_{c1} seconds - stable case



(d) Response to a fault cleared in t_{c2} seconds - unstable case