Consider a power system as in figure.

**Case 1:** When there is no fault

\[ P_e = \frac{E_1 \times E_2 \times \sin \theta}{X_T} \]

**Case 2:** When a short circuit fault occurs at Bus 2

\[ P_e = 0 \]

**Case 3:** When a 3D fault occurs at Bus 2

\[ P_e = \frac{E_1 \times E_2 \times \sin \beta}{X_L} \]

**Stable Swing**

\[ \begin{align*}
P_e &= \frac{E_1 \times E_2 \times \sin \theta}{X_T} \\
0 &= P_e \\
\frac{E_1 \times E_2 \times \sin \beta}{X_L} &= P_e
\end{align*} \]

A and B both are operating equilibrium points.

**Intersection of Initial mechanical power to electrical power beyond an operating equilibrium (STABLE SWING)**

Unstable swing because mechanical power is always greater than electrical power hence no intersection.
Unstable power swing because rotor angle is monotonically increasing.

Stable power swing because operational load angle is in a narrow range.

Unstable power swing is an indication that generator is going out of step.

Stable power swing

Power swing

Unstable power swing

After any disturbance, a generator is able to find its operating equilibrium, we call it a stable swing.

Impedance seen by the relay (during power swing):

\[ Z_{T} = Z_{SA} + Z_{L} + Z_{SB} \]

\[ V_{r} = E_{A}I_{S} - I_{r}Z_{SA} \]

\[ I_{r} = \frac{E_{A}I_{S} - E_{B}I_{O}}{Z_{T}} \]

where a power system involving two relays is considered and we are observing effect of power swing in relay impedance.
Now by rearranging the equation

\[ Z_T + \frac{E_B L_C}{I_T} - \frac{E_A L_C}{I_T} = 0 \]  \[ \text{--- D} \]

Now the relay impedance that is function of \( f(Ir) \times Z_r \)

\[ Z_r = -Z_{SA} + \frac{E_A L_C}{I_T} \] \[ \text{--- E} \]

Relay impedance is function of source angle/load angle

\[ Z_r = \frac{V_I}{I_T} \] \[ \text{--- F} \]

Plot the locus of Impedance

\[ Z_{SB} = 8 \text{ terminal generator impedance} \]

\[ Z_{TB} = A \text{ terminal} \]

Draw the locus for a given system (Power Swing)

Due to the power swing, impedance will fall in operating zone
out of step protection schemes

(1) When \( S \) increases, the apparent impedance approaches to the electrical centre and some times, it approaches to relay operating zone. For preclusion of this we need "out of step" blocking scheme.

(2) The location of power swing depends upon line and source impedances and it also depends upon

\[ |E_a| = |E_b| \] normal

\[ |E_a| > |E_b| \] shape 2

\[ |E_a| < |E_b| \] shape 3

Due to power swing impedance seen by relay variable, in the fig. let us assume that impedance seen by relay falls in zone 1.

\[ \frac{V_r}{I_r} \] b. out of step blocking relay characteristic with main relay.

3 stepped distance scheme \( T_e \)

No (Blocking with relay)

Timer with contact \( T_e \)

zone 1

A

B

C

D

re (Vr/Ir)

|Ir|

Blocking relay

Out of step blocking arrangement

At A: Power swing entered blocking relay at \( t = 0 \)
At B: \( k < T_e \) → completely block
At C: \( k = T_e \) → Power Swing entered out zone
Dr. Akash Saxena (Protection of Power System)