西交利物浦大學 Xi'an Jiaotong-Liverpool University

EEE340 Protective Relaying

Lecture 10 – Distance Protection 3

Today

- Distance Protection 3
  - Implementation Methods of Impedance Relay
  - Setting calculation
  - Impact of transition resistance
  - Impact of series compensation

Implementation Methods of Impedance Relay

- The operating characteristics can be expressed by two forms , i.e. impedance and voltage phasor.

- Two implementation methods:

Impedance comparison: operating characteristics in terms of impedance (phase comparison or amplitude comparison);

Voltage comparison: operating characteristics in terms of voltage phasor (phase comparison or amplitude comparison);

Implementation Methods of Impedance Relay

- Application of Two implementation methods:

Analog impedance relay: Voltage comparison is normally used; Two voltage phasors can be collected from input connection and then be compared by amplitude or phase angles.

Digital impedance relay: Both voltage comparison and impedance comparison can be implemented;

However, in digital impedance relay, the voltage phasors for voltage comparison are from calculation, but not from input connection.

Implementation of Amplitude Comparison

- Original comparison by amplitude of impedance

$$|Z_B| \leq |Z_A|$$

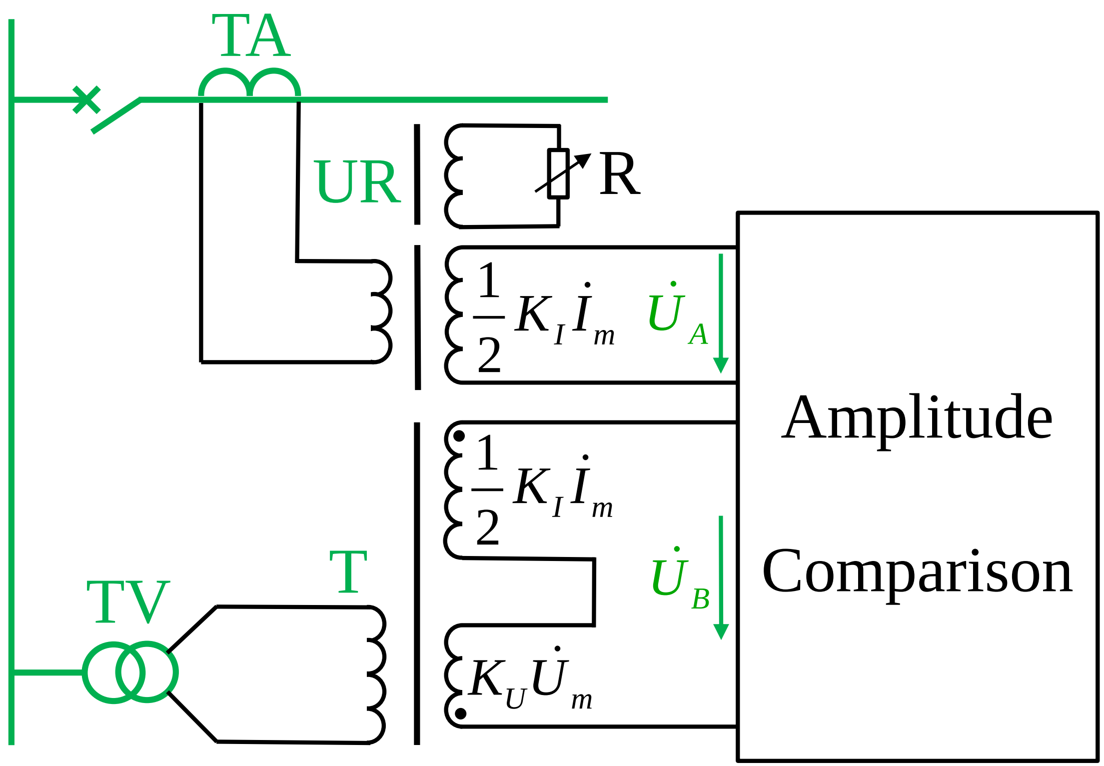
- Multiply with measured current at both sides:

$$|\dot{I}_m Z_B| \leq |\dot{I}_m Z_A|$$

- Then the amplitude comparison can be converted as:

$$|\dot{U}_B| \leq |\dot{U}_A|$$

Implementation of Amplitude Comparison



T: voltage transformer

UR: Reactance transformer (one input and three output)

$$\dot{U}_A = \frac{1}{2}K_I\dot{I}_m \qquad \dot{U}_B = \frac{1}{2}K_I\dot{I}_m - K_U\dot{U}_m$$

Implementation of Amplitude Comparison

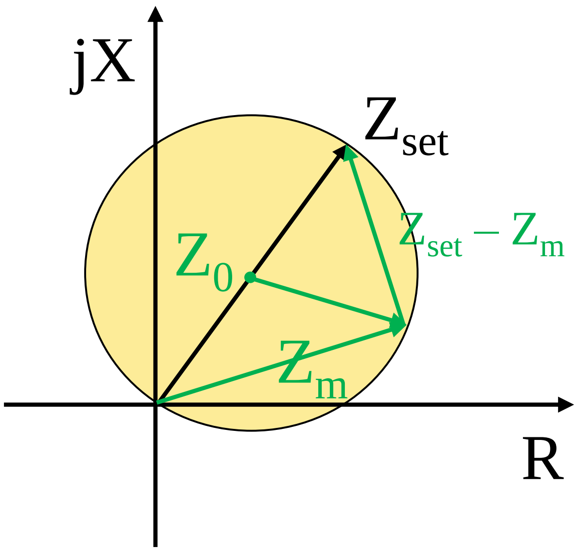
- Amplitude comparison can be written as

$$\left|\frac{1}{2}K_I\dot{I}_m - K_U\dot{U}_m\right| \le \left|\frac{1}{2}K_I\dot{I}_m\right|$$

- Both sides divided by $\left|K_U\dot{I}_m\right|$, and make $\frac{K_I}{K_U} = Z_{set}$:

$$\left| Z_m - \frac{1}{2}Z_{set} \right| \le \left|\frac{1}{2}Z_{set}\right|$$

This is just the directional circular characteristic for MHO relay.



Implementation of Phase Comparison

- Original comparison by phase angle of impedance

$$90^{o} \geq \arg \frac{Z_C}{Z_D} \geq -90^{o}$$

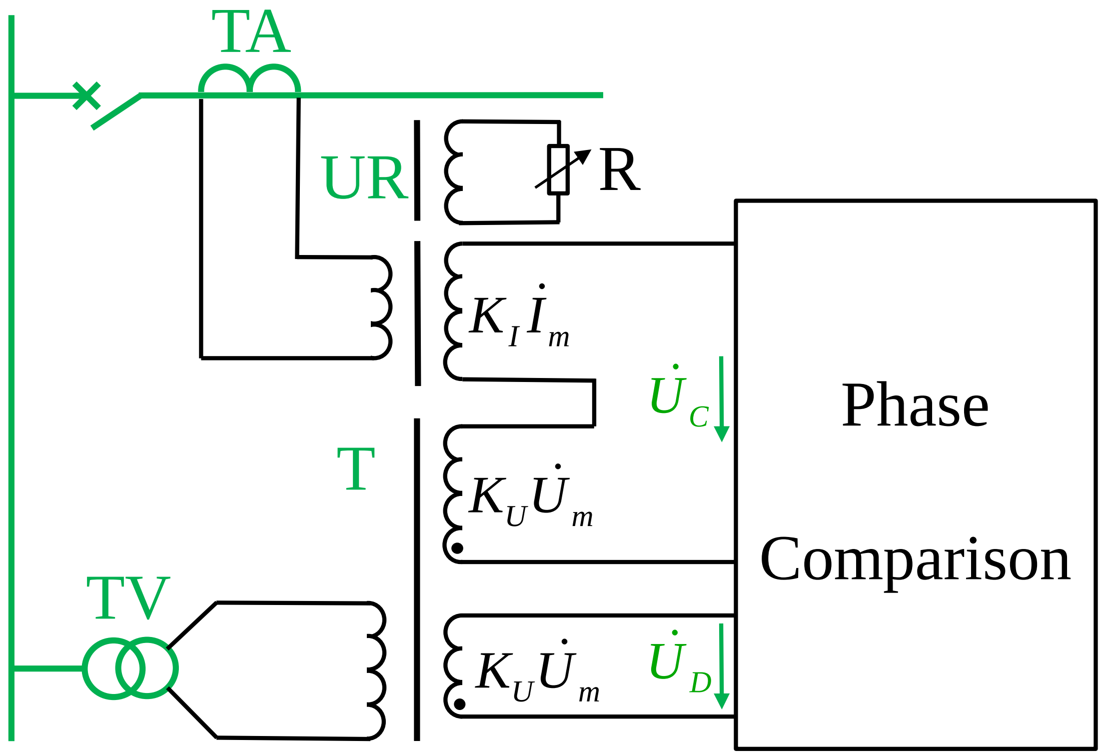
- Multiply with measured current at both sides:

$$\dot{I}_m Z_C = \dot{U}_C \qquad \dot{I}_m Z_D = \dot{U}_D$$

- Then the phase comparison can be converted as:

$$-90^{\circ} \leq \arg \frac{\dot{U}_C}{\dot{U}_D} \leq 90^{\circ}$$

Implementation of Phase Comparison



T: voltage transformer (one input, two output)

UR: Reactance transformer (one input and two output)

$$\dot{U}_D = K_U \dot{U}_m \qquad \dot{U}_C = K_I \dot{I}_m - K_U \dot{U}_m$$

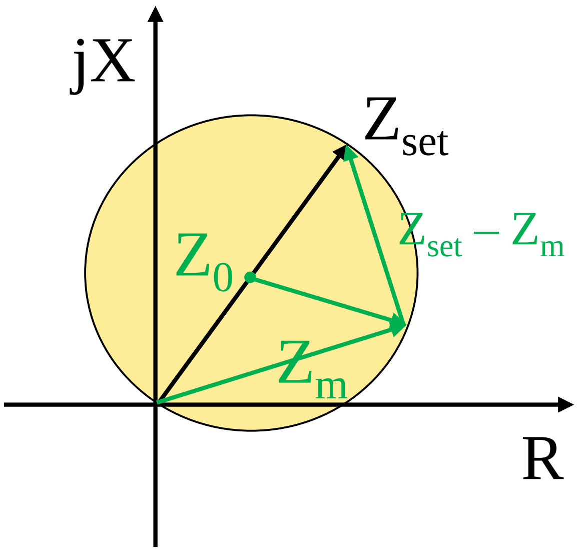
Implementation of Phase Comparison

- Phase comparison can be written as

$$-90^o \le \arg \frac{K_I \dot{I}_m - K_U \dot{U}_m}{K_U \dot{U}_m} \le 90^o$$

- All divided by $K_U \dot{I}_m$, and make $\dfrac{K_I}{K_U} = Z_{set}$:

$$-90^o \le \arg \frac{Z_{set} - Z_m}{Z_m} \le 90^o$$



This is just the directional circular characteristic for MHO relay.

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Setting Calculation

- Three Zones:

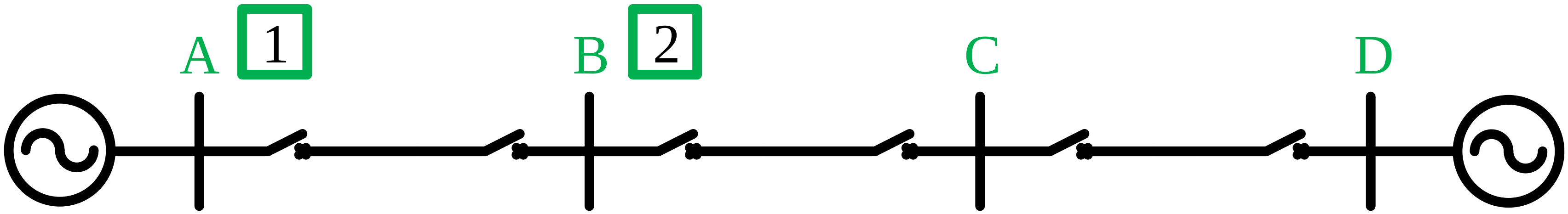
Distance protection also adopts the idea of coordination by three zones, which is similar to overcurrent protection.

- Zone I II III for distance protection:

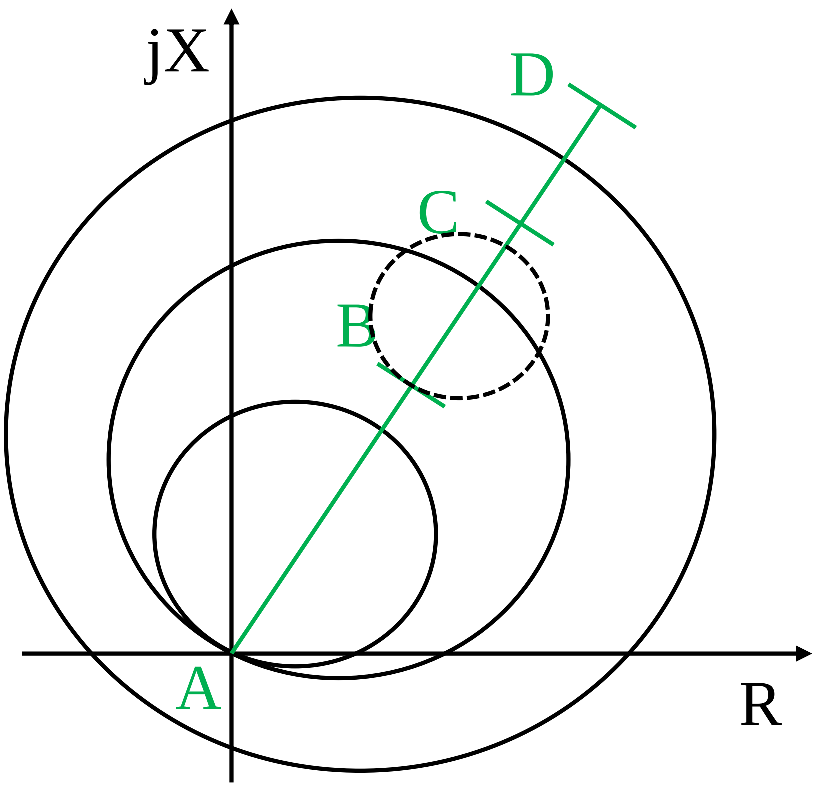
Zone I and zone II normally have directional operating characteristic as main protection for the protected line; Zone III normally has offset operating characteristic as backup protection for the current line, next line and faults at opposite beginning.

- The setting calculation for distance protection is to calculate the related setting impedances for corresponding operating characteristic.

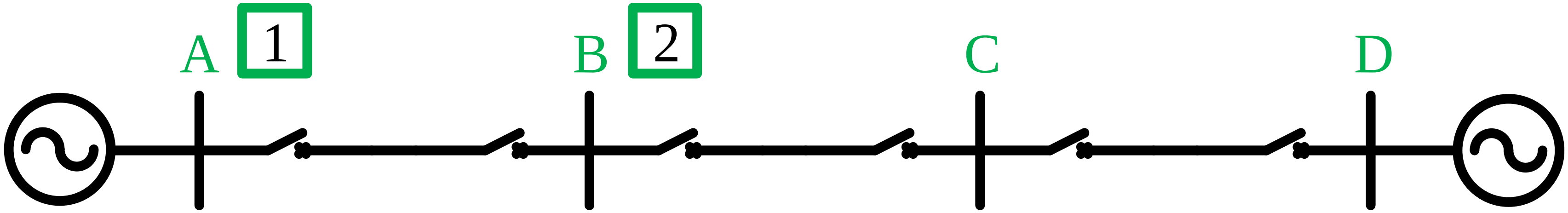
Example by Circular Characteristics



- Suppose the direction of setting impedance is same as the line impedance;
- Zone I and II are directional circle and Zone III is offset circle, as shown by three solid circles;
- The circle of broken line is Zone I at bus B.



Zone I of Distance Protection



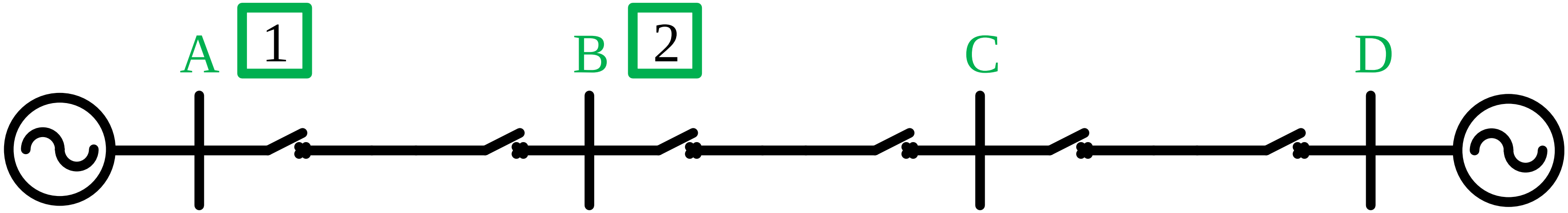
- Zone I has no time delay;
- Zone I should only response to faults of the current line;
- For faults at the beginning of next line, Zone I should not trip;
- So the setting impedance should avoid the measured impedance at the end of current line:

$$Z_{set.1}^{I} = K_{rel}^{I} Z_{AB} = (0.8 - 0.85) Z_{AB}$$

$$Z_{AB} = L_{A-B} z_1$$

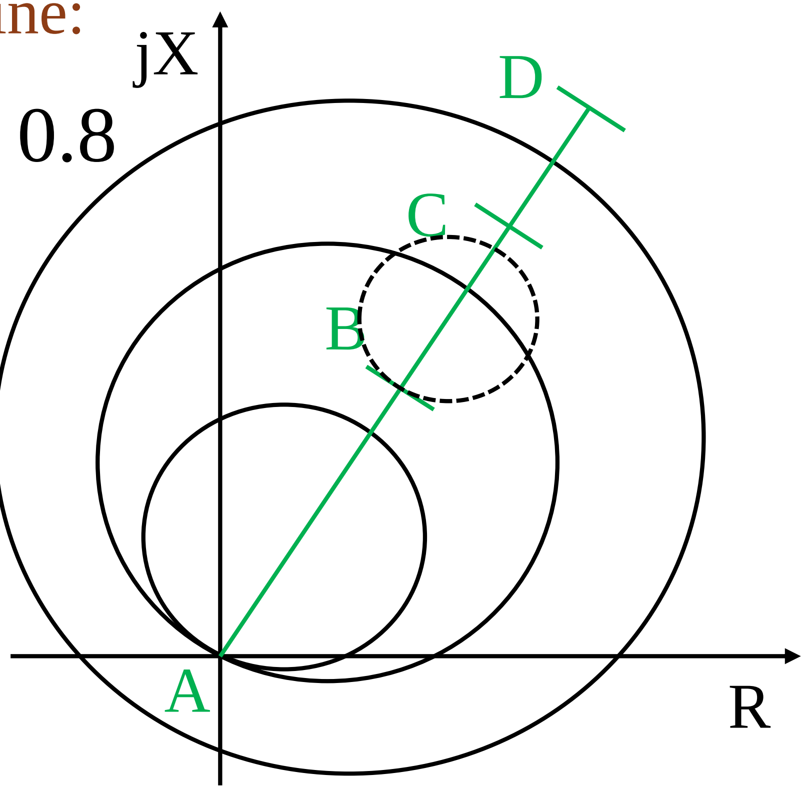
$$Z_{set.2}^{I} = K_{rel}^{I} Z_{BC} = (0.8 - 0.85) Z_{BC}$$

Zone II of Distance Protection

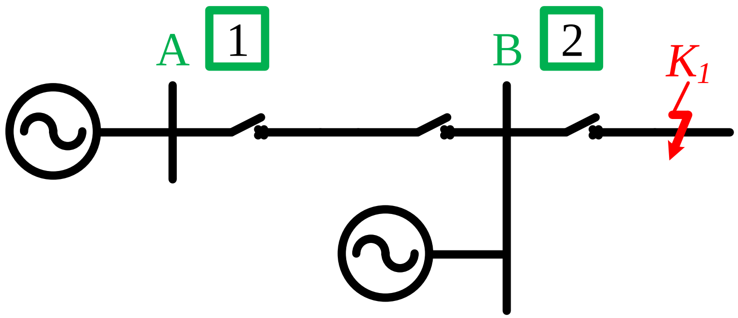


- Coordination with Zone I of next line:

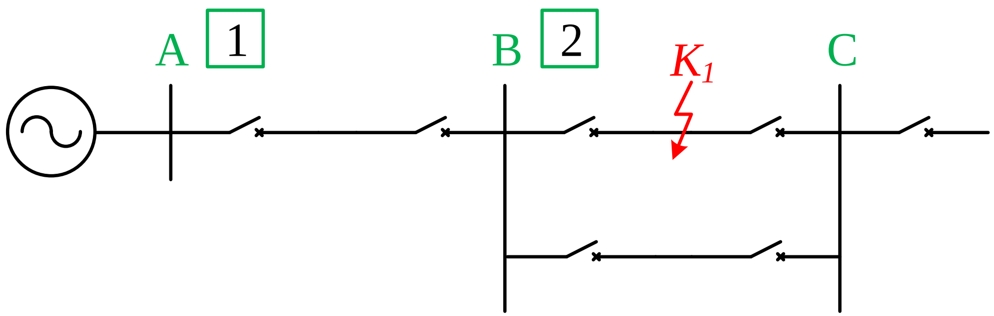
$$Z_{set.1}^{II} = K_{rel}^{II}(Z_{AB} + Z_{set.2}^{I}) \qquad K_{rel}^{II} = 0.8$$



Influence of Branches



(a)



(b)

$$Z_{m1} = \frac{\dot{U}_A}{\dot{I}_1} = \frac{\dot{I}_1 Z_{AB} + \dot{I}_2 Z_k}{\dot{I}_1} = Z_{AB} + K_b Z_k$$

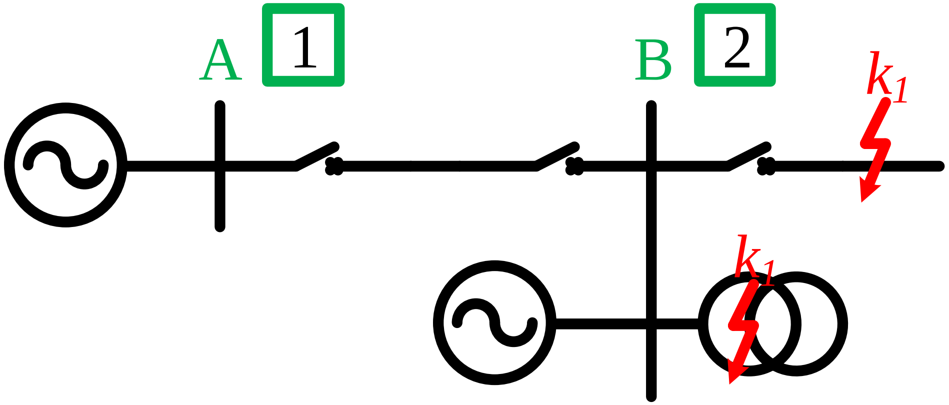
$$K_b = \frac{\dot{I}_2}{\dot{I}_1}$$

(a): $K_b > 1$: measured impedance is increased.

(b): $K_b < 1$: measured impedance is reduced.

$$Z_{set.1}^{II} = K_{rel}^{II}(Z_{AB} + K_{b.\min} Z_{set.2}^{I})$$

Coordination with Neighboring Transformer



- When a transformer is connected at the end of the protected line, Zone II should not exceed the protected zone of transformer protection.

$$Z_{set.1}^{II} = K_{rel}^{II}(Z_{AB} + K_{b.\min} Z_t)$$

$$K_{rel}^{II} = 0.7 - 0.75$$

Set by the minimum value

$$Z_{set.1}^{II} = K_{rel}^{II}(Z_{AB} + K_{b.\min} Z_{set.2}^{\mathrm{I}})$$

Sensitivity Checking

- Zone II should be able to protect the whole line, so the sensitivity should be enough for faults at the end of this line:

$$K_{sen} = \frac{Z_{set.1}^{II}}{Z_{AB}} \geq 1.25$$

- If the sensitivity is not enough, then Zone II should coordinate with Zone II of next line, but not Zone I of that.

$$t_1^{II} = t_2^{(x)} + \Delta t$$

- Time delay of Zone II should be longer than the coordinated protection ($t_2^{(x)}$ may be zone I or II) of neighboring line for Δt.

Zone III of Distance Protection

- Coordination with Zone II or III of next line:

$$Z_{set.1}^{III} = K_{rel}^{III}(Z_{AB} + K_{b.\min} Z_{set.2}^{II})$$

- Coordination neighboring transformer:

$$Z_{set.1}^{III} = K_{rel}^{III}(Z_{AB} + K_{b.\min} Z_{\min})$$

- To avoid the minimum load impedance at normal states:

$$Z_{set.1}^{III} = \frac{K_{rel}}{K_{SS} K_{re}} Z_{L.\min}$$

Sensitivity Checking

- As local backup, checked by faults at the end of this line:

$$K_{sen(1)} = \frac{Z_{set}^{III}}{Z_{AB}} \geq 1.5$$

- As remote backup, checked by faults at the end of next component:

$$K_{sen(2)} = \frac{Z_{set}^{III}}{Z_{AB} + K_{b.\max} Z_{next}} \geq 1.2$$

- Time delay of Zone III should be longer than the coordinated protection for Δt.

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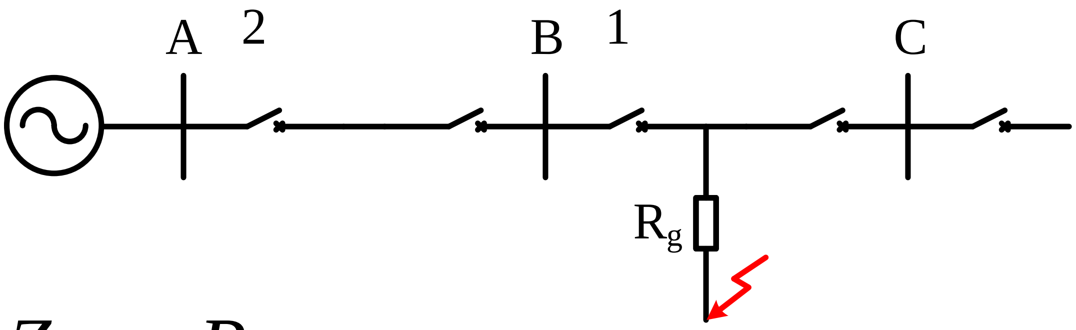
Transition Resistance

- Resistance of arc, resistance of any medial material, contact resistance between line and ground, grounded resistance of tower.

- For phase faults, resistance of arc is nonlinear, small at beginning and increases gradually.

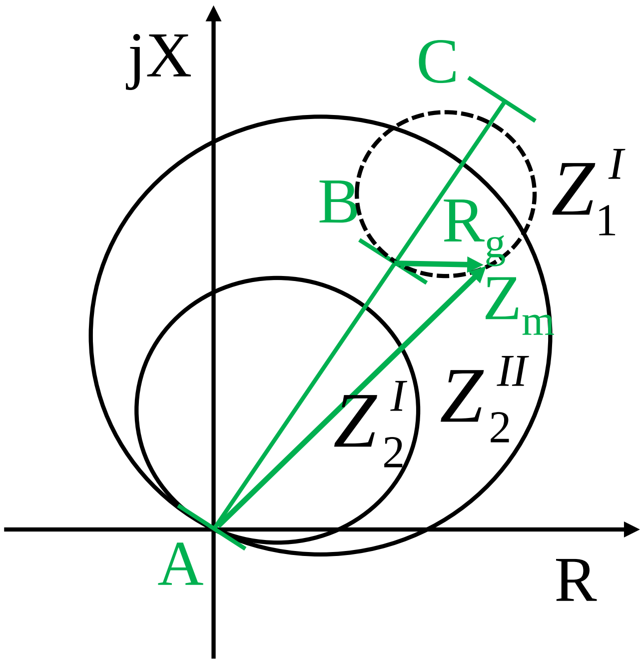
- In case of short circuit through tower, the grounded resistance of tower is the main transition resistance.
- If the short circuit is through trees, the transition resistance would be even higher.

Transition Resistance in Single Source Network



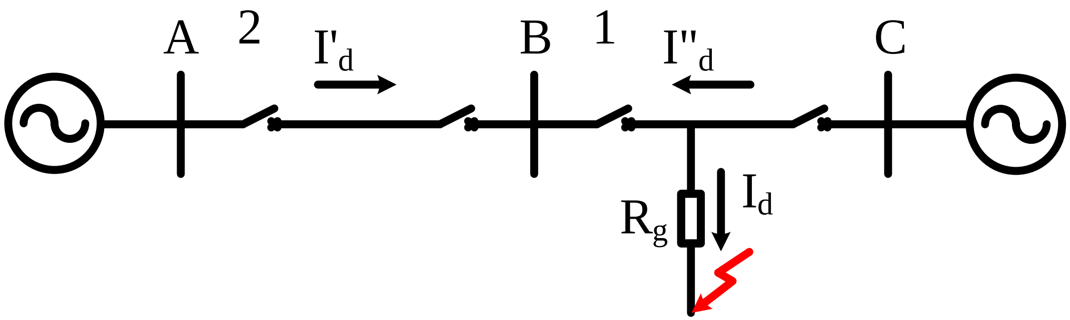
$$Z_{m1} = R_g$$

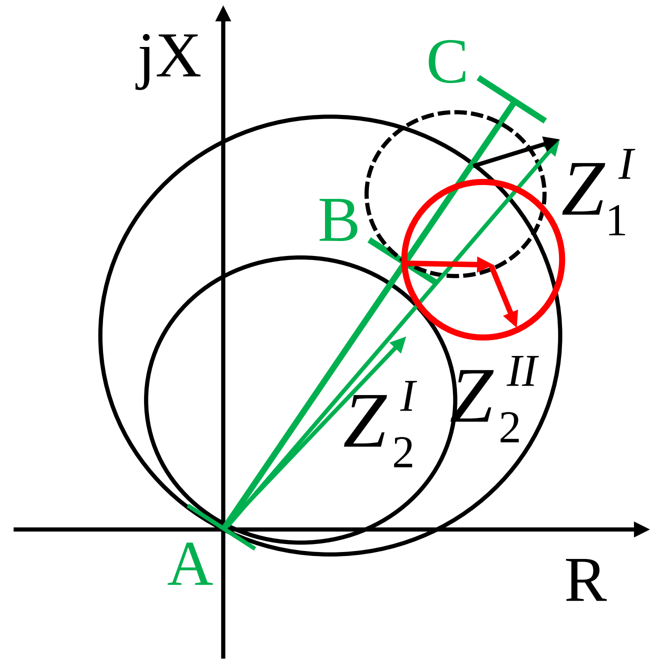
$$Z_{m2} = Z_{AB} + R_g$$



- The measured impedance may be increased and the protected zone may be reduced.
- Closer protection may be influenced much more (2 may trip, 1 may not trip).
- Smaller setting impedance may be influenced more.

Transition Resistance in Double Source Network





$$Z_{m1} = \frac{\dot{U}_B}{\dot{I}_d^{'}} = \frac{\dot{I}_d R_g}{\dot{I}_d^{'}} = \frac{\dot{I}_d^{'} + \dot{I}_d^{''}}{\dot{I}_d^{'}} R_g = R_g + R_g e^{j\alpha}$$

$$(\alpha = \arg \frac{\dot{I}_d^{''}}{\dot{I}_d^{'}})$$

$$Z_{m2} = \frac{\dot{U}_A}{\dot{I}_d^{'}} = Z_{AB} + R_g + R_g e^{j\alpha}$$

- α>0, reactance is increased, Zone II of P2 may not trip.
- α<0, reactance is reduced, false trip may be possible for Zone I of P2.

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Impact of series compensation

- Series capacitor can be used to reduce the impedance of transmission line, but the measured impedance will not be proportional to fault distance any more.

$$K_{com} = \frac{X_C}{X_L}$$

- Distance protection may not operate correctly due to the compensation

- Different methods may be applied to reduce the impacts of series compensation on distance protection.

Next Lecture

Distance Protection 4

Thanks for your attendance