Power System Protection

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Power Swing Detection, Blocking and Out of Step Relaying
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Power Swings can be classified as

- **Stable**: When the power swing is consequence of stable disturbance, unwanted tripping lead to instability.
- **Unstable**: When the power swing is consequence of unstable disturbance, interconnected operation of the system will not be possible.
  - Then the system has to be split into multiple islands, each having synchronism of generators.
  - In each island, generator load balance has to be ascertained.
  - If an island has excess generation, it should be shelved.
  - If an island has excess load, load shedding is required.
  - The boundary of islands has to be selected in such a way that loss of service is minimized.
During an unstable disturbance, let the electrical center be on line AB.
Relays $R_1$ and $R_2$ will trip and thereby islanding the system.
There will be loss of load in island B and loss of generation in island A.
Thus during unstable swings, distance relays should be blocked from operation.
Out of Step Blocking Relays

- It is similar to the Mho unit.
- It is a circle concentric to mho tripping characteristics with larger radius.
- This ascertains that any power swing which enters tripping will first enter the out of step characteristic.
- If the transit time is larger than the preset interval, it will operate auxiliary relays to block tripping.
- An out of step blocking scheme with an impedance also have the same principle.
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Fig 26.2 Out-of-Step Blocking by Offset - Mho Unit
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Fig 26.3 Out-of-Step Blocking with Offset - Impedance Unit
Out of Step Tripping Relay

- This scheme consists of two modified reactance units whose characteristics are set parallel to the system impedance.
- The unstable swing will cross these two characteristics.
- The two crossing indicate that swing has crossed the impedance characteristics and hence it is a loss of synchronism condition.
- This will lead to an out of step trip decision.
- This scheme will pick up for swing movement in the opposite direction and for the swings behind the relay.
- In order to avoid tripping on swings far away from the line, this relay is supervised by an overcurrent relay.
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Fig 26.4 Out-of-Step Tripping Relay
Setting of Out of Step Tripping Relay

- The primary step is to freeze the location of line segments.
- This setting is done in such a way that swing locus will remain between $XX^1$ for at least 0.005 sec.
- This is the operating time of the auxiliary relays which determines a loss of synchronism.
- The characteristics of these two units should not be set so far apart to pick up on load conditions.
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Fig 26.5 (a) Application of Out-of-Step Tripping Relay
Thus it can be seen that

- The trajectory of the impedance measured by relay during the power swing is straight line.
- The angle subtended by a point in the locus on S and R end points is the angle $\delta$.
- The swing intersects the line AB, when $\delta = 180$.
- This point of intersection of swing impedance trajectory on the impedance line is known as electrical center of the swing.
- At the electrical center, angle between two sources is $180^\circ$.
- The existence of the electrical center is an indication of system instability. i.e, the two generators are now out of step.
- If the post fault system is stable, the power swing retraces its path at $\delta_{max}$. 
Power Swings and Distance Relaying

Fig 24.4 (a) Power Swing along with Mho Characteristics (k=1)
Power Swings and Distance Relaying

If \( \frac{E_S}{E_R} = k \neq 1 \) then the power swing locus is an arc of the circle.
Power Swings and Distance Relaying

It can be shown that,

\[
\frac{E_S}{E_S - E_R} = \frac{k(cos\delta + jsin\delta)}{k(cos\delta + jsin\delta) - 1} = \frac{k[(k - cos\delta) - jsin\delta]}{(k - cos\delta)^2 + sin^2\delta}
\]

Then,

\[
Z_{seen} = -Z_S + \frac{k[(k - cos\delta) - jsin\delta]}{(k - cos\delta)^2 + sin^2\delta} Z_T
\]

- The location of electrical center depends upon \(\frac{|E_S|}{|E_R|}\) ratio.

Appearance of electrical center on a transmission line is a transient phenomenon.

- The electrical center vanishes after some time.
At the electrical center voltage is zero and the relays at both ends will trip the line.

Thus, existence of electrical center indicates system instability and nuisance tripping of the distance relay.
Power Swings and Distance Relaying

Fig 24.6 Single Line Diagram showing Three Protection Zones
Power Swings and Distance Relaying

Fig 24.7 Three Stepped Distance Protection to Double-end-fed Line
Let $\delta_{Z1}$, $\delta_{Z2}$ and $\delta_{Z3}$ are the rotor angles when swing just enters the 3 zones, then,

- If $\delta_{max} < \delta_{Z3}$, then the swing will not enter the relay characteristics.
- If $\delta_{Z3} \leq \delta_{max} \leq \delta_{Z2}$, then the swing will enter in zone 3.
- If $\delta_{Z2} \leq \delta_{max} \leq \delta_{Z1}$, then the swing will enter in both zone 2 and 3.
- If $\delta_{max} \geq \delta_{Z1}$, then the swing will enter in all the 3 zones and the relay will trip on zone 1.
Summary

- Introduction to power swings
- Distance relay perspective of power swings
- Swing locus seen by distance relay
- Electrical center
- Three stepped distance protection
- Possibility of distance relay tripping on power swings