# EEE340 Protective Relaying

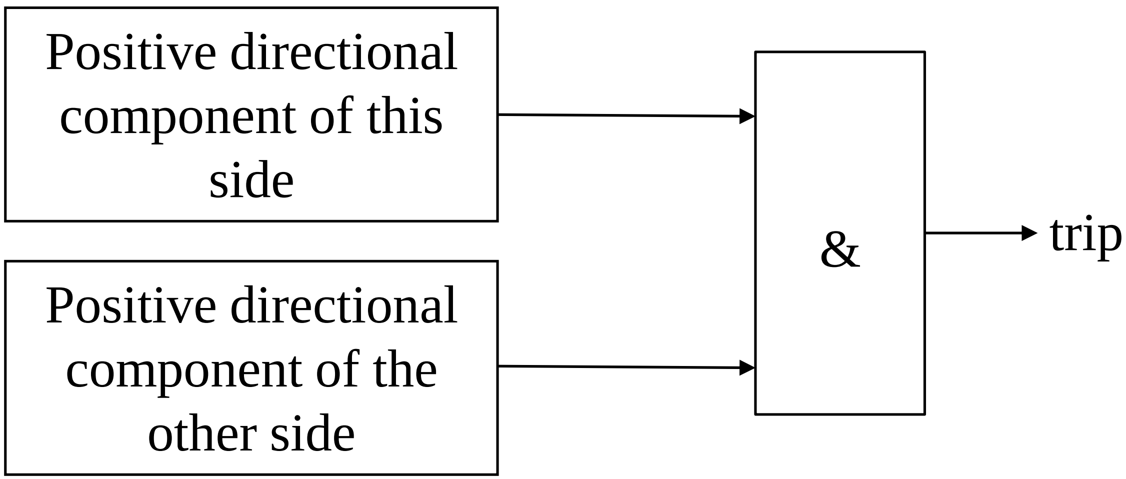
## Lecture 13 – Pilot Protection 2

# Today

- Pilot Protection 2
    - Directional Blocking Pilot Protection
    - Impedance Blocking Pilot Protection
    - Current Comparison Pilot Protection
    - Differential Relay with Restraining

# Directional Protection and Directional Component

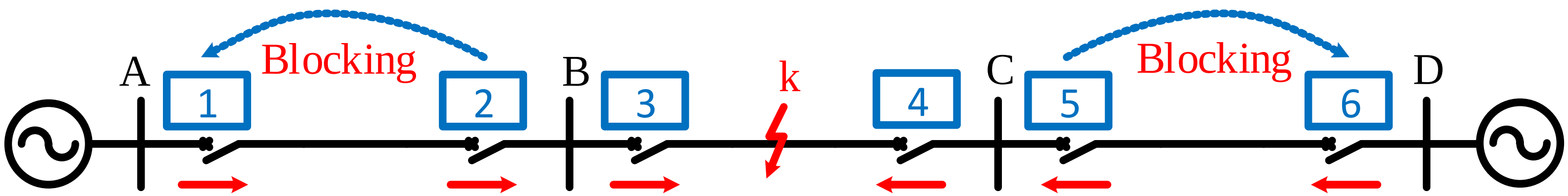
Internal faults: both sides judge as positive direction;
External faults: at least one side judges as negative direction.




Only the results of positive or negative directions will be communicated, simple and less signals.
Different directional components may utilize different electrical quantities to judge direction.

# Directional Blocking Pilot Protection

No high frequency current at normal states;
In case of faults, the side with negative power direction will send out blocking signal to block both sides; no blocking signal from the side with positive power direction.




Faulted line: both sides have positive power direction, no blocking signal is received, so breakers on both sides will trip;
Non-faulted line: one side with negative power direction send out blocking signal to block both sides.

# Directional Blocking Pilot Protection

Blocking signal is required to block the protection of non-faulted lines.

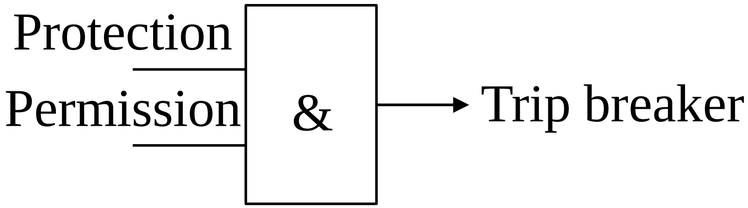
No signal is required for faulted line with internal faults, the protection can directly trip the breakers.

In case of internal faults and the communication channel is destroyed, the protections of faulted lines can still trip as expected.

# Directional Blocking Pilot Protection

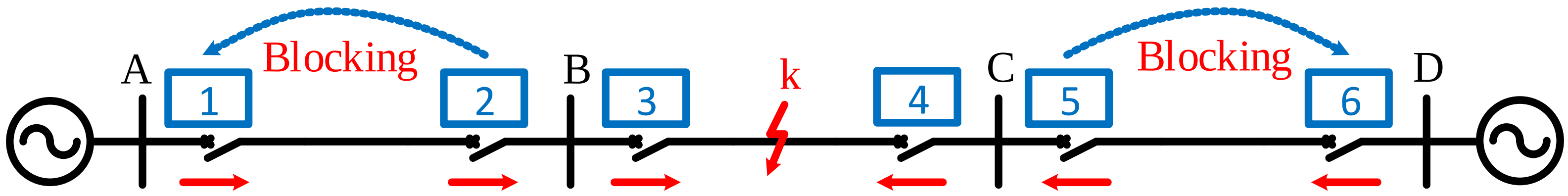
In case of external faults and the communication channel is destroyed, blocking signal cannot be transmitted, so false tripping is possible.

If the working mode is permission signal?




No false tripping for external faults;
Failure to trip for internal faults is possible.

# Directional Blocking Pilot Protection

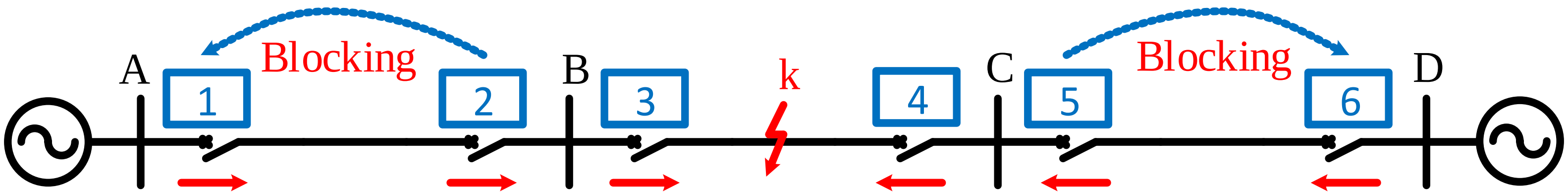



The activating component should be sensitive enough;

In case of external faults, protection should be blocked reliably.

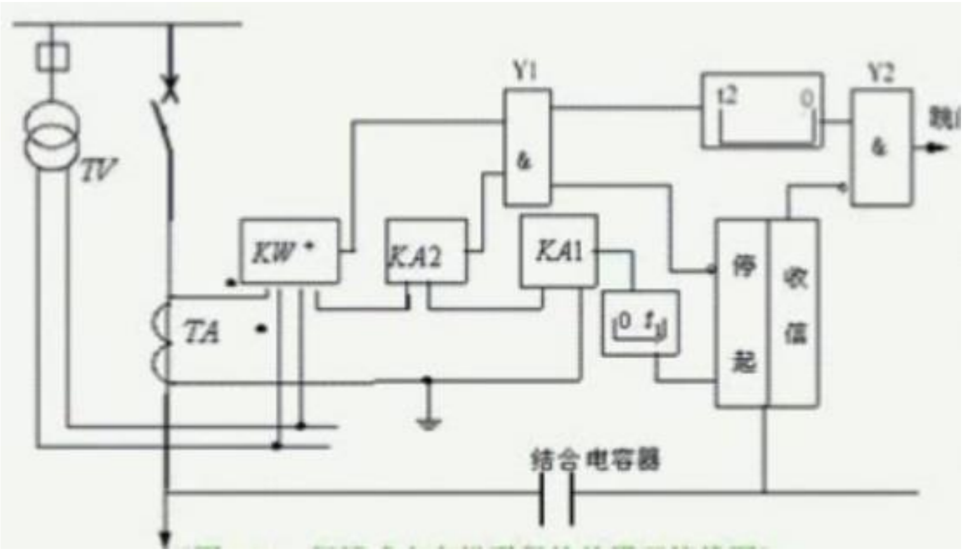
Blocking signal needs some time to be transmitted to the other side; when one side judges positive power direction, then 1). The other side is also positive and no blocking signal; 2). The other side is negative but the blocking signal has not arrived.
So time delay is needed to confirm blocking signal.

# Directional Blocking Pilot Protection

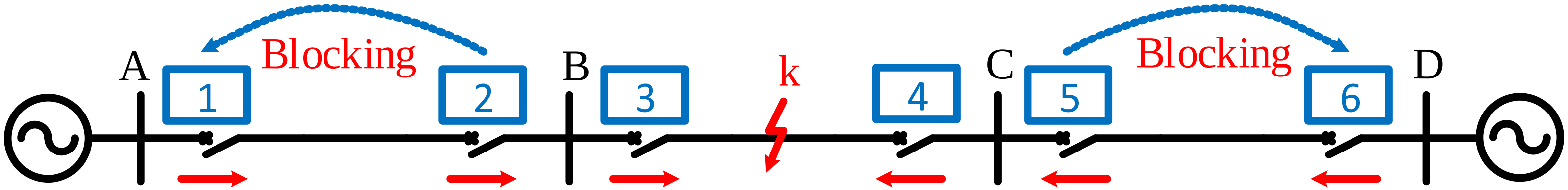



For external faults: for 2 at B, KA1 is activated to send out blocking signal, KW+ will not act because of negative power direction. Y1 and Y2 will not act.

For 1 at A, KA1 may be activated to send out blocking signal; but KA2 and KW+ will also be activated, then Y1 has output to stop blocking signal. After t2, one input condition for Y2 is met. Y2 will trip or not depends on if blocking signal from the other side is received.

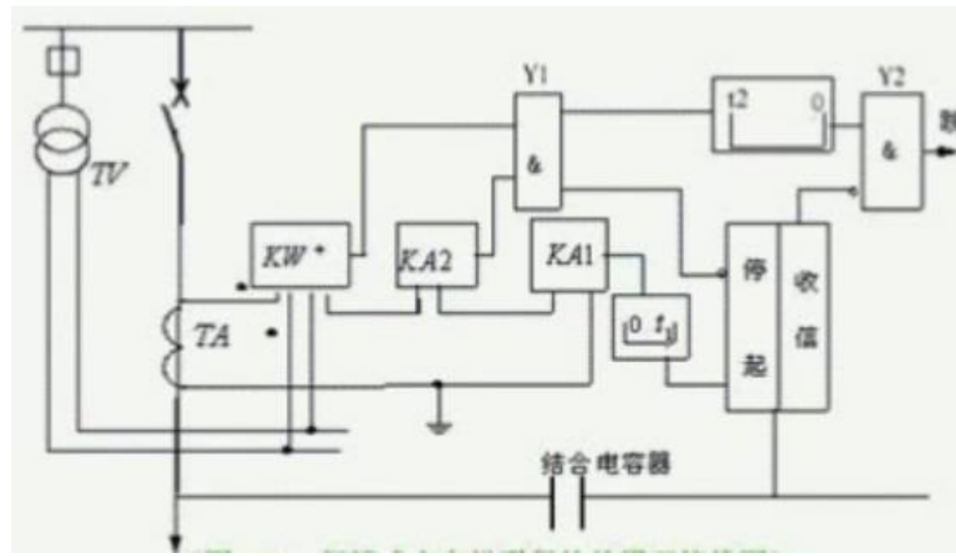


# Directional Blocking Pilot Protection

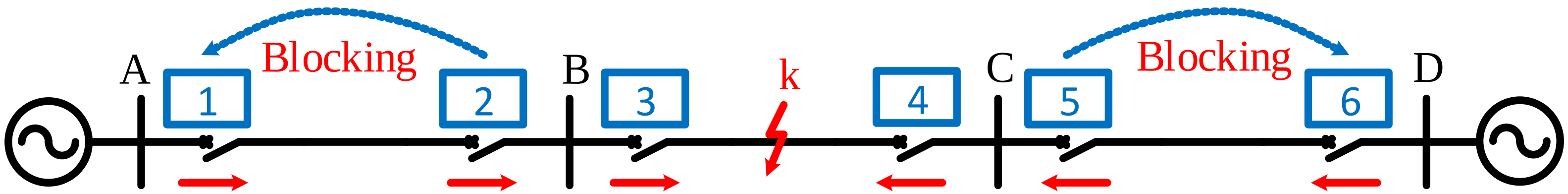



Before the external fault is cleared, 2 at B keep sending out blocking signal, Y2 at A will not trip. After the external fault is cleared, KA2 and KW+ will return instantaneously, KA1 of A and B will return instantaneously, after t1 B will stop sending blocking signal. Even KW+ of A returns slowly, it can also be blocked.

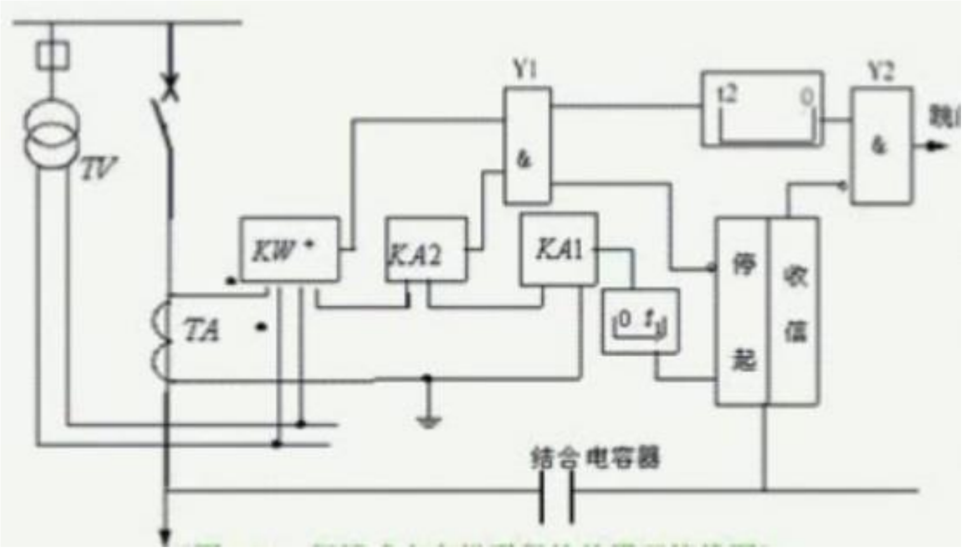
A has to wait for t2 to confirm if there is no blocking signal from the other side (B), or it may falsely trip.



# Directional Blocking Pilot Protection




For internal faults, KA1 at 3 and 4 will all be activated to send out blocking signal. But the power direction are both positive, so both KW+ are activated to stop sending blocking signal, then both will trip after t2.
If the power source on D is stopped, protection 4 at C will not act and will not send out blocking signal, so protection 3 can still trip as expected.



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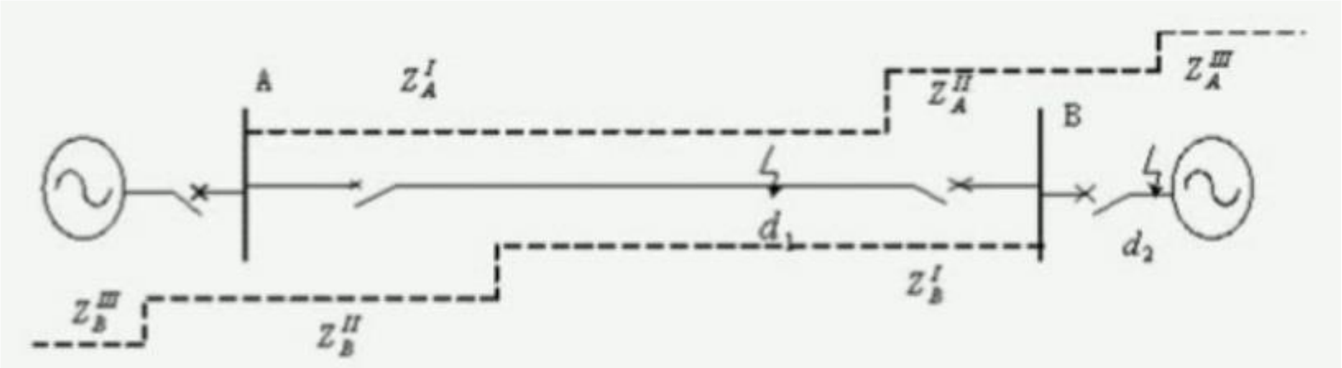
# Impedance Blocking Pilot Protection



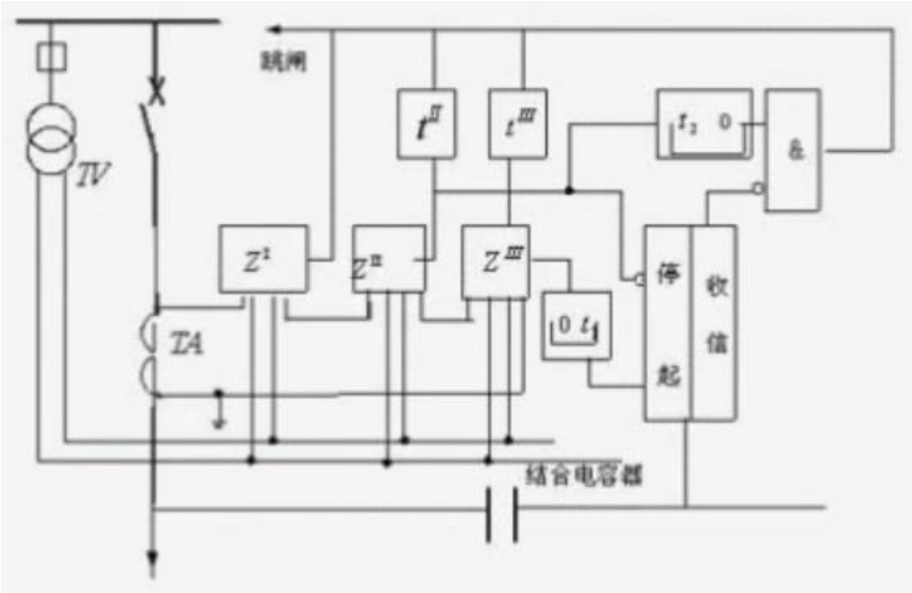

To use the directional impedance component as directional component, the directional comparison pilot protection can be integrated with the distance protection.

It can clear internal faults instantaneously, but also act as backup protection for external faults.

It consist of three zones of distance protection at two sides plus communication channel.

# Impedance Blocking Pilot Protection

Relay of Zone III is utilized to activate sending blocking signal (similar to KA1 in the former case).
Relay of Zone II is utilized to judge direction and stop sending blocking signal (similar to Y1 in the former case).
Zone I on both sides can trip independently.



For internal faults, Zone III will act to send out blocking signal on both sides. Then Zone II of both sides judge the fault is on positive direction, then stop sending out blocking signal of both sides, trip the breaker instantaneously.

For external faults, Zone III will act to send out blocking signal on both sides. Zone II of one side will judge the fault is on negative direction and keep sending blocking signal.

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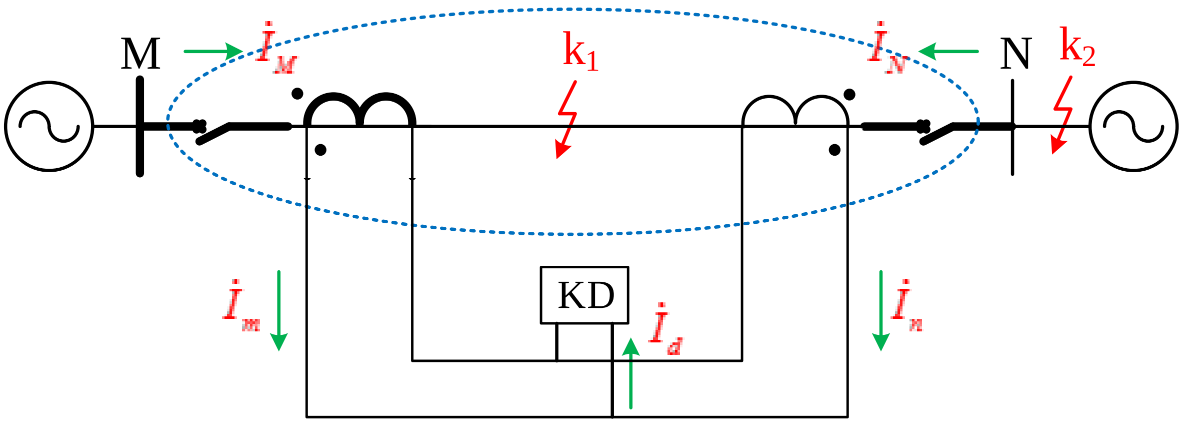
# Principles of Current Comparison Pilot Protection

## Kirchhoff's law



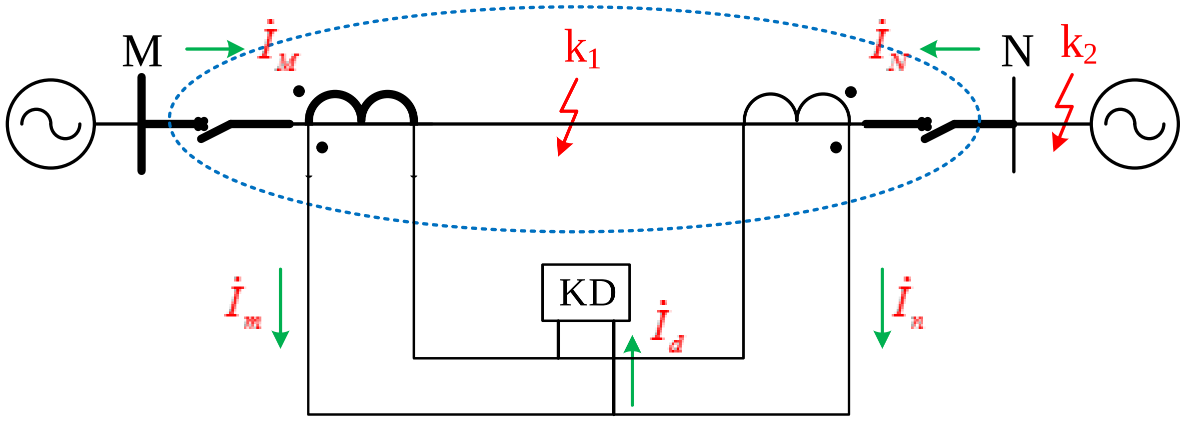

Normal States or External Faults: $\dot{I}_M + \dot{I}_N = 0$

Internal Faults: $\dot{I}_M + \dot{I}_N = \dot{I}_K$

You can compare the sum of currents, as one may be almost zero and one is as big as short-circuit current. (Current comparison)

You can compare phase angles of currents, as they are almost same for one case, and almost opposite for the other case. (Current phase comparison)

# Unbalance Current




Sum of currents from secondary side of TA will flow through the deferential relay KD;

TAs on both sides may not have the same characteristics of magnetization and always have excitation currents;

The current through KD in case of external faults or normal states may not be equal to zero, this current is called as unbalance current.

# Unbalance Current

Current of secondary side

$$\dot{I}_m = \frac{1}{n_{TA}}\left(\dot{I}_M - \dot{I}_{\mu M}\right)$$

Excitation current

$$\dot{I}_n = \frac{1}{n_{TA}}\left(\dot{I}_N - \dot{I}_{\mu N}\right)$$

Excitation current

Turns ratio

In case of external faults or normal states, $I_M = -I_N$, so the unbalance current can be calculated as:

$$\dot{I}_{unb} = \dot{I}_m + \dot{I}_n = -\frac{1}{n_{TA}}\left(\dot{I}_{\mu M} + \dot{I}_{\mu N}\right)$$

To operate correctly, the protection should avoid possible unbalance current for external faults and normal states:

$$\dot{I}_d = \left|\dot{I}_m + \dot{I}_n\right| \geq I_{set}$$

# Differential Relay without Restraining

$$\dot{I}_d = \left| \dot{I}_m + \dot{I}_n \right| \geq I_{set}$$

(1). To avoid the maximum possible unbalance current of external faults:

$$I_{set} = K_{rel} K_{np} K_{er} K_{st} I_{k.\max}$$

$K_{rel}$ : Reliability factor, 1.2~1.3;

$K_{np}$ : Aperiodic component factor;

$K_{er}$ : 10% error factor of TA;

$K_{st}$ : Factor for same TA type, 0.5 for same type, 1 for different type;

$I_{k.max}$ : Maximum current through TA for external faults (secondary side);

# Differential Relay without Restraining

$$\dot{I}_d = \left|\dot{I}_m + \dot{I}_n\right| \geq I_{set}$$

(2). To avoid the maximum load current:

$$I_{set} = K_{rel} I_{L.\max}$$

$K_{rel}$ : Reliability factor, 1.2~1.3;

$I_{L.max}$ : Maximum load current during normal operation (secondary side);

The larger value between (1) and (2) is selected as setting value for the differential relay. But the sensitivity is difficult to guarantee:

$$K_{sen} = \frac{I_{k.\min}}{I_{set}} \geq 2$$

$I_{k.min}$ : Minimum possible fault current through protection (fault at the end of the protected line with only one minimum power source);

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# Differential Relay with Restraining

In fact, unbalance current is not a fixed value, but related to the fault current in case of external faults:

$$I_{unb} = 0.1 K_{st} K_{np} I_k$$

No matter how the real unbalance current is, to set the setting value according to the maximum value is not efficient and negative for sensitivity.

Why not make the setting value variable according to the real currents through TA?

# Differential Relay with Restraining

The actual fault current through TA of both sides for external fault can be estimated as:

$$I_{res} = 0.5\left|\dot{I}_m - \dot{I}_n\right|$$

$$I_{res} = 0.5\left(\left|\dot{I}_m\right| + \left|\dot{I}_n\right|\right)$$

$$I_{res} = \begin{cases} \sqrt{\left|\dot{I}_m\right|\left|\dot{I}_n\right|\cos\left(180^\circ - \theta_{mn}\right)} & \cos\left(180^\circ - \theta_{mn}\right) > 0 \\ 0 & \cos\left(180^\circ - \theta_{mn}\right) \le 0 \end{cases}$$

$I_{res}$ can be used as a threshold for differential relay, so will work as restraining current, the differential current through differential relay will work as operating current, the operating equation is:

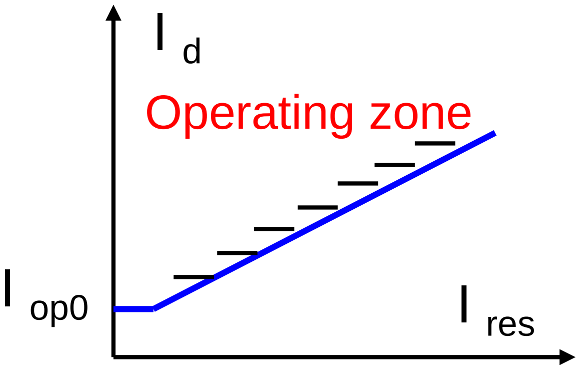
$$I_r \ge K_{res} I_{res}$$

$K_{res}$ : Restraining factor;

# Differential Relay with Restraining

The differential relay has two sets of coils, circulation current $\left|\dot{I}_m - \dot{I}_n\right|$ will flow through the restraining current; the sum current $\left|\dot{I}_m + \dot{I}_n\right|$ will flow through the operating current:

$$\left|\dot{I}_m + \dot{I}_n\right| - K\left|\dot{I}_m - \dot{I}_n\right| \geq I_{op0}$$




$I_{op0}$ is a very small threshold value.

Both reliability for external faults and sensitivity of internal faults can be guaranteed.

# Next Lecture

Pilot Protection 3
Autoreclosure 1

Thanks for your attendance