# EEE340 Protective Relaying

## Lecture 11 – Distance Protection 4

# Today

- Distance Protection 4
  - Characteristic of Power Swing
  - Measured Impedance During Power Swing
  - Power Swing Blocking
  - Distance Protection Using Power Frequency Fault Components

# Power Swing

- Power Swing:

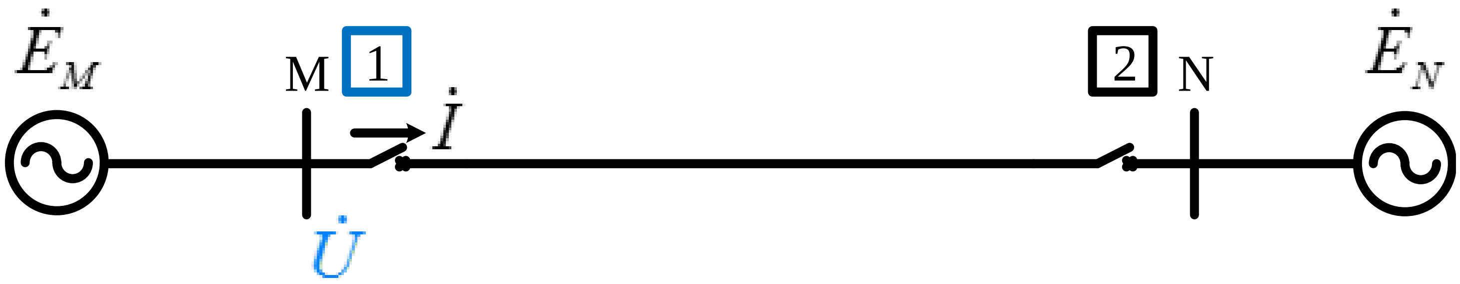
Concept: power angles of parallel systems or generators have large periodical variation;

Reasons: Power transmission exceeds limit; Slow fault clearance; Inadequate reactive power; Asynchronous autoreclosure;

Impact: $U_m \downarrow,\ I_m \uparrow, Z_m \downarrow$ false trip is possible, the situation can be worsen;

Power swing blocking: power swing is an abnormal state, but not fault, so distance protection should be blocked to avoid false trip.

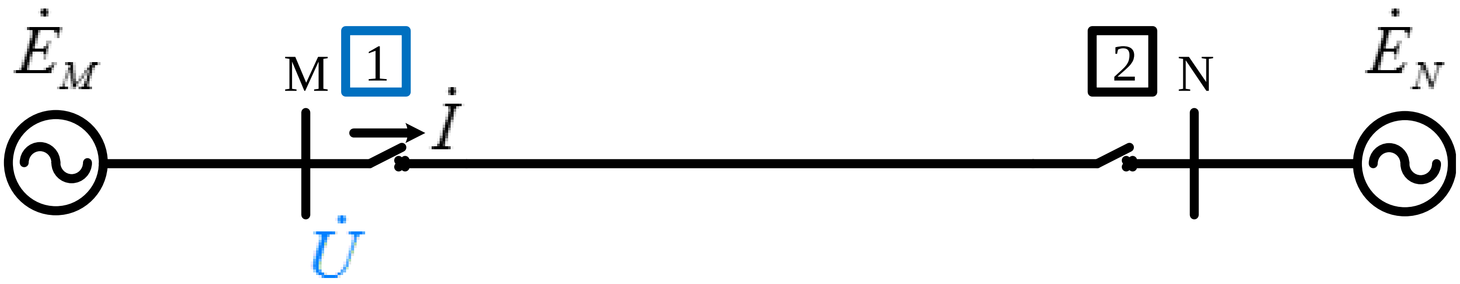
# Characteristic of Power Swing




Assumption: the amplitudes of two voltage sources are equal, only their phase angle difference (power angle) will be considered;

Objective: to find out the difference between characteristics of power swing and faults, make analysis of the action of distance protection during power swing, then find criterion for power swing blocking.

# Characteristic of Power Swing



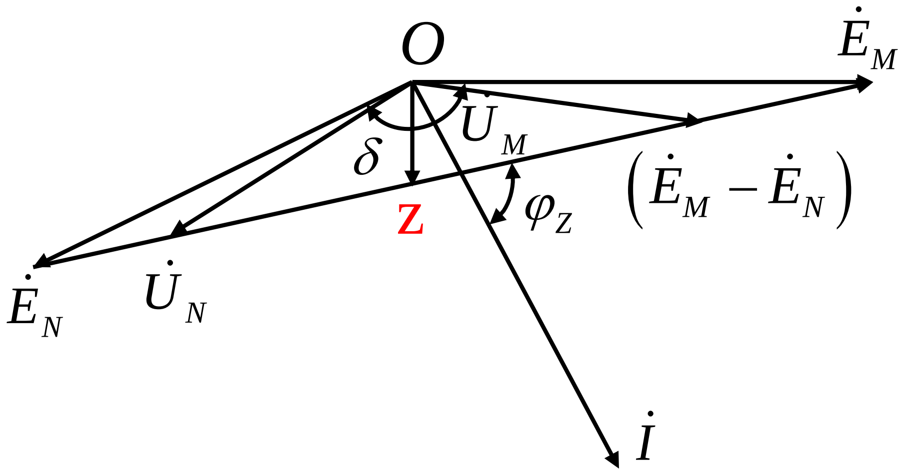

$$\dot{I} = \frac{\dot{E}_M - \dot{E}_N}{Z_\Sigma} = \frac{\dot{E}_M (1 - e^{-j\delta})}{Z_\Sigma}$$

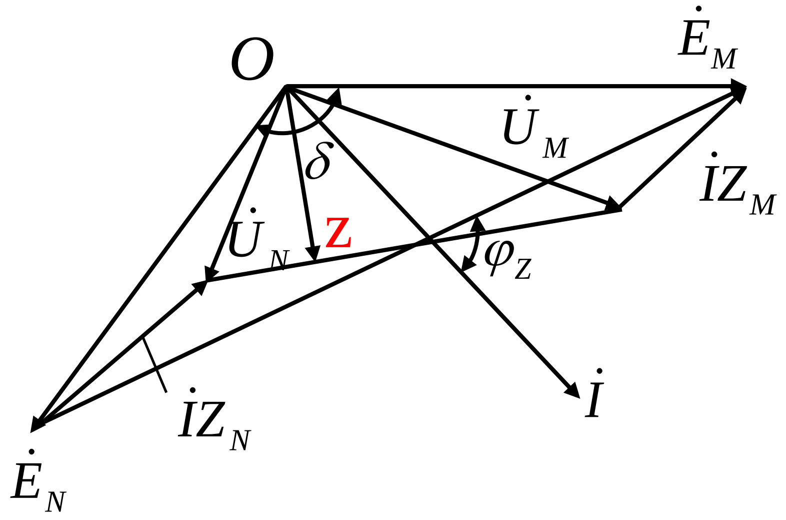
$$\dot{U}_M = \dot{E}_M - \dot{I} Z_M$$

$$\dot{U}_N = \dot{E}_N + \dot{I} Z_N$$

$$Z_\Sigma = Z_M + Z_L + Z_N$$

# Characteristic of Power Swing

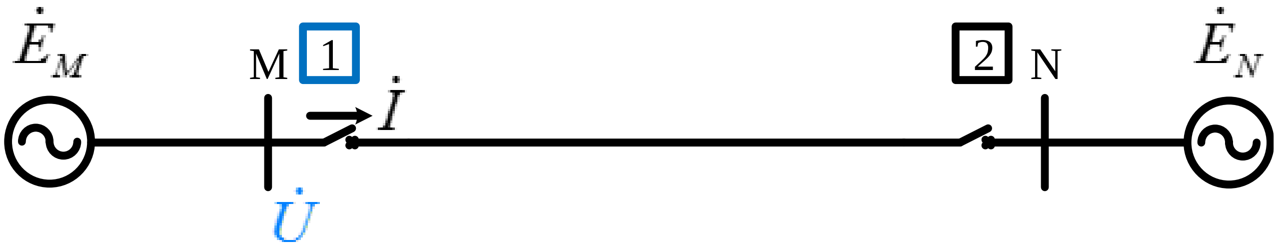


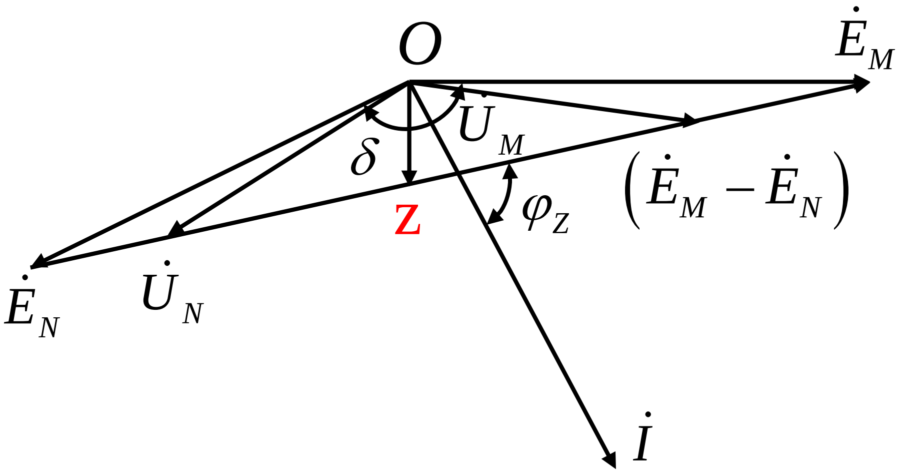




System impedance angle = Line impeance angle

System impedance angle ≠ Line impedance angle

# System impedance angle = Line impedance angle



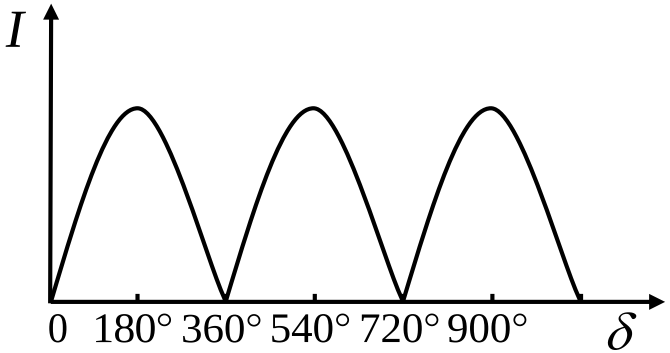

$$\Delta E = 2E_M \sin\frac{\delta}{2}$$

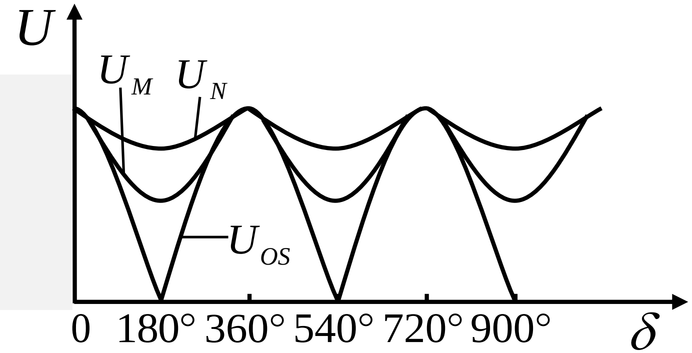
$$I = \frac{\Delta E}{|Z_\Sigma|} = \frac{2E_M}{|Z_\Sigma|}\sin\frac{\delta}{2}$$

The terminal of voltage phase for any point of the line should on the line between $E_M$ and $E_N$.

Power angle changes from 0 to 360 degree.

# Characteristic of Power Swing




The point with the minimum voltage amplitude during power swing is the swing center (point z in the former case).

When $\delta=180^o$, the voltage at swing center $U_{os}$ is 0, which is equivalent as three-phase short circuit for distance protection.

For different installed locations of protection, the influence from power swing is different; the protection closer to the swing center will be influenced more.

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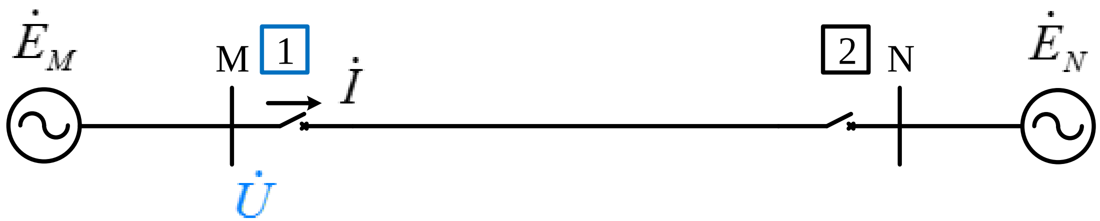
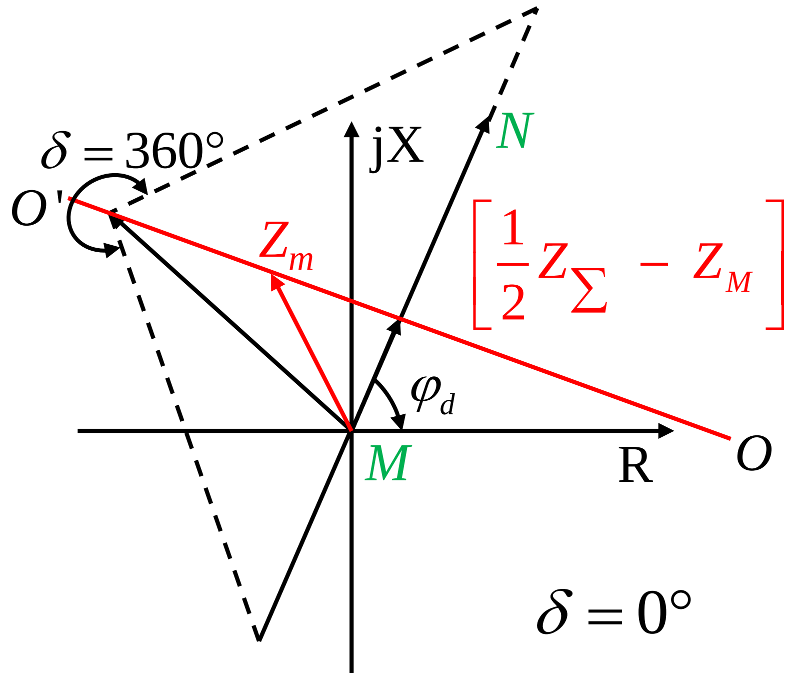
# Measured Impedance During Power Swing



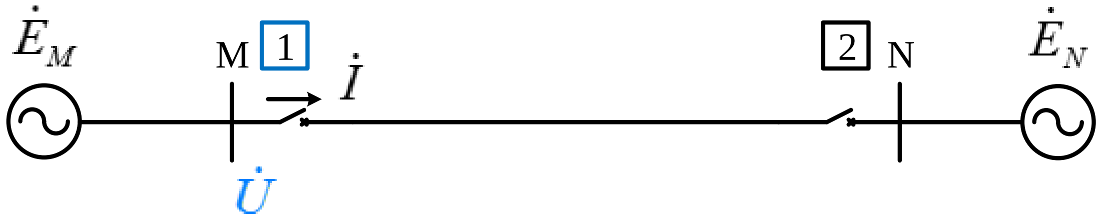

$$Z_m = \frac{\dot{U}_M}{\dot{I}_M} = \frac{\dot{E}_M - \dot{I}_M Z_M}{\dot{I}_M} = \frac{\dot{E}_M}{\dot{I}_M} - Z_M$$

$$= \frac{1}{1 - e^{-j\delta}} Z_\Sigma - Z_M$$

$$= (\frac{1}{2} Z_\Sigma - Z_M) - j\frac{1}{2} Z_\Sigma \, ctg \frac{\delta}{2}$$

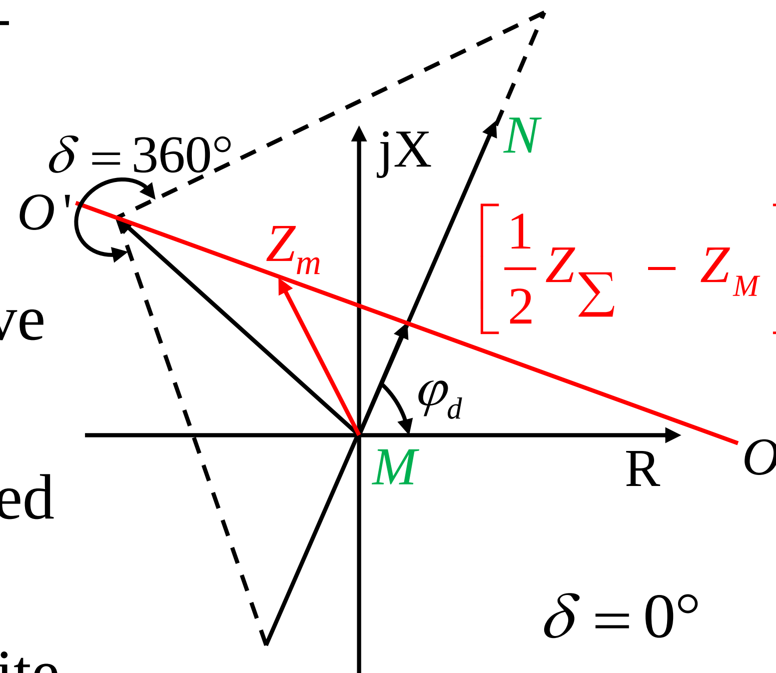


# Measured Impedance During Power Swing




$$Z_m = (\frac{1}{2}Z_\Sigma - Z_M) - j\frac{1}{2}Z_\Sigma ctg\frac{\delta}{2}$$

$$Make\ Z_M = mZ_\Sigma,$$

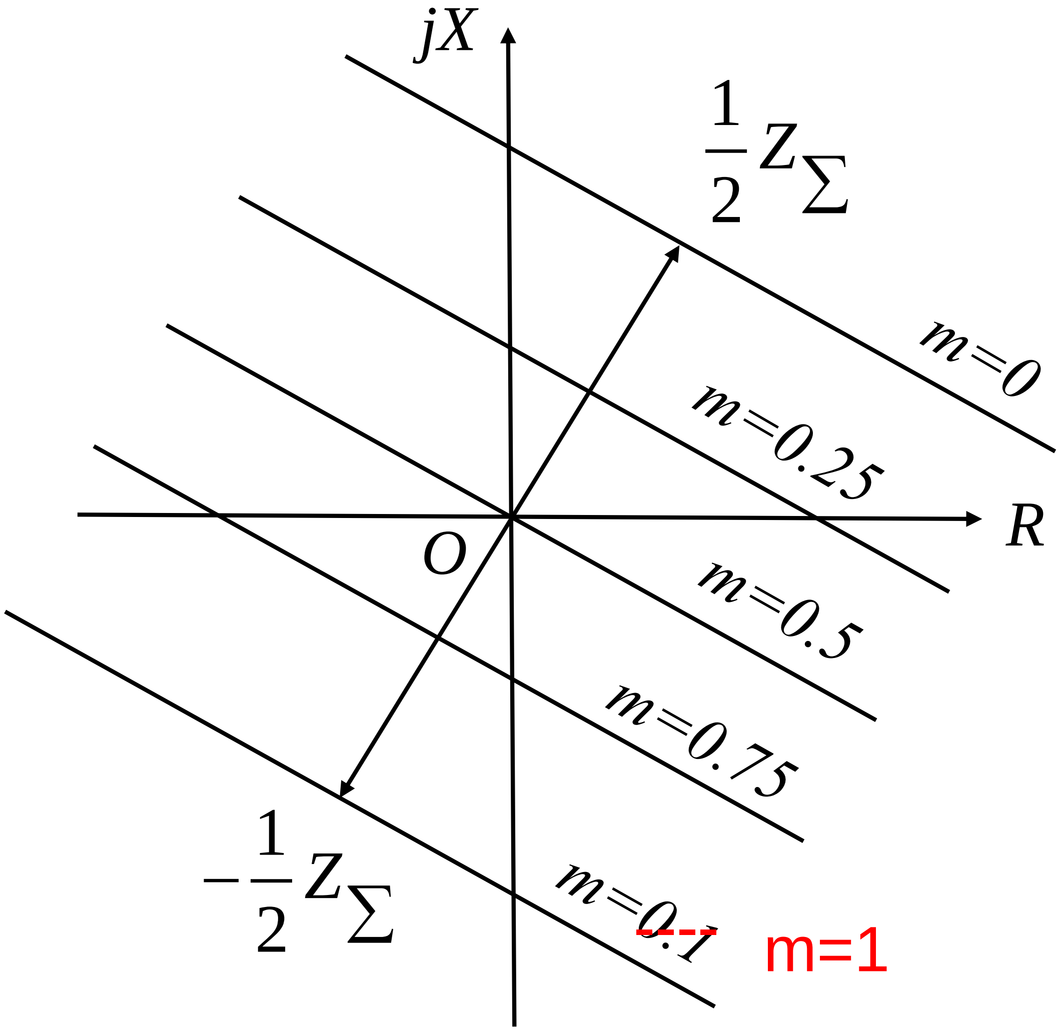



$m < \frac{1}{2}$ The swing center is on the positive direction of protection;

$m = \frac{1}{2}$ The swing center is just at installed location of protection;

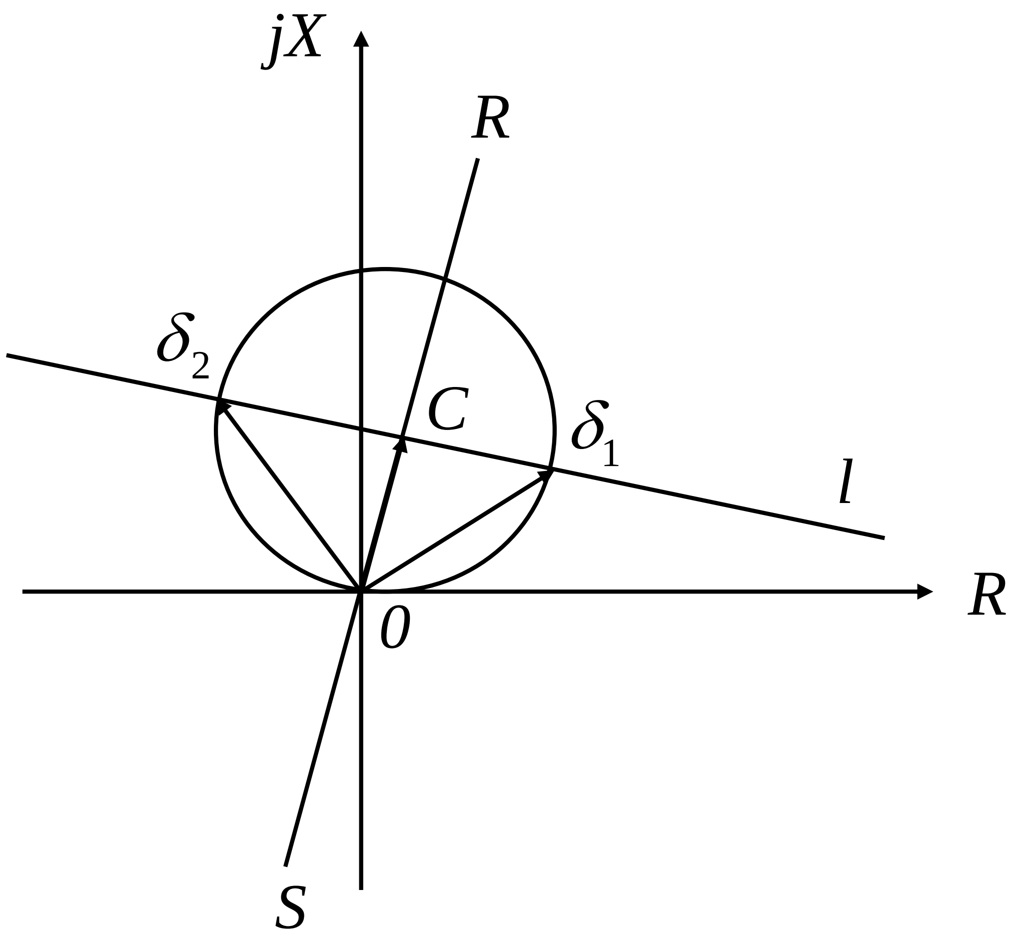
$m \overset{>}{\cancel{<}} \frac{1}{2}$ The swing center is on the opposite direction of protection;

# Measured Impedance for Different m




For different installed locations of protection, the influence from power swing is different;
The protection closer to the swing center will be influenced more.

# Measured Impedance During Power Swing

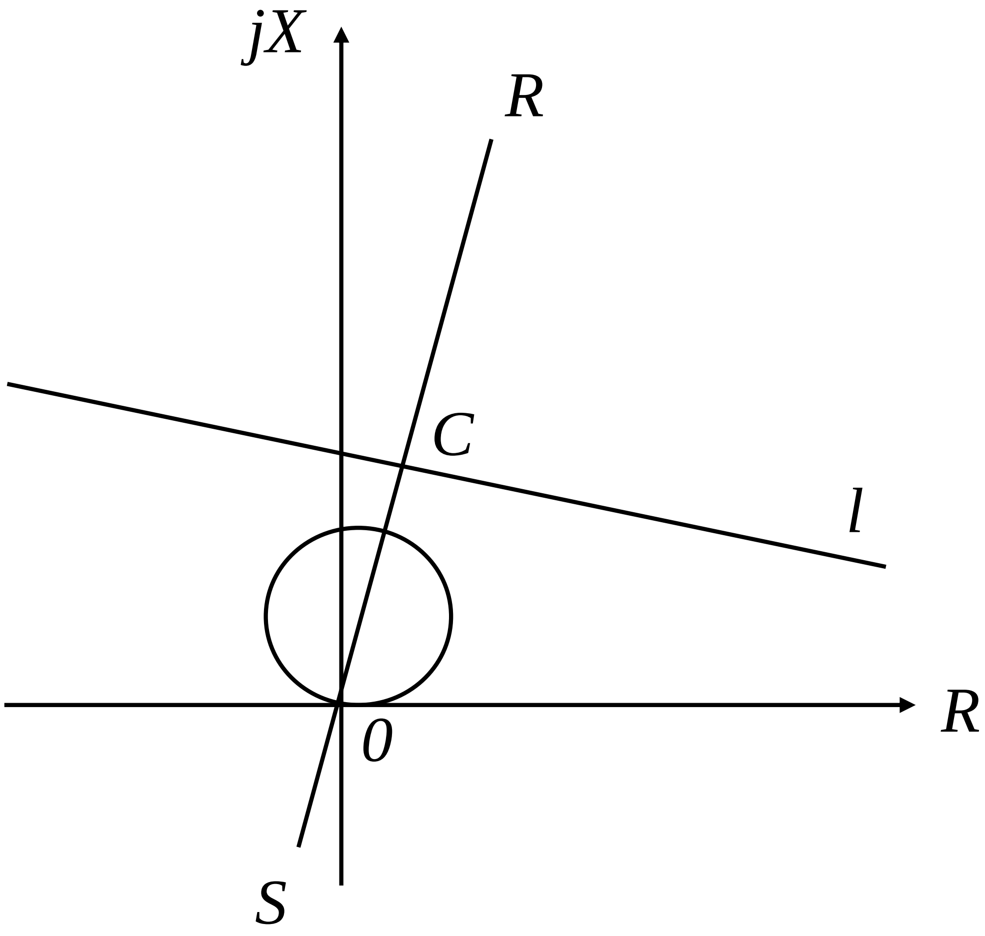



The swing center is inside the trip zone of the relay;

When power angle change between δ1 and δ2, the protection may make false trip;

The time for false trip depends on the value of δ1 and δ2.

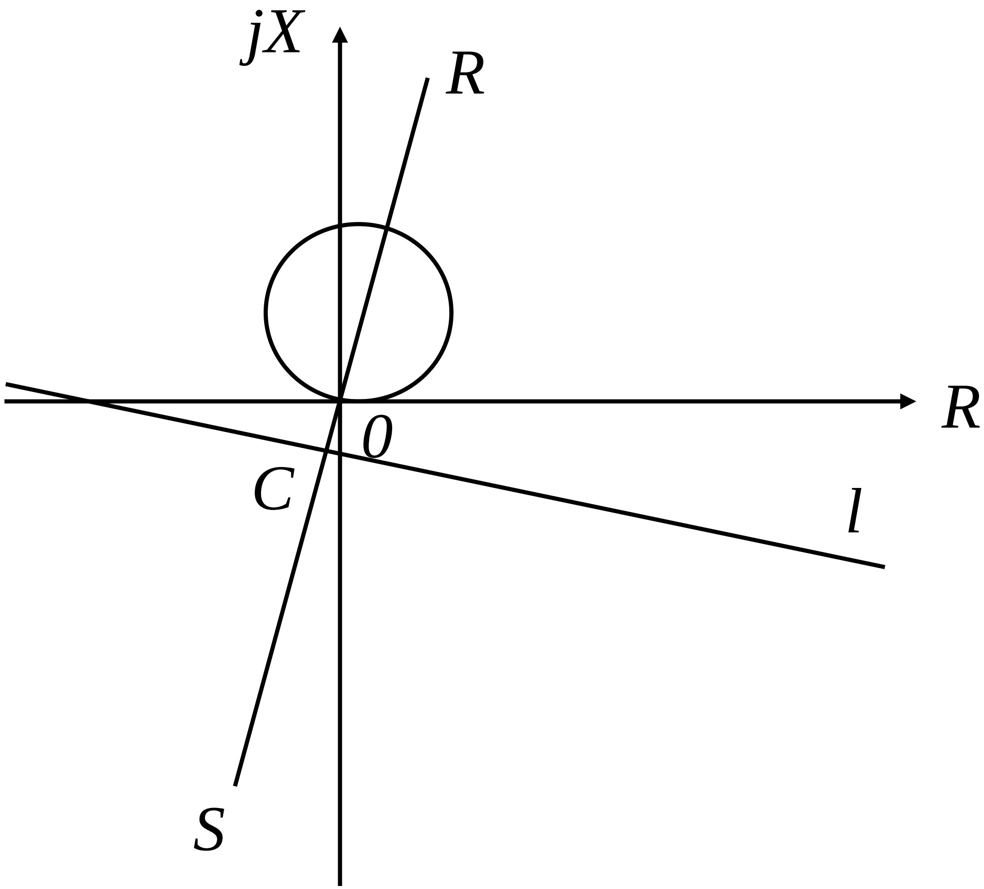
# Measured Impedance During Power Swing




The swing center is out of the trip zone of the relay;

No false trip will happen.

# Measured Impedance During Power Swing




The swing center is out of the trip zone of the relay;

No false trip will happen.

# Impacts of Power Swing on Distance Protection

- An impedance relay trips or not during power swing, and the time length of false trip mainly depend on:

The installed location of impedance relay (with reference to the swing center);

Trip Zone (Setting value, shape of trip zone);

Time delay of the protection.

# Solutions for Impacts of Power Swing

- Time delay for operating time (such as Zone III);
- To change setting value so that the swing center is out of the trip zone;
- To apply power swing blocking which will block the distance protection during power swing.

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# Power Swing Blocking

- Requirements:

No false trip during power swing;
In case of unsymmetrical faults during power swing, protections should operate correctly;
In case of three phase short circuit during power swing, protection should reliably trip, short time delay is permitted.

- Difference between power swing and faults:

Power swing is symmetrical without zero or negative sequence component; but faults may have in long time (unsymmetrical faults ) or instantaneous (at beginning of three-phase fault) zero or negative components.

# Power Swing Blocking

- Difference between power swing and faults:

During power swing, the electric quantities have periodical variation, and the varying rate (dU/dt, dI/dt, dZ/dt) would be slow and consistent with that of power angle. But the variation before and after short circuit would be very fast and keep stable after that.

- Difference between power swing and faults:

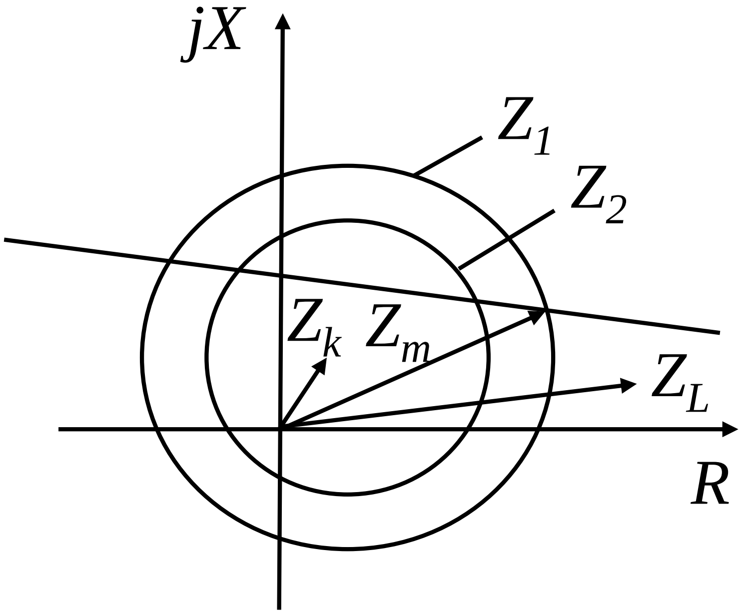
Because power swing is periodical, so impedance relay may trip and then return in each period. But in case of short circuit, relay may trip and not return until the fault is cleared.

# Measures of Power Swing Blocking

- According to zero or negative sequence current, or sudden variation, to open blocking for operation of protection.

Distance protection is normally blocked when no fault is detected;
If a fault is detected, then the protection is opened for short time;
During this short time, if the fault is inside the protected zone, the protection will operate and clear it;
If the fault is outside protected zone, the relay will not trip, and the protection will be blocked again.

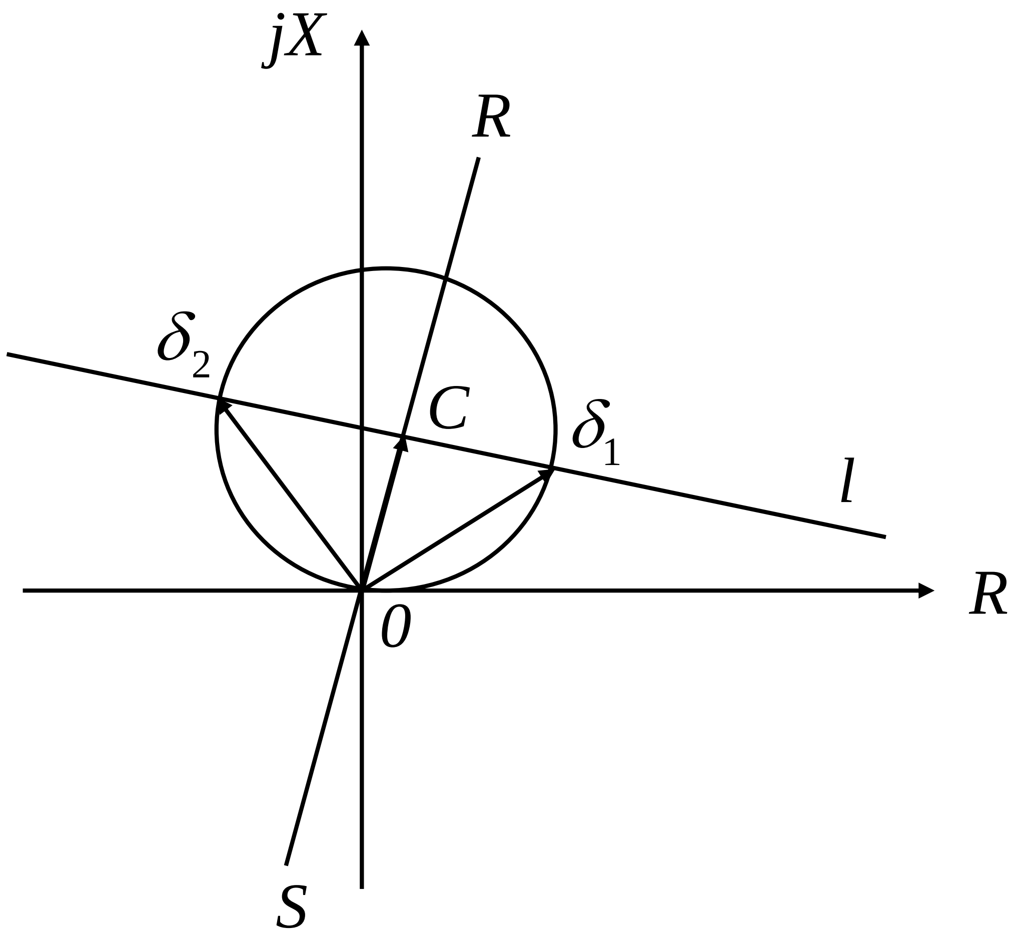
# Measures of Power Swing Blocking




- According to varying speed of impedance, because the impedance under fault should change faster than in power swing.

If KZ1 trip first and then KZ2 trip within time of Δt, then the protection will be opened; if KZ2 cannot trip within Δt, protection will be blocked.

# Measures of Power Swing Blocking




- The measuring unit will trip at δ1 and return at δ2. If the time delay of protection is longer than the time between δ1 and δ2, no false trip may happen.
- In practice, for Zone III, the time in trip zone is smaller than 1~1.5s, so if the time delay for Zone III is longer than 1~1.5s, no false trip will happen during power swing.

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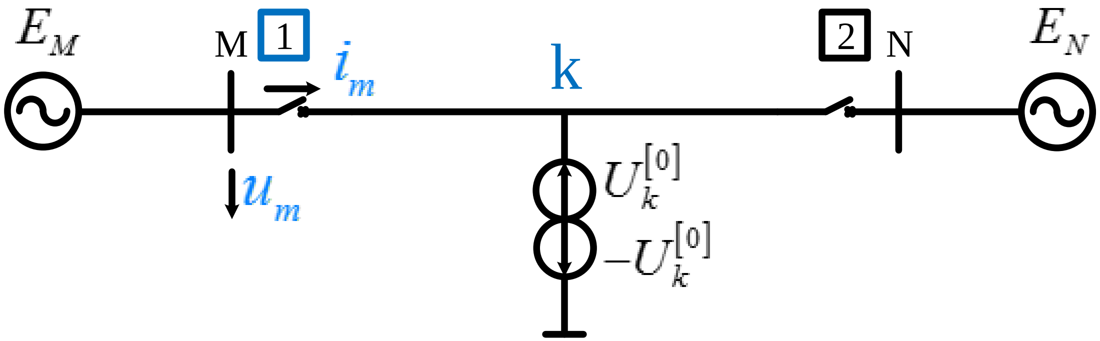
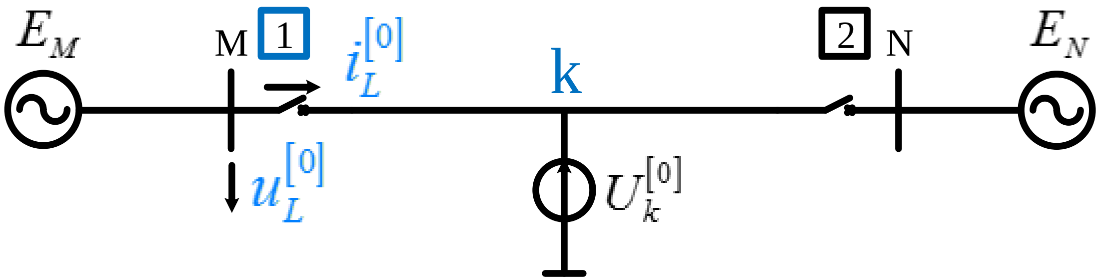
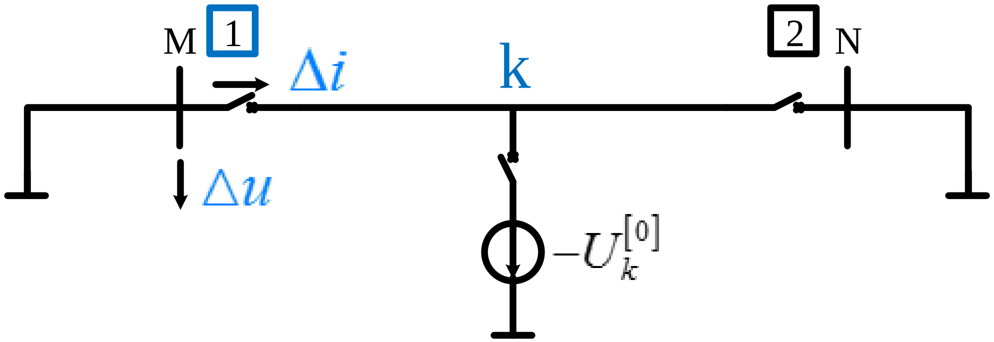
# Power Frequency Fault Component




$$\begin{cases} u_m = u^{[0]} + \Delta u \\ i_m = i^{[0]} + \Delta i \end{cases}$$



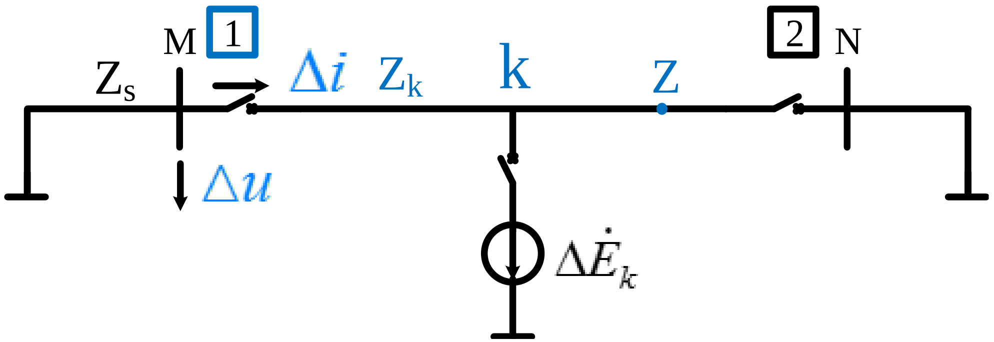

$$\begin{cases} \Delta u = u_m - u^{[0]} \\ \Delta i = i_m - i^{[0]} \end{cases}$$




$$\begin{cases} \Delta u = u_{st} + \Delta u_{tr} \\ \Delta i = i_{st} + \Delta i_{tr} \end{cases}$$

Power frequency component

# Distance Protection Using Power Frequency Fault Components



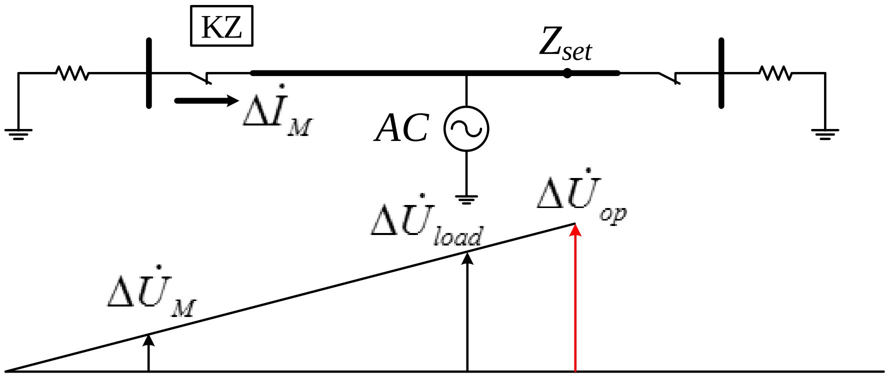

$$\Delta\dot{I} = \frac{\Delta\dot{E}_k}{Z_s + Z_k}$$

$$\Delta\dot{U} = -\Delta\dot{I} Z_s$$

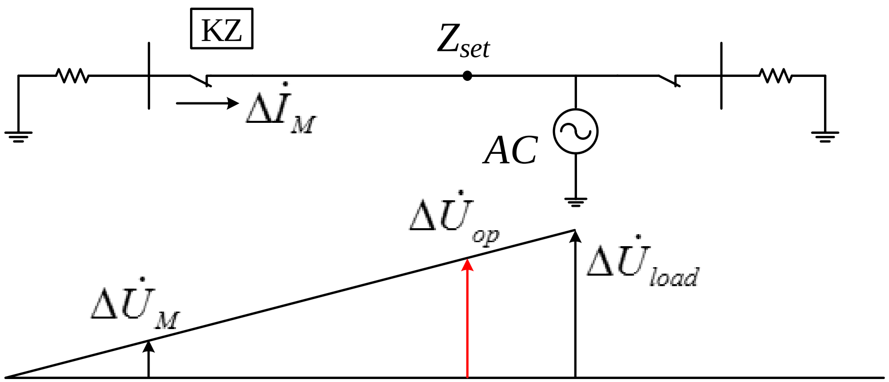
$$\Delta\dot{U}_{op} = \Delta\dot{U} - \Delta\dot{I} Z_{set} = -\Delta\dot{I}(Z_s + Z_{set})$$

$U_{op}$ is just corresponding to the voltage of point z.

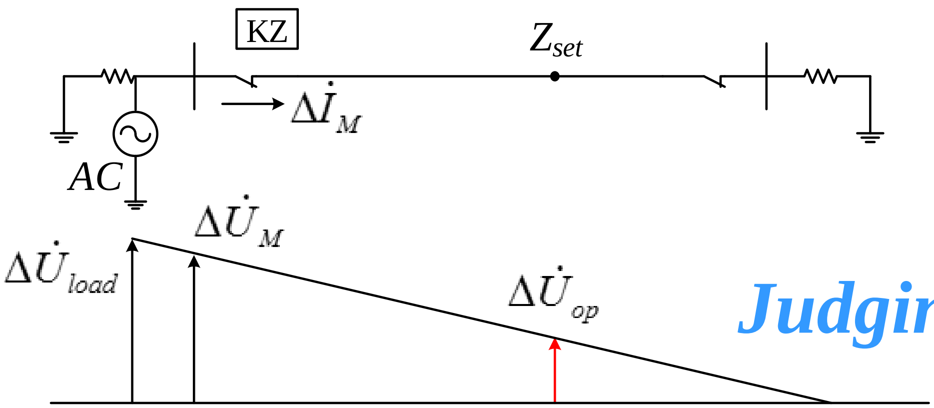
# Distance Protection Using Power Frequency Fault Components




$$\left|\Delta \dot{U}_{op}\right| > \left|\Delta \dot{E}_{k1}\right|$$




$$\left|\Delta \dot{U}_{op}\right| < \left|\Delta \dot{E}_{k2}\right|$$




$$\left|\Delta \dot{U}_{op}\right| < \left|\Delta \dot{E}_{k3}\right|$$

***Judging Criteria:*** $\left|\Delta \dot{U}_{op}\right| \geq \left|\Delta \dot{E}_{k}\right|$

# Next Lecture

## Pilot Protection 1

Thanks for your attendance