INTELLIGENT AGENT ABSED PROTECTION FOR SMART DISTRIBUTION SYSTEMS

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ABSTRACT

In this paper, the communication based protection scheme for a conventional radial system and also for the DG connected loop system. The proposed protection scheme adopts an intelligent agent technology assuming a peer to peer communication among protection IEDs or protection agents. Each protection agent exchanges information related to a fault and performs its primary protection and backup protection in case of a fault and eliminates various problematic issues related to the DG introduction into a current distribution system.

INTRODUCTION

In a traditional radial power distribution system, power flows from a substation down to loads connected to the feeder. In this radial feeder, a fault current similarly flows in one direction. Thus protection of such radial feeder is relatively simple and an overcurrent protection scheme has been most widely used owing to its economy and simplicity. With the recent development of Smart grid that assumes DGs connected to a distribution feeder, the conventional overcurrent protection scheme that assumes unidirectional fault current flow is facing many difficult protection problems [1,2] due to bidirectional fault current flow. Further, the issues related to DGs include different short circuit current behavior depending on the DG type like SCIG, DFIG, Full Converter type, which adds more difficulty in protection. Recent development of communication technology has opened a new era in a protection technology. As has been observed in IEC 61850 which is an international standard for a substation automation (SA). In this IEC61850 based SA, protection is performed by sampled values (SV) and GOOSE communication. The communication based protection is expected to find its wider applications in distribution systems due to its less strict requirements on reliability and security compared to the transmission systems.

In this paper, the communication based protection scheme for a conventional system and also for the DG connected system. The proposed protection scheme adopts an intelligent agent technology assuming a peer to peer communication among protection IEDs or protection agents. Each protection agent exchanges information related to a fault and performs its primary protection and backup protection function in case of a fault and eliminates various problematic issues related to the DG introduction into a distribution system.

COMMUNICATION BASED PROTECTION SCHEME FOR RADIAL DISTRIBUTION SYSTEMS

Intelligent protection agent

In this study, a protection IED becomes an intelligent agent with P2P (peer to peer) communication ability and more intelligent functions added. This protection IED agent could make an accurate decision on identifying a fault and issuing a trip command to associated breakers for the primary protection function and upon recognizing a breaker failure event, it sends a trip command to its neighboring protection IED for a fast backup operation, that is expected to greatly enhance the backup operation speed than the conventional protection scheme. Each agent also will keep monitoring the system operating conditions and adjust its operating parameters autonomously, keeping the protection capability level at the optimum.

In this paper, an agent based protection scheme for conventional radial (or open loop) system and closed loop system is proposed.

Agent based protection for a radial system

Fig. 1 shows a protection logic which is supposed to be embedded in each protection agent in a radial distribution feeder. Once recognizing a high fault current, it is supposed to send its fault detection information which is used as a block signal (BL) to its backward neighboring agent and receive a blocking signal (BL) from its forward neighboring agent. By combining its own fault detection information (FDs) and received BL information from its forward remote agent, it makes a trip decision for its associated circuit breaker.

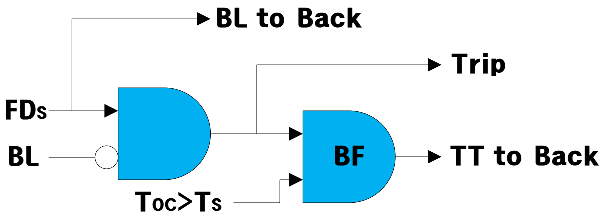

Fig. 1 Protection logic for radial system

Let's consider an example system in Fig. 2. With this logic embedded in the protection agent, for a fault between two protection agents R2 and R3, Agents R2 CB1, R1, R2 detect a high fault current but R3 does not. So R1 sends BL to its backward agent CB1, and R2 sends BL to R1. However agent R3 does not see a fault current and does not send BL to R2. Then CB1 although it sees a fault, since it receives BL from its forward agent, it does not issue a trip command. Similarly R1 does not issue a trip since its forward agent reports that it sees a fault also. In case of R2, which does not receive BL from its forward remote agent, it recognizes that the fault is within its protection range and issues a trip command to its associated circuit breaker. R3 does not do anything since it does not see a fault.

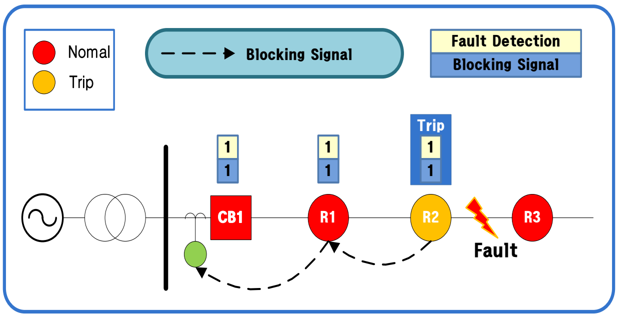

Fig.2 Agent based protection for a radial system

Breaker-failure protection

Once issuing a trip command to a circuit breaker, the protection agent keeps monitoring a fault current. If the fault current does not disappear within a certain time, it issues a breaker failure and sends BF signal to its backward agent (transfer trip or TT). Then the backward agent that receives BF signal, is forced to issue a trip command to its circuit breaker. This is expressed in the logic in Fig. 3.

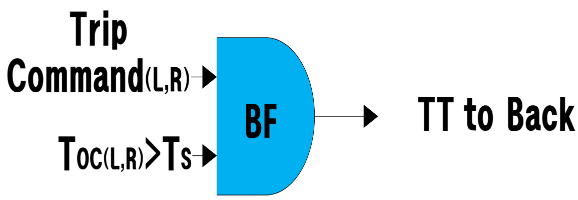

Fig. 3 Breaker failure logic

In Fig.4, for the same fault as the previous case, suppose that a breaker associated with R2 does not open for a certain time although R2 issued a trip command, then recognizing this situation R2 agent will issue a trip command (TT) to its back, and R1 will trip the circuit.

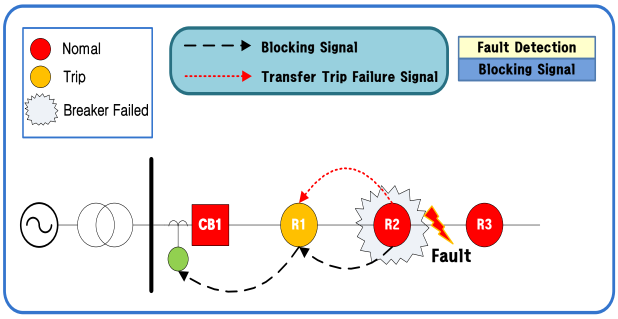

Fig. 4 Breaker failure example in a radial system

Agent-based protection for closed loop systems

While the conventional distribution system has been operated in an open loop resulting in a radial system, a closed loop system recently begins to come into operation for its high service reliability. DG connected to a radial distribution system yields a closed loop system as well. In each case a fault current is fed from both ends. In the former case, two strong sources exist at both ends providing a high short circuit current from both ends, which results in easy fault detection but a directional element is required for protection. In the latter case the grid side feeds a high short circuit current while the other end with DG may give a small fault current. The fault current from DG may be too small and too short in its duration to be detected by a conventional overcurrent relay raising potential problems in protection. In the system where a large capacity wind turbine with SCIG or DFIG type provide a fault current high enough and can be considered as a closed loop system with two strong sources at both ends. The protection logic for each case proposed in this study is described below.

Closed loop system with strong sources

A protection agent in the system now has a directional function that determines a direction of a current in addition to the overcurrent detection function. So the fault detection is performed in both directions (FD_R, FD_L).
Figure 5 shows the protection logic for the case with two strong sources. Note that the protection logic has two trip decision logics: one for each direction. Each trip decision is same as the one in the radial system.

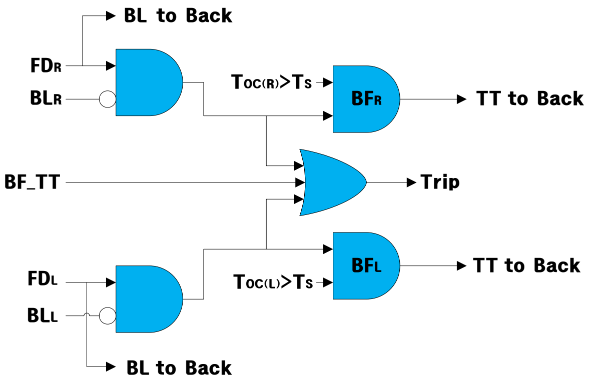

Fig.5 Protection logic for CLS with strong-strong sources

A trip is issued either a fault is detected in its protection zone or breaker failure is informed from its forward adjacent agent. A protection agent also sends a trip signal (TT) to its backward adjacent agent if a breaker failure is detected.
Let's take an example in Fig.6.

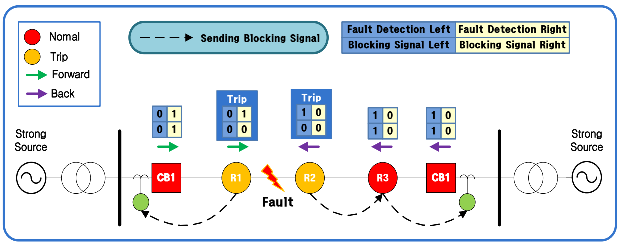

Fig. 6 Protection example of closed loop system with strong and strong sources

For a fault in the figure, R1 detects a fault current to its right direction (FD_R) and R2 detects a fault current to its left direction (FD_L) and both sends a blocking signal (R1: BL_R, R2: BL_L) to its backward agents CB1 and R3 respectively whose trip is blocked as a result. R1 and R2 do not receive a blocking signal from their forward agents and both trip to separate the fault from the circuit.

Closed loop system with strong and weak sources

From a strong source like a grid side source or a large capacity DG, a fault current is high enough to be detected by a protection agent. However a fault current from a weak source like a small capacity DG or DG with full converter connection can be hardly detected by an overcurrent based detection method due its small magnitude and/or a short duration. In this case, one that sees a fault and trip its circuit breaker is required to send a trip command to its remote agent which upon receiving this signal is supposed to trip its circuit. This transfer trip logic is added to the one for two strong sources case as can be seen in Fig.7.

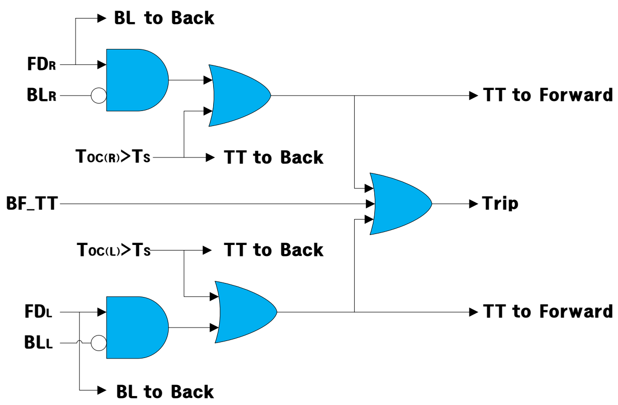

Fig. 7 Protection logic for closed loop system with strong and weak sources

In case a breaker failure happens, a trip command is sent to its backward agent (BF) and one that receives this trip command is supposed to trip its breaker.
Let's take an example. Consider a system in Fig. 8.

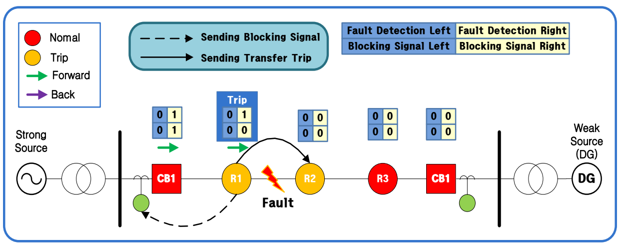

Fig. 8 Protection example of closed loop system with strong and weak sources

Based on the trip logic same as before, R1 will trip its breaker and at the same time it will send a trip command to R2. But R2 which should trip, since it can't detect a fault due to a small fault current from DG, does not trip. Receiving a trip command from R1 finally will trip its breaker, successfully completing fault isolation.

COLCLUSIONS

More and more distributed generations are coming into distribution and causing troubles in protection. This paper p roposes agent based protection that can eliminate troubles related to the protection. The proposed agent has protecti on logic that determines trip to handle a fault. The protect ion logic has been developed for not a conventional radial system and closed loop system. In a closed loop system, t wo cases have been dealt with: one with two strong sourc es and the other with one strong source and one weak sour ce. The proposed scheme has been described with exampl es.

The proposed agent scheme not only eliminates troubles r elated to the current protection practices but also could op en new applications in system operation and control in a f uture.

Acknowledgments

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