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Kansai Transmission and Distribution
Kansai Electric Power Group power with heart

Study Committee B5

Protection and Automation

10612_2022

Line protection relay with IP network

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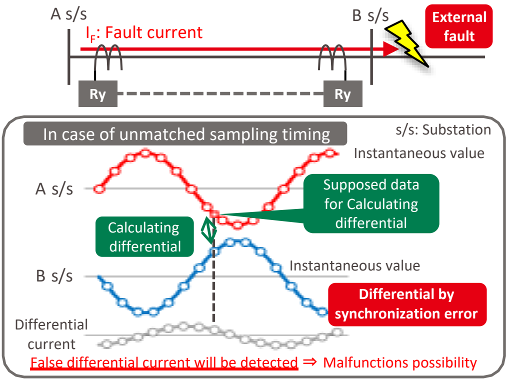
Motivation

- Line current differential relays are quite common in Japan for the reason below:
  - Short fault removal time
  - Better performance of fault line recognition in short distance power lines and power lines with multiple terminals.
- Conventional line current differential relays require private data transmission lines and specific devices such as Carrier Relay Multiplex equipment (CR-MUX) and Plesiochronous Digital Hierarchy equipment (PDHs) to realize high-precision relay operation.
- To decrease the cost of data transmission lines, we have considered to introduce IP network to the line current differential relays.

Difficulties to introduce IP network in conventional method

- Conventional line current differential relays operate differential current calculation by simply adding instantaneous value of current in each terminal with synchronised condition.
- Synchronise operation is made by the communication delay time (Td) from one terminal to other terminals.
- Upstream and downstream communication delay time (Td) in private data transmission lines are almost the same and constant.
- HOWEVER, the communication delay time in shared IP network should be more fluctuate.
  - Upstream path and downstream path may not be same.
  - QoS control can cause switching latency.
- Communication delay variation, called jitter, will increase sampling synchronisation error.

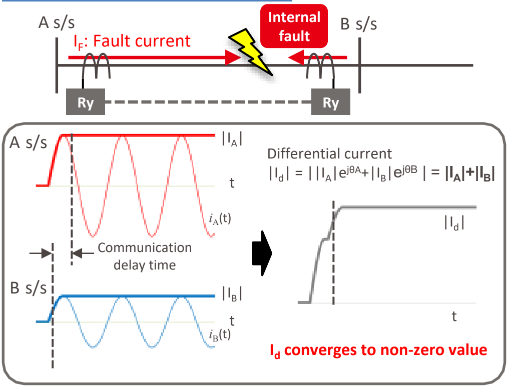


Proposed method: Phasor value based line current differential relay

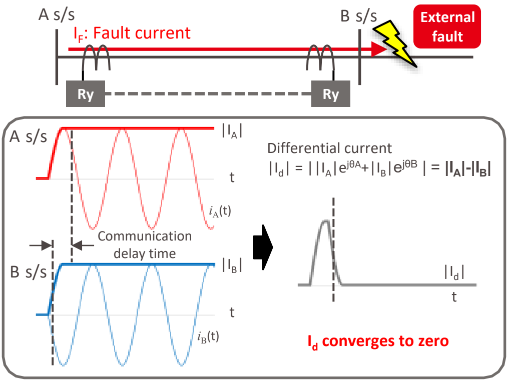
- New method to eliminate the need for overall synchronisation of sampling.
- Sampling synchronisation error and variation in communication delay will not need to be considered.

1. Calculate the effective value and phase (phasor value) of the current at local end.
2. Calculate the phase difference with respect to the reference voltage, which is different depending on its fault type, and unify the reference vector of current at each end to the reference voltage.
3. Simply sum up the phasor values obtained above, and differential current is obtained

Differential current when internal fault



Differential current when external fault



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Calculation method for ground faults

Zero-sequence voltage for a reference vector

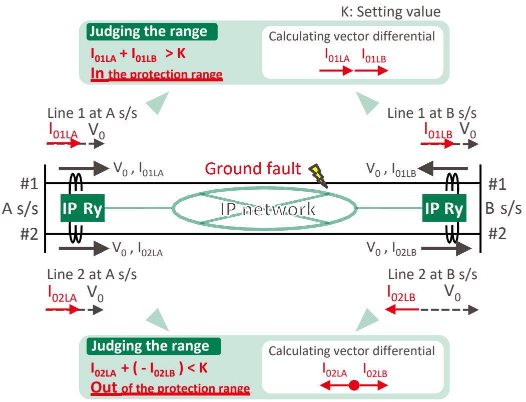
- Zero-sequence voltage is used as a reference vector.
- Zero-sequence voltage is obtained by calculation from three-phase instantaneous voltage.
- The magnitude of zero-sequence voltage is distinctive enough when a single-phase ground fault occurs.
- The phase of zero-sequence voltage is almost the same in each terminal when a single-phase ground fault occurs.

Fault range judgement

- Consider ratio characteristic and phase characteristic.
  - Ratio characteristic: Composed by the vector sum and the scalar sum of zero-sequence current.
  - Phase characteristic: Composed by zero-sequence differential current and zero-sequence voltage.
- In the case an **INTERNAL** ground fault occurs,
  - Both conditions above match,
  - The fault point is judged to be "In the protection range"
  - Circuit breakers surrounding the protection range trip off.
- In the case an **EXTERNAL** ground fault occurs,
  - One or more condition(s) above doesn‘t match,
  - The fault point is judged to be "Out the protection range"

NO sampling synchronisation is required in this method.

Ground differential protection



Calculation method for short circuit faults

Scalar differential instead of vector differential

- Phase reference voltage such as zero-sequence voltage cannot be obtained in case of short circuit fault.
- Each phase differential current cannot be calculated in the same way with the method for ground faults.
- THUS, scalar differential calculation is performed instead of vector differential current calculation.

Scalar differential current calculation

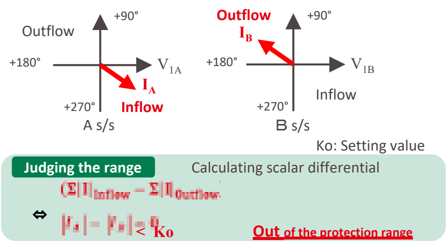
- The current direction of inflow and outflow at each terminal is distinguished by the phase difference between each phase current and positive phase voltage.
- The sum of inflow current and the sum of outflow current are simply calculated respectively.
- Scalar differential current is obviously expressed as the difference of inflow current and outflow current.

Fault range judgement

- In the case an **INTERNAL** short circuit fault occurs,
  - Inflow current is larger than outflow current
  - Scalar differential current is larger than the setting value K_0
  - The fault point is judged to be "In the protection range"
  - Circuit breakers surrounding the protection range trip off.
- In the case an **EXTERNAL** short circuit fault occurs,
  - Inflow current is almost equal to outflow current
  - Scalar differential current is almost zero, and is smaller than setting value K_0
  - The fault point is judged to be "Out of the protection range"

NO sampling synchronisation is required in this method.

Short circuit differential protection



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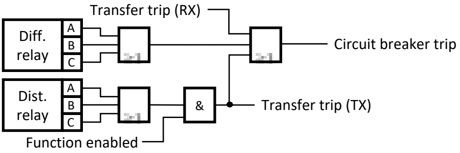
Calculation method for short circuit faults continued

Supplemental implementation of distance relay

- In case of 3-phase short circuit fault occurred nearby a substation, positive phase voltage at the substation is no more reliable to be used as a referential vector.
- Each-phase distance relay is implemented to supplement current differential relay when the fault above occurs.
- The operation of distance relay is transferred to other terminals.



Communication Channels

Characteristics

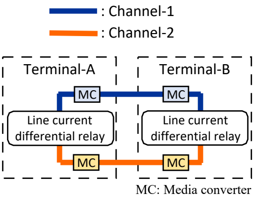
- Can be operated with normal IP (Layer 3) network.
  - No requirement of special equipment such as PTP master clock or PTP capable switches.
- Simultaneously use 2 channels for redundancy.

Conditions

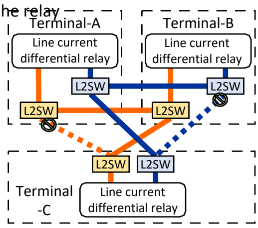
- Communication delay time requirement is 5ms or less.
  - No requirement of jitter and communication delay time difference in upstream and downstream.
- The maximum throughput requirement is about 70Mbps for 10-terminal system.

Topologies

- 2-terminal configuration
  - Connect directly to the other terminal via media converters, which provide bi-directional WDM.
- 3 or more terminal configuration
  - Connect to L2SW-1, L2SW-2 which consist logically separated network for the relay



(a) 2-terminal configuration



(b) 3-terminal configuration

Conclusion

- We introduced line current differential relay with IP (Layer 3) network.
- The proposed method uses asynchronous calculation, and eliminates the influence of communication delay time, which would be more obvious in IP network than that of conventional channel.
- The only requirement for communication channel of proposed method is maximum delay time of 5ms, while conventional method requires suppression of communication time fluctuation (jitter) and of upstream / downstream communication time difference in addition.
- By introducing IP network to relay communication, we can decrease the cost of data transmission lines by using shared network. The use of common devices such as switching hubs and routers which are commercially available is also beneficial, while conventional relays require to be equipped with special communication devices.
- With the commodity of the networking component, we can also enhance the condition of supply chain.
- The relays with proposed method is now our standard specification for the line current differential relays in resistance grounded system, and we have installed or are planning to install 100+ units of the relays since 2020.