Development and Evaluation of a GOOSE Simulator for IEC 61850-10

ICT Research Lab: Lin, Jing-Lun; Chen,Wei-Guang; Xu, You-Ning; Chen, Yi-Yen

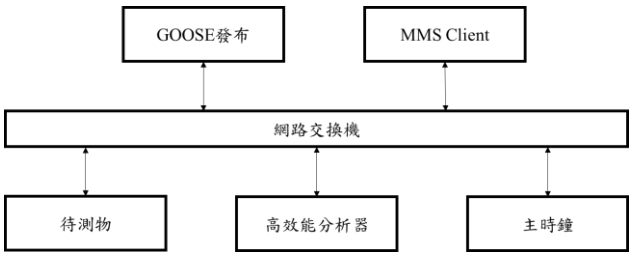
1. Purpose

In the past, digital relays in substations commonly relied on proprietary communication formats defined by their manufacturers, making information exchange between different brands difficult and the data integration process relatively complex. With the introduction of IEC 61850, intelligent electronic devices (IEDs) from different vendors can exchange data in a unified format, thereby improving system interoperability and simplifying operations and maintenance.

The IEC 61850-5 and IEC 61850-10 standards specify the required transmission times and time accuracy for various substation applications. Among these, GOOSE (Generic Object Oriented Substation Event) messages provide fast and reliable event communication, which is essential for protection and control systems. Based on IEC 61850-10, this study analyzes the performance-testing sections, develops a GOOSE simulator, and evaluates the feasibility of incorporating GOOSE performance testing. The results aim to provide a practical approach for establishing future GOOSE performance testing platforms.

2. Research results

The GOOSE performance testing setup defined by UCAIug includes a GOOSE simulator, an MMS client, a high-performance analyzer, and a master clock, as shown in Figure 1. The GOOSE simulator is responsible for publishing all GOOSE messages, including those used for GOOSE ping-pong tests and background GOOSE traffic. The MMS client connects to the device under test (DUT) to receive Report data, while the master clock provides accurate time synchronization. A high-performance analyzer is deployed to monitor the DUT's performance test results.



Source: R. Schimmel and S. Gerspach. "Test procedures for GOOSE performance according to IEC 61850-5 and IEC 61850-10," UCAIug, Version 1.1, Jan. 2011.

Figure 1. UCAIug GOOSE performance testing Setup

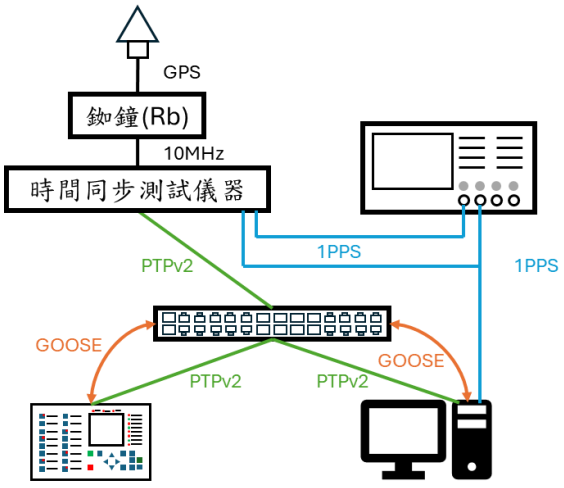
To conduct GOOSE performance testing and automate the generation of test results along with the calculation of related metrics, this study integrates GOOSE publishing and high-performance analysis functions within the test setup. It develops a GOOSE simulator for future testing applications.

The IEC 61850-10 standard specifies that a GOOSE simulator should transmit time-related GOOSE messages with an accuracy within 0.2 ms. Therefore, in developing the simulator for this study, a Linux operating system was adopted. The GOOSE publisher was implemented using either the time synchronization software provided by the network interface card vendor or the open-source project *linuxptp* together with the *libIEC61850* library. Devices equipped with hardware-based PTP-capable network interface cards were used for both GOOSE message subscription and publishing, as well as for analyzing and

recording round-trip times. Additionally, all GOOSE messages generated during the testing process were logged for subsequent analysis.

To verify that the designed GOOSE simulator meets the testing requirements defined in IEC 61850-10, this study simplifies the GOOSE performance testing setup specified by UCAIug to assess the simulator's feasibility. The MMS client, which generates the background traffic, is removed so that the GOOSE simulator transmits only the messages related to the GOOSE ping-pong test and does not send any additional GOOSE messages as background traffic.

The test was conducted using the GOOSE ping-pong method. A GOOSE message containing a Boolean value and its Quality attribute was sent from an industrial computer. Upon receiving the GOOSE message, the device under test (DUT) immediately returned the received Boolean value. Once the industrial computer received the same value, it toggled the Boolean state to initiate the next round of the ping-pong test. Each test round consisted of 1,000 ping-pong exchanges, after which calculations were performed, as shown in Figure 2.



Source: This project

Figure 2. Architecture of Simplified GOOSE Performance Testing

Before testing, the GOOSE simulator was synchronized with the master clock. During the test, an oscilloscope was used to verify the GOOSE simulator's time synchronization. To ensure test accuracy, a time-synchronized testing instrument was employed as the master clock in the test setup. The yellow signal represents the 1PPS output of the master clock, while the blue signal represents the 1PPS output of the GOOSE simulator. The time difference was observed to range from 5 ns to 35 ns, as shown in Figure 3, ensuring that all devices maintained sufficient accuracy during the GOOSE performance test to guarantee the correctness and reliability of the data.

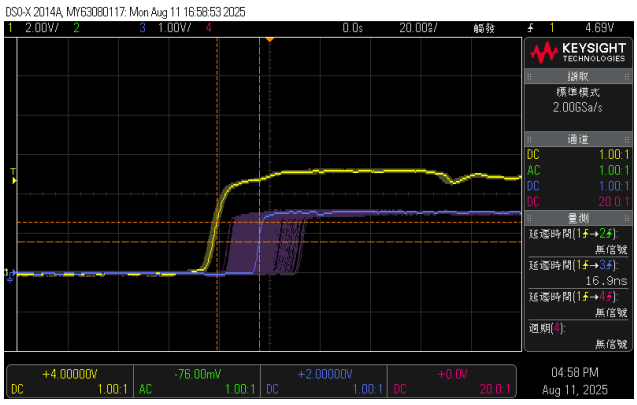


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Figure 3. 1PPS Signal Comparison between GOOSE Simulator and Master Clock

In this study, during the design of the GOOSE simulator for publishing and subscribing to GOOSE messages, the contents of the GOOSE packets were simultaneously recorded, and parameters such as the maximum, minimum, average, and standard deviation of round-trip times were calculated to enable automated test verification. For each test round, the GOOSE simulator transmitted 10,000 GOOSE messages, which were received and returned by the device under test (DUT) in a GOOSE ping-pong manner. During testing, each DUT was tested 10 times. The test results are summarized in Table 1.

Table 1. Test Results for a Specific Vendor

Times	Maximum (ms)	Minimum (ms)	Average (ms)	Standard (ms)	Measure Scan cycle
1	4.0696	1.8470	2.0036	0.1570	2.2226
2	4.2778	1.8402	1.9995	0.1260	2.4376
3	3.6924	1.8368	1.9992	0.1502	1.8556
4	3.4902	1.8340	1.9911	0.1457	1.6562
5	3.4505	1.8379	1.9985	0.1313	1.6126
6	3.7874	1.8402	1.9976	0.1517	1.9472
7	3.7006	1.8278	1.9972	0.1523	1.8728
8	3.8259	1.8360	1.9915	0.1537	1.9899
9	3.7761	1.8426	2.0005	0.1513	1.9335
10	4.2049	1.8419	2.0022	0.1571	2.363

Source: This project

From the implementation process, it is evident that the simulator achieves high time-synchronization accuracy and robust message handling. It can synchronize with PTP signals provided by the master clock while simultaneously publishing and subscribing to GOOSE messages and performing high-performance analysis. The test results demonstrate that the GOOSE simulator achieves excellent time accuracy and message processing performance, making it suitable for use as a GOOSE simulation device in IEC 61850-10 performance testing. Furthermore, the simulator can be implemented on a Linux computer equipped with a hardware-based PTP-capable network interface card, achieving high time-synchronization accuracy. By developing software programs, it is possible to record packets and analyze data, including packet information and GOOSE message contents, providing a flexible, scalable, and low-cost solution for GOOSE performance testing systems.