Study of IEC 61850 Distribution Substation Communication Simulations

(ICT Research Laboratory: Xu, You-Ning; Chen, Wei-Guang; Lin, Jing-Lun; Chen, Fung-Fei)

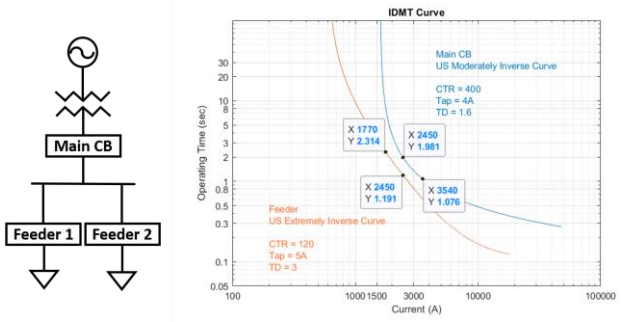
I. Purpose

Taiwan Power Company has introduced the IEC 61850 international standard for substation automation and formulated the GOOSE (Generic Object Oriented Substation Event) logic strategy for substations. The GOOSE protocol enables IEDs (Intelligent Electronic Devices) to publish their feeder fault signals and subscribe to the fault signals of other feeders. If faults involve more than one feeder, the fault signal can be transmitted quickly to speed up the feeder circuit breaker tripping, avoiding the upstream circuit breaker tripping to expand the scope of the power outage.

This study established a GOOSE communication test platform, utilizing OPAL-RT to simulate a substation model with a single busbar and double feeders. With the IEC 61850-9-2LE Sampled Values communication protocol, voltage and current signals are transmitted to IEDs that have completed the configuration of the GOOSE logic strategy. By interfacing with physical devices through OPAL-RT for communication and fault simulations, the correctness of the GOOSE logic configuration of IEDs is verified.

II. Research Results

In the Taiwan Power Company GOOSE Logic Strategy[1], Case 1 of strategy 1 is designed to prevent the Main CB from tripping due to the superposition of fault currents in the event of simultaneous faults of two feeders. The schematic diagram of the simplified fault scenario is shown in Figure 1. The relay setting values are shown in Figure 1, assuming a simplified single-line diagram with a single busbar and double feeders. When faults occur simultaneously in both feeders, the fault current passing through the Main CB is the sum of the fault currents in the two feeders. For a single feeder fault current of 1770A, the trip time is 2.314 seconds. The fault current passing through the Main CB, when both feeders have faults, is 3540A, with a trip time of 1.076 seconds, as shown in Figure 1. At this point, the Main CB will trip first instead of both faulty feeders, so the GOOSE logic for Case 1 is formulated as follows: when both feeders reach the fault current pickup value and sustain it for 20 cycles, initiate an accelerated trip for the feeders.



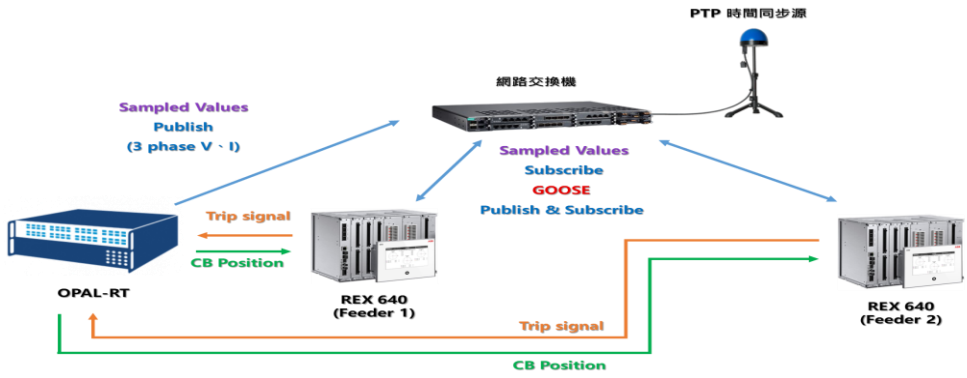
Reference: This project

Figure 1. Case 1 of strategy 1 Fault Scenario

To verify the correctness of the GOOSE logic configuration in IEDs, the GOOSE communication test platform is established to simulate fault scenarios, which are interfaced with the real IED to conduct HIL (Hardware-in-the-loop) tests.

As shown in Figure 2, the platform utilizes the PTP (Precision Time Protocol) for time synchronization. The OMICRON CMGPS 588 converts GPS signals into PTP protocol network packets and transmits them to the network switch. OPAL-RT and two ABB REX640 IEDs are also connected to the network switch for time synchronization.

[1] Reference: Taiwan Power Company Department of Power Distribution, "GOOSE Logic Strategy," June 2023

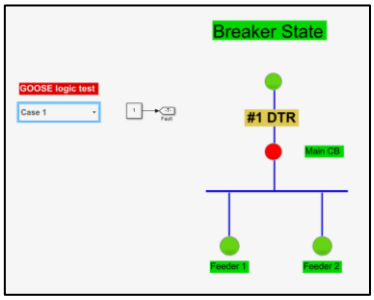


Reference: This project

Figure 2. Architecture of the GOOSE communication test platform

In the platform, a single busbar and double feeders model is built using MATLAB/Simulink simulation software, as shown in the left half of Figure 1. The model with fault scenarios is simulated and loaded into OPAL-RT. Voltage and current signals are transmitted from OPAL-RT to two IEDs through the IEC 61850-9-2LE Sampled Values protocol. Then, in the IED Configuration Tool, settings for Sampled Values subscription, GOOSE publishing and subscribing, and GOOSE logic are configured. When the IED outputs trip signals, they are transmitted to OPAL-RT using hardwired connections. OPAL-RT simulates circuit breakers' operation time and sends the status of circuit breakers back to the IEDs.

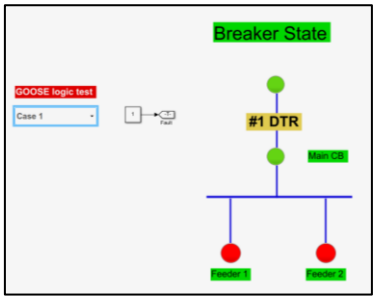
When simulating the scenario of Case 1 of strategy 1, the simulation involves a fault on the first feeder, followed by a fault on the second feeder after 0.1 seconds. When both feeders experience faults simultaneously, locking the GOOSE function results in the Main CB tripping rather than the two faulty feeders, as illustrated in Figure 3. Only the Main CB trips, and the indicator light turns red.



Reference: This project

Figure 3. Case1 fault scenario result (GOOSE Locked)

With the GOOSE function enabled, OPAL-RT is utilized to simulate the fault scenario of Case 1. In the event of simultaneous faults, both feeders receive the GOOSE Start signals from each other and detect faults on their respective feeders. After 20 cycles, the GOOSE logic is established, accelerating the tripping of the circuit breakers on each feeder. The test results are depicted in Figure 4.



Reference: This project

Figure 4. Case1 fault scenario result (GOOSE Enabled)

The GOOSE communication test platform established in this study enables the design of fault scenarios to test the correctness of the GOOSE logic configuration in IEDs. Furthermore, by utilizing the HIL tests, the simulation and validation of the introduction of the GOOSE Logic Strategy in real substations, especially in scenarios involving potential incidents, can achieve the effectiveness of accelerating tripping and reducing the scope of faults. In addition, for future needs, such as the addition of GOOSE logic strategies or other relevant applications,

this platform can be utilized for simulation and scenario testing to formulate appropriate logic strategies.

This platform currently adopts the IEC 61850-9-2LE Sampled Values communication protocol for transmitting voltage and current signals. To more closely match the actual situations on site, there is a plan to expand the current or power amplifiers to transmit the actual voltage and current signals to IEDs using hardwired connections. This enhancement will make the platform compatible with the current two-level and one-bus architecture used by the Taiwan Power Company and the three-level and two-buses architecture for communication environment testing.