EEE340 Protective Relaying

Lecture 14 – Pilot Protection 3
Autoreclosure 1

Today

- Pilot Protection 3
  - Current Comparison Pilot Protection
  - Current Phase Comparison Protection
  - Factors Affecting Current Comparison Protection

- Autoreclosure 1
  - Current Comparison Pilot Protection

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:

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

(2). To avoid the maximum load current:

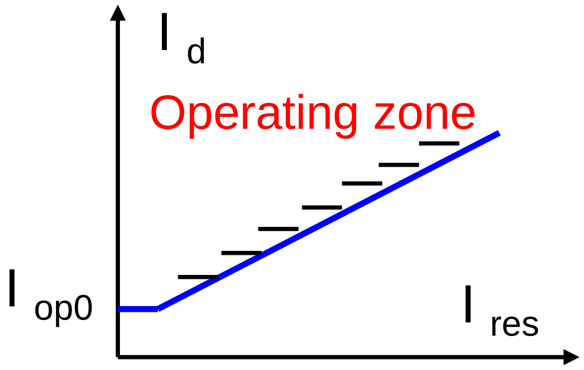
$$I_{set} = K_{rel} I_{L.\max}$$

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

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.

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Current Phase Comparison Protection

Problems for current comparison protection:

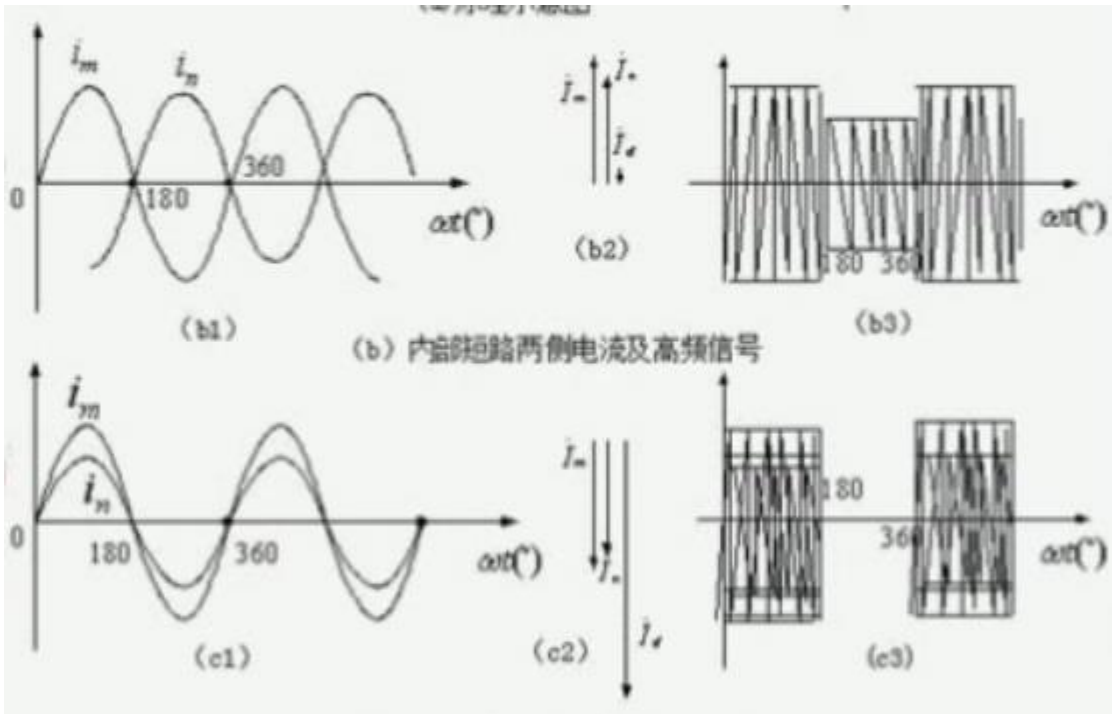
•Synchronization measurement: currents measured **at the same time** of both sides should be compared.
•Magnitude and phase angles are all needed for transmission and comparison, high requirement for communication channel.
•Impacts from saturation of TAs.

Advantages of Current Phase Comparison Protection:

•Low requirement for synchronization, only the time for zero current of both sides need to be communicated.
•Low communication load, no high requirement for communication channel.
•Easy for implementation by Power Line Carrier.

Principles

Ideally, the phase angle difference for currents of both sides is 180 degree for external faults or normal operation, 0 degree for internal degree.



Both sides will send out high frequency current during positive (or negative) half-wave:
High frequency current should be continuous for external faults;
High frequency current should be discontinuous for internal faults.

Setting of Blocking Angle

In practice, the high frequency current may not be continuous, errors need to be estimated:

- Errors of TAs on both sides, no larger than 7 degree;
- Errors of signal operation, no larger than 15 degree;
- Time delay of signal transmission, (L/100)*6^o.

Protection should not operate for phase angle difference:

$$180^o \pm \left(7^o + 15^o + \frac{L}{100} \times 6^o\right)$$

Blocking angle

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Unbalance Current

• In theory, the sum of primary currents on both sides of the protected line in case of external faults should be zero;

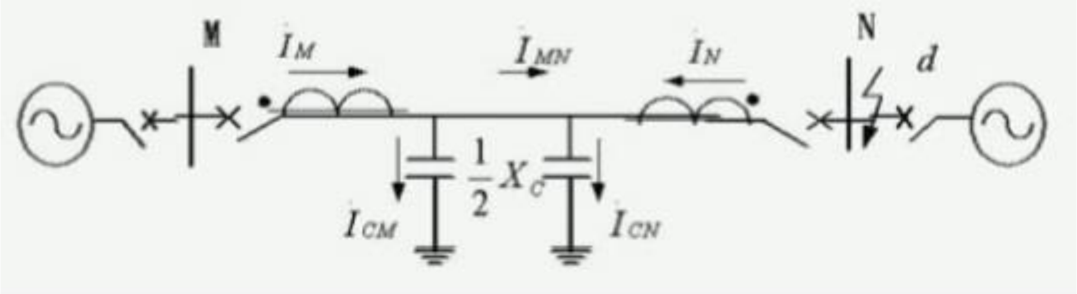
• Because of the errors from TA transmission and excitation current, the sum of secondary currents is not zero (unbalance current), which may cause false trip;

•To ensure selectivity, the setting value for differential relay must avoid the maximum unbalance current. To reduce the maximum unbalance current, that is a central problem for any differential protection;

•Features of TAs on both sides should be as similar as possible (same type, magnetization characteristics, iron core…)

Distributed Capacitance

- Because of distributed capacitance of lines, the sum of currents on both sides in case of external faults is not zero;
- For short transmission lines, this sum of currents may not be very large;
- For high voltage and long transmission lines, to avoid this current by high setting value, the sensitivity will be greatly impacted;
- By using centralized parameters, the phase angle difference of currents I_M and I_N is not 180 degree any more; but the phase angle difference between I_{MN} and I_{NM} is still 180 degree. So I_{MN} and I_{NM} should be utilized for differential relay.



Distributed Capacitance

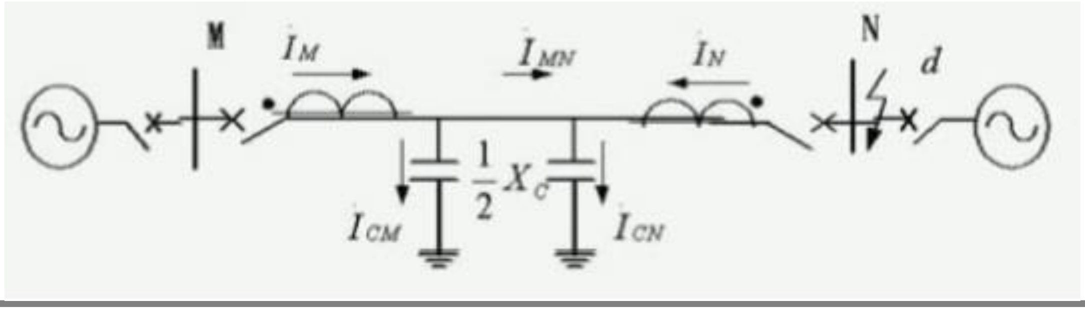
$$\dot{I}_C = 2\left(\frac{\dot{U}_1}{-jX_{C1}} + \frac{\dot{U}_2}{-jX_{C2}} + \frac{\dot{U}_0}{-jX_{C0}}\right)$$

- If $X_{C1}=X_{C2}$:

$$\dot{I}_C = 2\left(\frac{\dot{U}_\varphi - \dot{U}_0}{-jX_{C1}} + \frac{\dot{U}_0}{-jX_{C0}}\right)$$

$$\dot{I}_{MN} = \dot{I}_M - \dot{I}_{CM} = \dot{I}_M - 2\left(\frac{\dot{U}_{M\varphi} - \dot{U}_{M0}}{-jX_{C1}} + \frac{\dot{U}_{M0}}{-jX_{C0}}\right)$$

$$\dot{I}_{NM} = -\dot{I}_N - \dot{I}_{CN} = -\dot{I}_N - 2\left(\frac{\dot{U}_{N\varphi} - \dot{U}_{N0}}{-jX_{C1}} + \frac{\dot{U}_{N0}}{-jX_{C0}}\right)$$



Load Current

• The overall current is the sum of load current and fault component;

• When the fault is through a big resistor, the fault component is not so large compared with the load current;

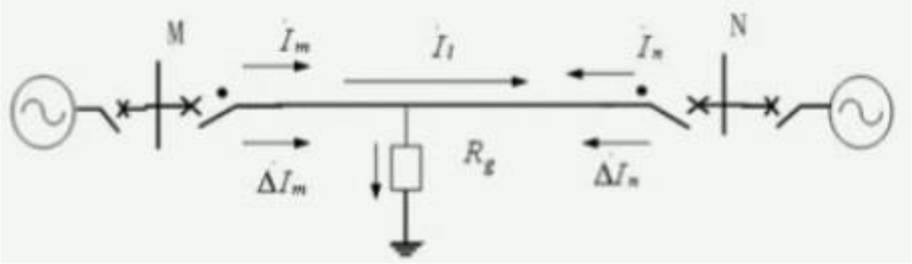
$$\dot{I}_m = \Delta\dot{I}_m + \dot{I}_L \qquad \dot{I}_n = \Delta\dot{I}_n - \dot{I}_L$$

$$\dot{I}_r = \left|\dot{I}_m + \dot{I}_n\right| = \left|\Delta\dot{I}_m + \Delta\dot{I}_n\right| \quad K\left|\dot{I}_m - \dot{I}_n\right| = K\left|\Delta\dot{I}_m - \Delta\dot{I}_n + 2\dot{I}_L\right|$$

Operating

Restraining

If I_r is small and I_L is very large, the operating force may be smaller than the restraining force, the protection may fail to trip.



Load Current

• To solve the problem, to use fault components to construct judging criterion:

$$\left|\Delta\dot{I}_m + \Delta\dot{I}_n\right| > \dot{I}_{set}$$

Assisted judging criterion

$$\left|\Delta\dot{I}_m + \Delta\dot{I}_n\right| > K\left|\Delta\dot{I}_m - \Delta\dot{I}_n\right|$$

Main judging criterion

• Good sensitivity because all judging criterions have nothing to do with load currents;

•During normal operation, all fault components are zero, no operation reliably;

• In case of external faults, ΔI_m and ΔI_n have the same amplitude and opposite phase angles, no operation reliably;

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- Autoreclosure 1
  - Function and Basic Requirements of Autoreclosure
  - Single Shot Three Pole Autoreclosure for Single Source System

Function of Autoreclosure

• More or less close to 80%, to as high as 90% of faults on most overhead lines are transient (temporary);

• These result primarily from flashover of the insulators by high transient voltages induced by lightning, by wind causing the conductors to move together to flashover, or from temporary tree contact, usually by wind;

•By de-energizing the line long enough for the fault source to pass and the fault arc to deionize, service can be restored more expeditiously by automatically reclosing the breaker;

•Reclosing can be one single attempt (one-shot) or several attempts at various time intervals (multiple-shot).

Function of Autoreclosure

Advantages:

• Better reliability for power supply, especially for single source system;

• False trips due to mechanical or human mistakes can be corrected;

• System stability can be improved.

Defects:

• In case of permanent faults, it may worsen the working conditions of breakers;

• In case of permanent faults, system may be impacted for twice in short time, which may harm system stability;

Basic Requirements of Autoreclosure

• No reclosing in case of manual or remote control to open breaker;

• In case of manually closing breakers, if a fault still exists, no reclosing is permitted;

• No reclosing if the breaker is abnormal (low gas or liquid pressure);

• Autoreclosure is needed for all other reasons of breaker tripping.

Basic Requirements of Autoreclosure

- Number of attempts should be consistent with presetting;

- After operation, reset is needed for next operation (automatic and manual);

- Time of reclosing can be set (adjusted), and protection can be accelerated before or after reclosing;

- For system with double sources, synchronization can be checked.

Classification of Autoreclosure

- Three pole autoreclosure: no matter what type of fault is, three phases are disconnected and then reclosed; if unsuccessful, three phases are disconnected again;

- Single pole autoreclosure: in case of single line-to-ground fault, single phase (faulted phase) is disconnected and then reclosed; if unsuccessful, three phases are disconnected again; no reclosing for phase-to-phase faults.

- Compromise Poles autoreclosure: in case of single line-to-ground fault, single phase (faulted phase) is disconnected and then reclosed; if unsuccessful, three phases are disconnected again; for phase-to-phase faults, three phases are disconnected and then reclosed; if unsuccessful, three phases are disconnected again.

Classification of Autoreclosure

- Line autoreclosure;
- Transformer autoreclosure;
- Bus autoreclosure;

- When breaker is open, but the control switch is closed, autoreclosure will be activated;
- In case of false trip when protection has no tripping command, that can be corrected.

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  - Single Shot Three Pole Autoreclosure for Single Source System

Single Shot Three Pole Autoreclosure for Single Source System

Working Mode:

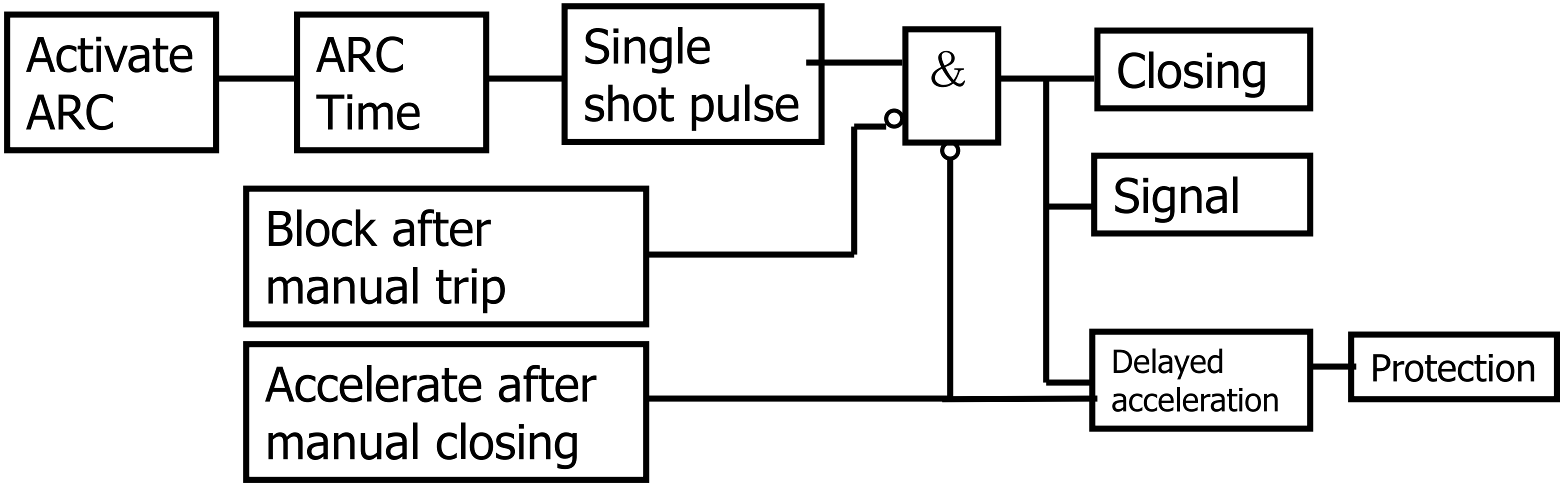
• Faults on line => three phases are disconnected by breaker => autoreclosure is activated => reclosing three phases:

1. Transient faults: successful;
2. Permanent faults: unsuccessful => disconnect three phases again => no more reclosing;

Characteristics:

• No consideration of synchronization because of single source;
• No consideration of type of faults;
• Easy for implementation.

Single Shot Three Pole Autoreclosure for Single Source System



Single Shot Three Pole Autoreclosure for Single Source System

- Activate Autoreclosure: When breaker is tripped by protection or other non-manual reasons, autoreclosure is activated;
- Autoreclosure time: After ARC is activated, timing is started; after preset time delay, send out a pulse for closing; this time can be set;
- Single shot pulse: After sending a closing pulse, timing for reset is started (about 15~25s); during this time, even more closing commands are sent, no closing pulse will be sent out to ensure single shot;
- Block after manual trip: to block autoreclosure after manual trip operation;
- Accelerate after closing: to accelerate second clearance of faults in case of reclosing to permanent faults.

Next Lecture

Autoreclosure 2

Thanks for your attendance