EEE340 Protective Relaying

Lecture 12 – Pilot Protection 1

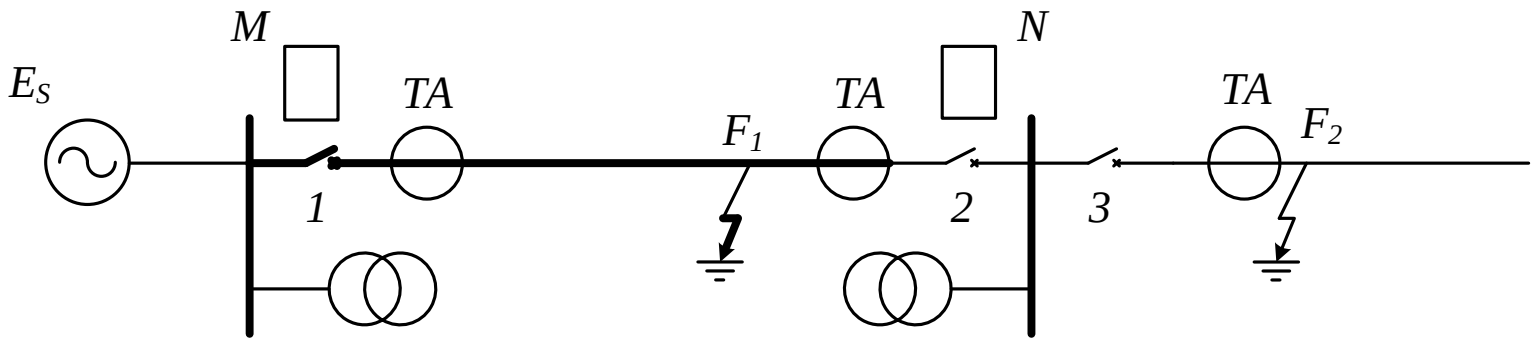
Today

- Pilot Protection 1
  - Principles of Pilot Protection
  - Typical Pilot Protection
  - Classification of Communication Channels

Defects of Overcurrent and Distance Protection

Overcurrent and distance protections make use of electrical quantities of only one terminal of the protected line;

They cannot distinguish the faults at the end of this line or at the beginning of the next line because of errors in transformers and protection devices;



Defects of Overcurrent and Distance Protection

Protected zones are used to make coordination (zone I II III)

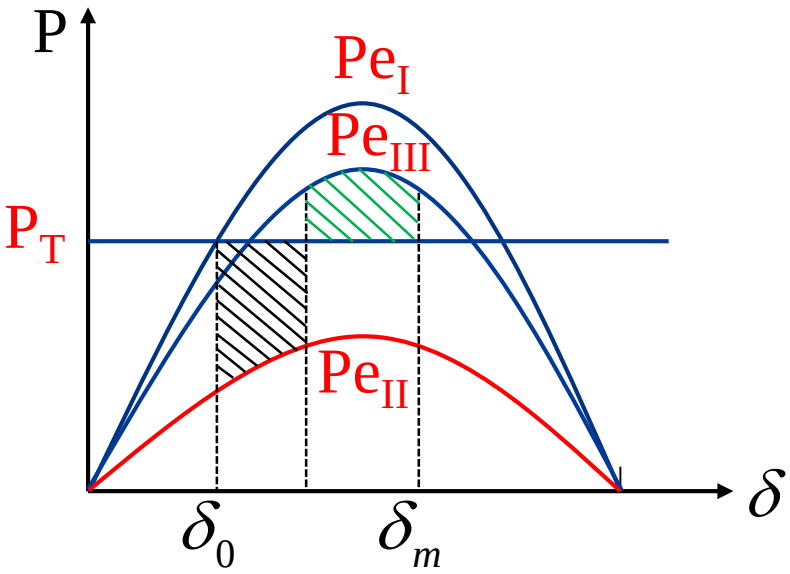
But the faults at the end of this line will be cleared with time delay;

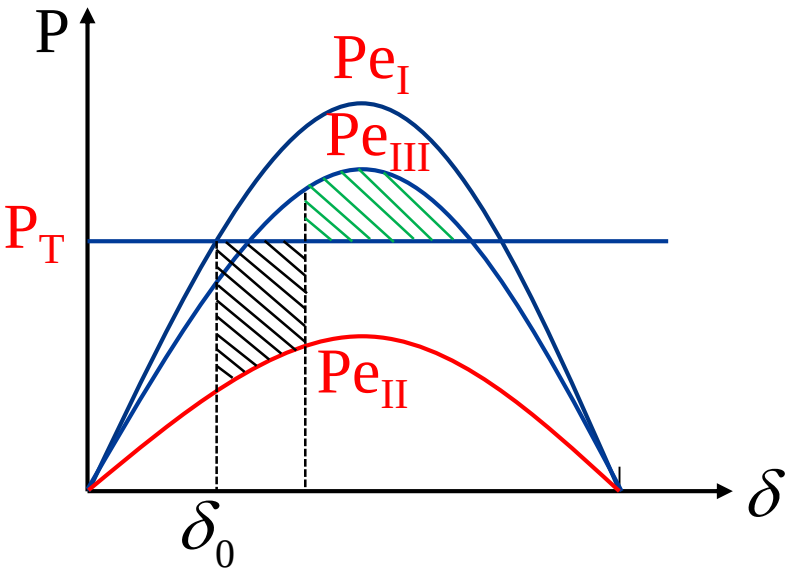
This time delay may be unacceptable for systems with voltage higher than 220kV because of stability.

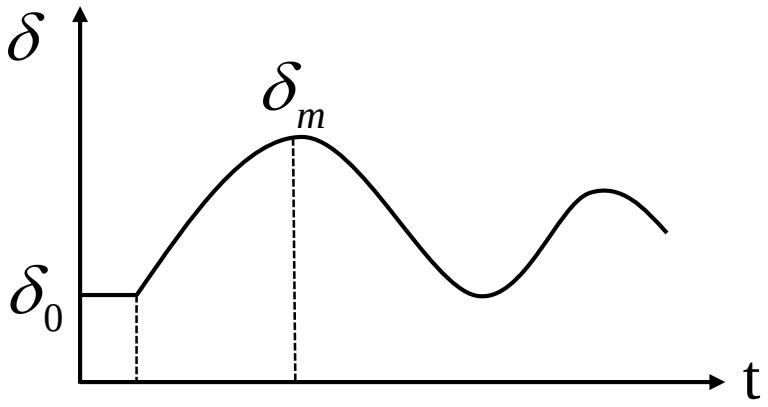
It is required to clear the faults at any location of the protected line instantaneously.

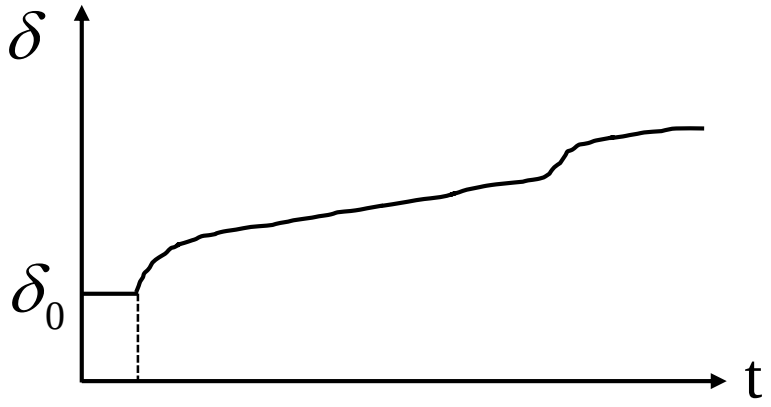
How to achieve it?

Clearing Time and System Stability









Principles of Pilot Protection

How to detect and clear all faults at any location of the protected line?

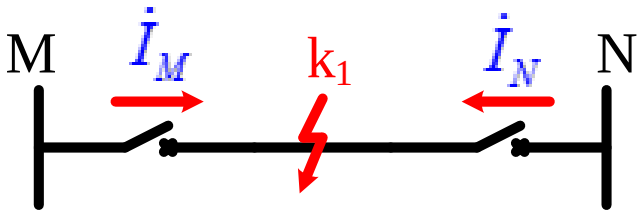
How about to make judgement by electrical quantities of both terminals?

To transmit the electrical quantities from one terminal to the other terminal for comparison and judgement.

The measured electrical quantities of one terminal need to be transmitted to the other side by communication channels.

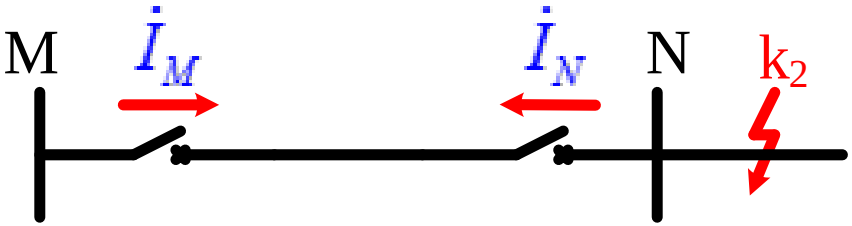
Characteristics of Faults in Pilot Protections

Sum of current phasors:



Inside

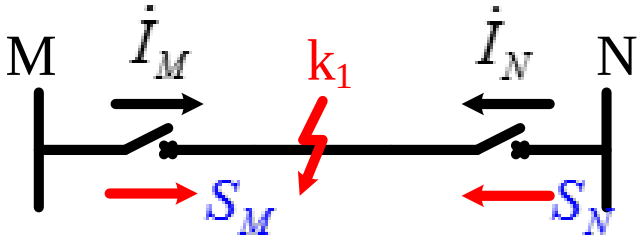
$$\Sigma\dot{I} = \dot{I}_M + \dot{I}_N = \dot{I}_{K1}$$



Outside

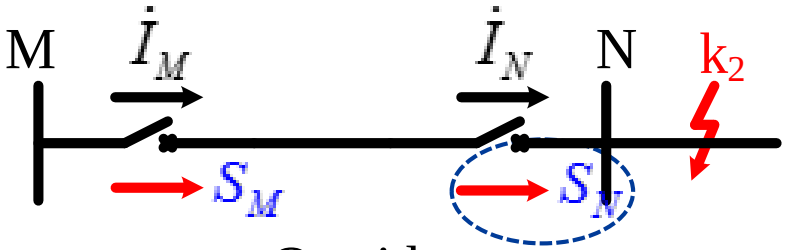
$$\Sigma\dot{I} = \dot{I}_M + \dot{I}_N \approx 0$$

Comparison of power directions:



Inside

Power directions of both sides are positive.



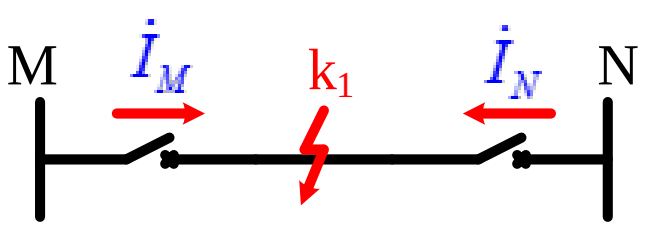
Outside

Power direction of one side is negative.

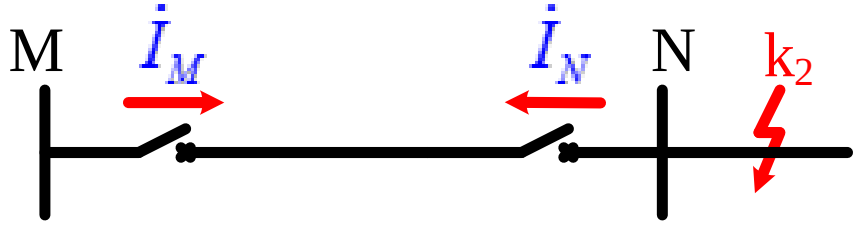
Characteristics of Faults in Pilot Protections

Phase angles of currents:

Suppose same phase angles for power sources and impedance;
Suppose no distributed capacitance and errors in measurements.



Inside
0°



Outside
180°

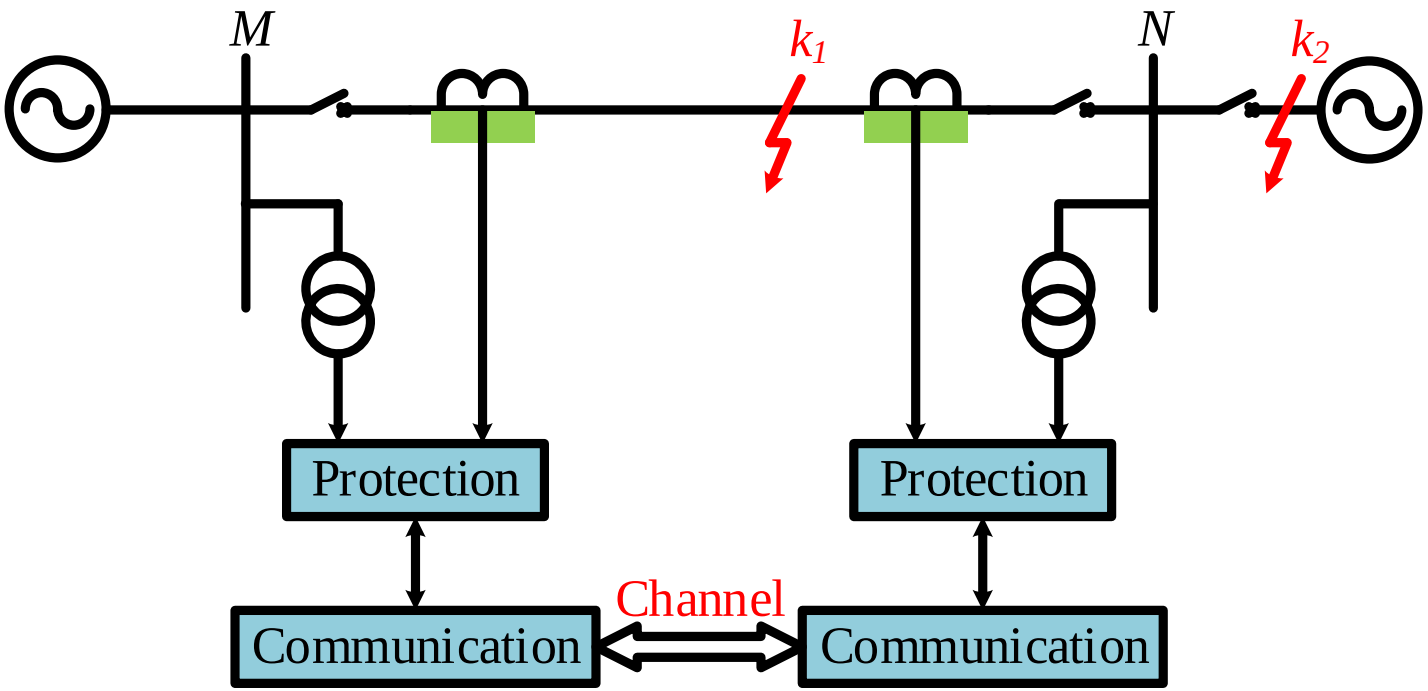
Impedance:

Faults inside: impedance of short-circuit for both sides, both sides trip;

Faults outside: impedance of short-circuit for both sides, but one side is negative and will not trip;

Normal state: load impedance of both sides, no protection will trip.

Principles of Pilot Protection



Today

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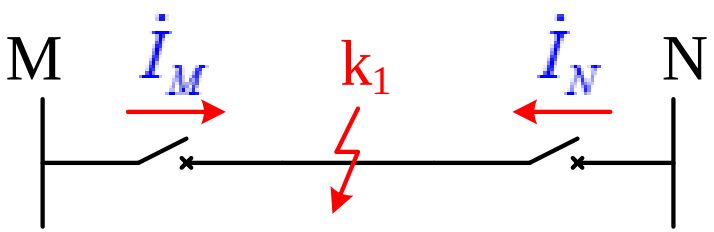
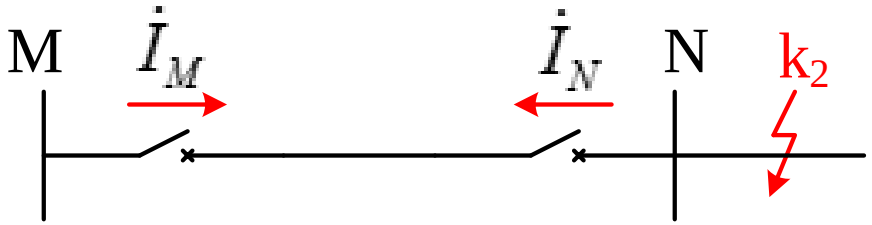
Current Comparison Pilot Protection





Internal fault

$$\Sigma\dot{I} = \dot{I}_M + \dot{I}_N = \dot{I}_{K1}$$

External fault or normal states

$$\Sigma\dot{I} = \dot{I}_M + \dot{I}_N \approx 0$$

$$\Sigma\dot{I} = \dot{I}_M + \dot{I}_N = \dot{I}_{K1}$$
$$\Sigma\dot{I} = \dot{I}_M + \dot{I}_N \approx 0$$

$$\Rightarrow \quad \dot{I}_M + \dot{I}_N \geq I_{set}$$

Because of errors of TA and distributed capacitance, the sum of current in case of external faults or normal states may not be equal to zero. Therefore, a threshold value I_{set} is needed.

Waveform of phase angles of currents need to be transmitted to the other side (not logical signal), communication load is heavy.

Directional Comparison Pilot Protection

Protection on each side makes judgement if the fault is inside the protected zone according to the measured impedance and power directions;

The judging results (**logical signal**) will be transmitted to the other side. Few signals for transmission, but high reliability required.

The protections on both sides will make decision according to the judging results of both sides.

Blocking Pilot System: For internal faults, the power (current) flows into the line at the terminals, so simultaneous high-speed tripping at the terminals is permitted. For external faults, the information that current flows out at one of the terminals is used to block tripping of all terminals.

Unblocking Pilot System: For internal faults, the relay-blocking signal is shifted to unblock, to permit the relays to trip instantaneously. Because a signal must be transmitted, the unblock signal can be used to augment tripping.

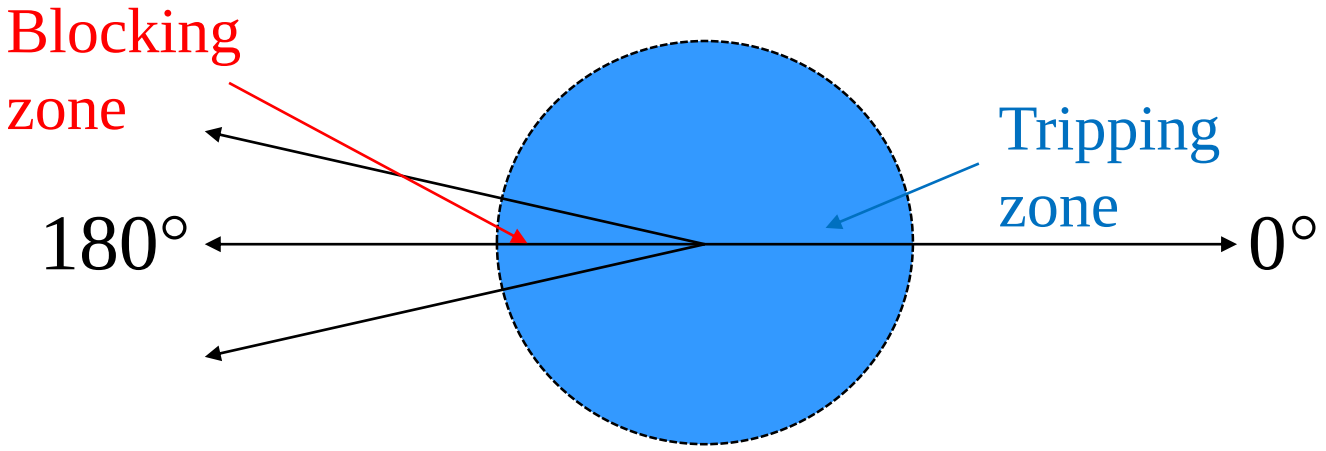
Current Phase Comparison Pilot Protection

To compare the phase angles of currents on both terminals;

Ideally, in case of internal faults, the difference of phase angles between two terminals is zero, so both protections will trip corresponding breakers;

In case of external faults and normal states, the difference of phase angles between two terminals is 180 degree, none of both protections will trip;

Because of errors in measurement and distributed capacitance, the phase angle difference for external faults or normal operation may not be 180 degree, but closed to it.



Distance Pilot Protection

The basic principles are similar to directional comparison pilot protection, but the power direction components are replaced by impedance components;

Normally, high voltage transmission line protection may use distance protection for backup protections, so the impedance relay for distance protection can be utilized as directional component for main protection (pilot protection);

Only when the fault is inside zone II of distance protection, the corresponding directional components will be activated; when the fault is outside zone II, the directional components will not be activated;

When the backup protection is under maintenance, the main protection has to be stopped.

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Classification of Communication Channels

- Pilot Wire Communication: A twisted wire pair for transmitting signal between terminals. Originally telephone pairs were used, privately owned dedicated pairs are preferred.

Investment will increase as the length increases;

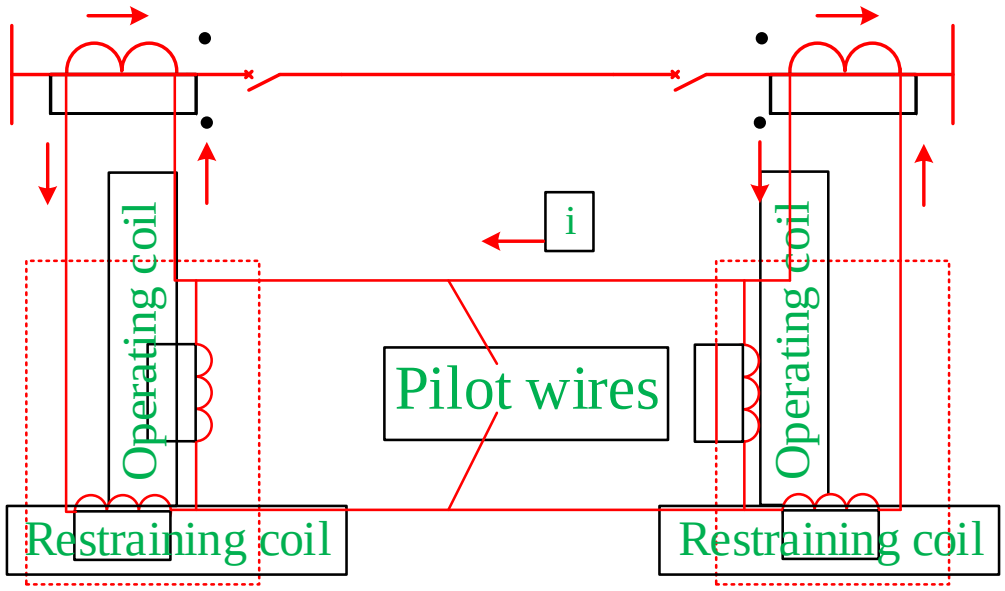
Longer length may reduce the security of operation;

Requirement for high level of insulation, which may increase the investment;

Parameters of wires (resistor and distributed capacitance) may affect the performance of protection;

So it is inappropriate for long transmission lines;

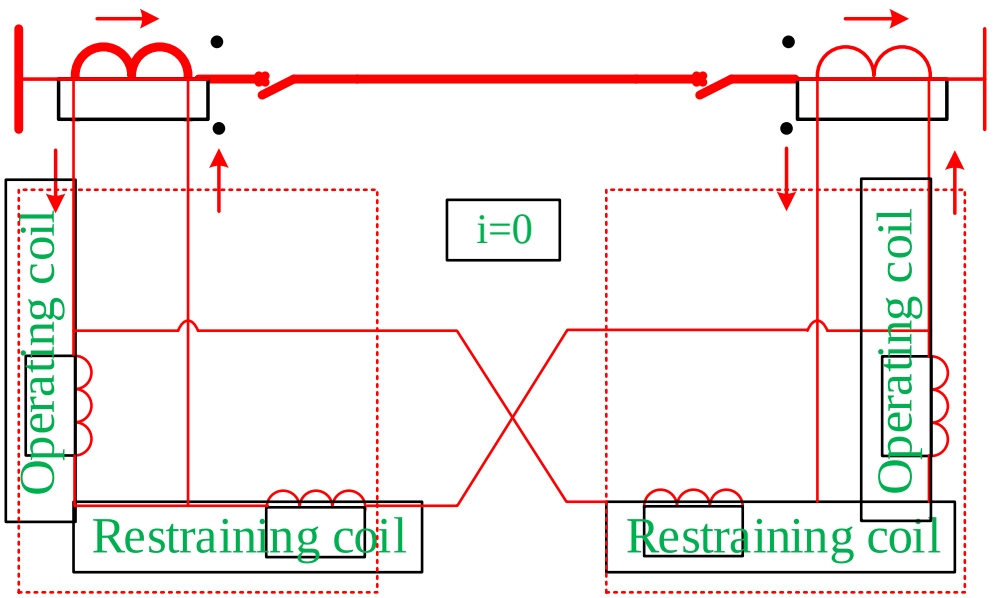
Wire Pilot



(a) Circulation

Terminals of the same polarity of CT are connected through pilot wires;
When the force of operating coil (sum of currents) is larger then the restraining coil (differential current), the protection will trip;
For external faults or normal states, there is no current flowing through the operating coil; circulating current will flow through the pilot wires;

Wire Pilot



（b）voltage-balancing

Terminals of the opposite polarity of CT are connected through pilot wires;

For external faults or normal states, there is no current flowing through the operating coil and pilot wires;

The voltages of two sides for pilot wires are equal with opposite directions for external faults or normal states.

Classification of Communication Channels

- Power Line Carrier Communication: Radio frequencies between 30 and 300 kHz, transmitted chiefly over high-voltage transmission lines.

Transmission line is the communication channel itself, no other dedicated channel needs to be constructed;

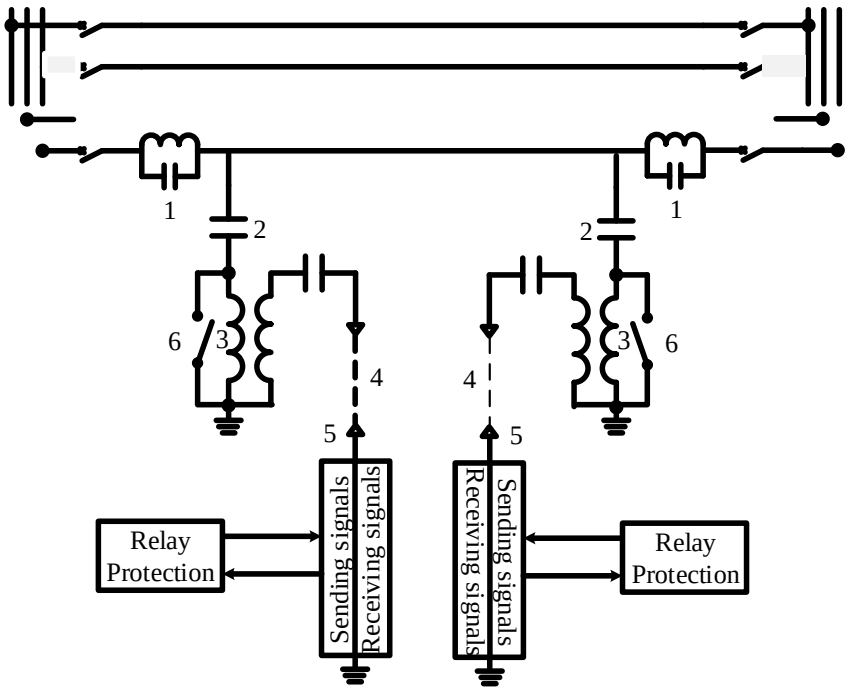
With good mechanical strength of transmission line, security and reliability of operation is good.

In case of fault at this line, the communication channel may be destroyed.

Protection must be able to act in case of fault at this line and interruption of signal.

Power Line Carrier Pilot

- Narrow bandwidth 50-400kHz.
- Convenient and economical
- Easy for implementation



Defects: as the communication channel is through the power transmission lines, any interference from power transmission lines may possibly impact on the communication channel.

Phase-to-phase circuit: small damping for signal transmission
Phase-to-ground circuit: more economical.

Working Mode for Power Line Carrier Pilot

No high frequency current at normal states: During normal operation of power system, no high frequency current is communicated; Only in case of faults, high frequency current will be activated and transmitted. Communication channel should be checked periodically.

High frequency current at normal states: During normal operation of power system, high frequency current is keeping communicated; high reliability but with interference problem.

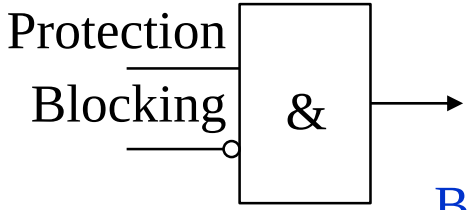
Frequency shift: During normal operation of power system, current of high frequency f_1 is communicated; in case of faults, current of high frequency f_2 is communicated. It has good reliability, but uses more bandwidth.

Types of Signal in Power Line Carrier Pilot

Blocking signal: to prevent the protection to trip the breaker; In case of external faults, one terminal will send blocking signal to block protection of both sides; in case of internal faults, no blocking signal is sent. (trip is permitted without blocking signal)
Permission signal: In case of internal faults, both sides will send permission signal to the other side; in case of external faults, one side will not send out permission signal, the other side cannot trip. (trip is forbidden without permission signal)
Tripping signal: the tripping signal from the other side can directly trip the breaker of this side; the protection of this side can trip the breaker without any signal from the other side; each side should be able to distinguish internal or external faults by itself.
High frequency current is not equivalent to concept of signal; no current can also represent a signal.

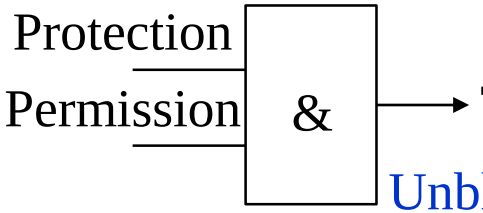
Types of Signal in Power Line Carrier Pilot

Blocking signal



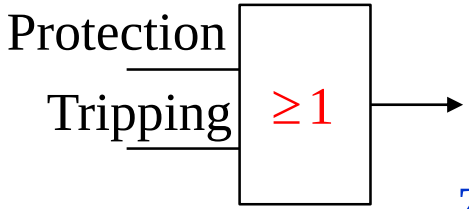
Blocking directional comparison system

Permission signal



Unblocking directional comparison system

Tripping signal



Zone I of two sides must be overlapped

Classification of Communication Channels

- Microwave Communication: Radio signal between 2 and 12 GHz, transmitted by line-of-sight between terminals. Multiple channels with protection by a subcarrier or audio tone.

With large bandwidth ;

With PCM, the quantity of signal transmission and anti-interference can be improved very much.

It is a good communication channel, but dedicated channel and devices for protection are not economical.

Classification of Communication Channels

- Fiber-Optic Communication: When owned by the utility, fiber-optic cables can be imbedded in the ground wire, wrapped around a power cable, or buried along the right-of-way. It may also be leased from an outside telecommunications company.

Similar advantages with microwave;

The fiber-optic channels are normally coordinated with the whole communication system of power system;

To convert electrical signals to optic signals for transmission, and then convert back to electrical signals for comparison.

Because of no interference for optic signals and similar economical features to wire pilot, it is widely applied for pilot protection with short distance.

Next Lecture

Pilot Protection 2

Thanks for your attendance