

LABORATORY TESTING OF THE COMMUNICATION BASED PROTECTION RELAYS

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Abstract: The proper operation of control and protection applications in Substation Automation System (SAS) demands very high-speed and reliable communications that has being achieved by using IEC 61850. Moreover, the practical implementation and testing of protection scheme requires a communication system that can be conventional or high-speed peer-to-peer communication. This paper presents the evaluation of the performance advantage of GOOSE (Generic Object Oriented Substation Event) message over its conventional hard-wired counterpart for the same relays protection.

Keywords: IEC 61850 standard, GOOSE, peer-to-peer communication, functional testing

1. INTRODUCTION

Substation Automation Systems (SASs) is being increasingly implemented in transmission and distribution substations. Functions of substation automation are highly critical time and require a high reliability communication network [1]. Earlier, traditional method of communication in SAS was hard wired between protective relays. Currently, SASs are no longer composed of individual devices; In addition, protection and control are not independent technologies as long as they are now integrated using powerful communication links.

GOOSE model, which is part of the standards IEC 61850, provides the high-speed peer-to-peer communication among IEDs (Intelligent Electronic Devices) within the substation, for protection purposes. Ethernet Local Area Network (LAN) based communication provides more flexible, fast and reliable option [2].

SAS originates from multiple components, which have multiple functions and each component must be testable in order to perform the multiple distributed applications as are designed. Laboratory testing of protection schemes is preferred before commissioning to debug the interactions among IEDs in SASs.

This paper focuses upon the evaluation of the performance of GOOSE message advantage over the conventional hardwired testing for the same devices. It also shows laboratory setup used for this purpose.

2. MEASURING THE TRANSFER TIME

Measuring the messaging latency according to the one way trip messaging transferring latency method (Fig. 1, a) cannot reflects the real behavior of the device under test (DUT) based on defining the priority of the received messages, extract the information from the received messages, execute the inner functions and send the response to the communication network [3]. Thus, this paper will provide measuring the round trip transferring messages latency (Fig.1, b). The transfer time latency for messages is influenced by several parameters such as communication network

speed, communication network back ground traffic. Measuring the round-trip time for the messages from/till the publisher-subscriber-publisher involve five individual times as

$$t_{RT} = t_{out.TD} + t_{in.D} + t_{App} + t_{out.D} + t_{in.TD}, \quad (1)$$

where t_{RT} is round trip time, $t_{out.TD}$, $t_{in.TD}$ are the time out and time in for Tested Device that publish the GOOSE message, $t_{in.D}$ and $t_{out.D}$ are the time in and out for the second device, t_{App} is the application time for IED.

Therefore, several assumptions have to be made to achieve useful results. The first assumption is the network time can be neglect. This assumption can be achieved by using one high performance Ethernet switch within a 100mbit/s network. The second assumption is symmetry of the time in and time out for each device.

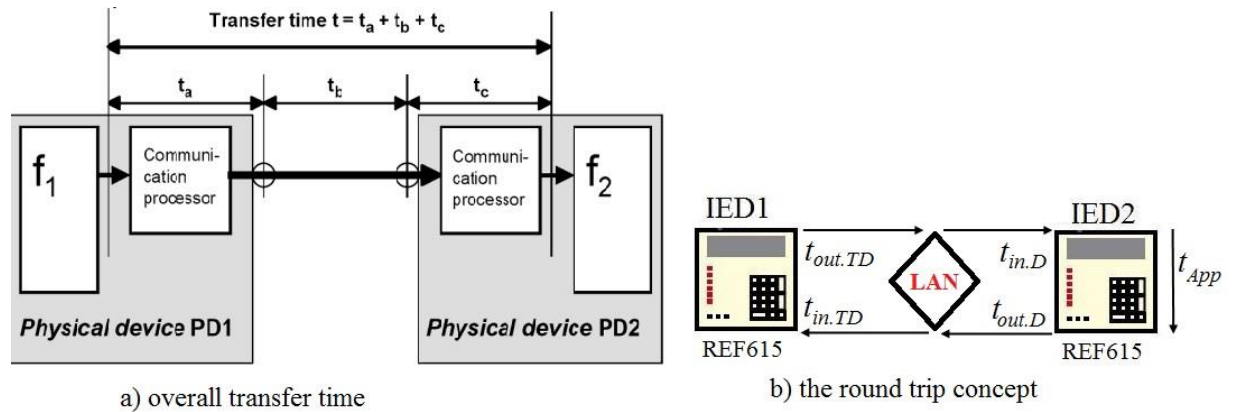


Fig. 1: Measured time, a) overall transfer time [4], b) round trip time

3. LABORATORY TESTING OF GOOSE MESSAGES

IEC 61850-7-2 has defined a generic substation event service that provides a fast and reliable distribution of input and output data values, including both digital and analogue values. This service is depended on the concept of an autonomous decentralization method that supports an efficient way allowing the simultaneous delivery of the same event information to more than one physical device by using the multicast services.

IEC 61850-7-2 has defined two classes of messages expressed as:

- a) Generic object oriented substation event (GOOSE): supports the exchange of a wide range of possible common data organized by a Date-Set
- b) Generic substation state event (GSSE): provides the capability to convey state change information.

Type of exchanged information is the major difference between GOOSE and GSSE services. The GSSE service only supports a simple list of status information; while the GOOSE service provides a flexible means to specify which information is to be exchanged. In this paper, only GOOSE service is based on the implemented applications.

The evaluation the timing performance of the GOOSE message transmission is crucial to realize its use in real time protection applications. In addition, the main aim of the measuring task is to verify that the performance of the IED publisher GOOSE messages are compliant with the IEC 61850 (not exceed 4ms). laboratory setup has included tow modern IEDs (REF615- ABB), IED Scout software, Ethernet switch, PC and modern configuration software tool (PCM 600) as illustrated in Fig.3, a.

According to the experiment initialization, there are many steps for integration GOOSE in the substation as are following:

1) Configuration DataSet in individual IEDs

Different Data in IED is grouped as DataSet which is always accompanied with the GOOSE message. Changing in the value of any Data Attributes of DataSet causes a new event and sent new GOOSE message.

2) Configuration Individual IEDs

After a published Data set has been set, the configuration shall be downloaded for at least all the subscribing IEDs. IEDs must be configured to obtain the System Configuration Description (SCD) files necessary for system configuration. All information about the configured relay and the published/subscribed GOOSE messages, are provided by the (SCD) files. In laboratory, IED2 has configured to publish GOOSE (START) when it operates under abnormal conditions (e.g. overcurrent) as in Fig. 2, a. Subscriber IED1 has configured to receive the GOOSE from the network and execute the internal function and then publish another GOOSE (TRIP).

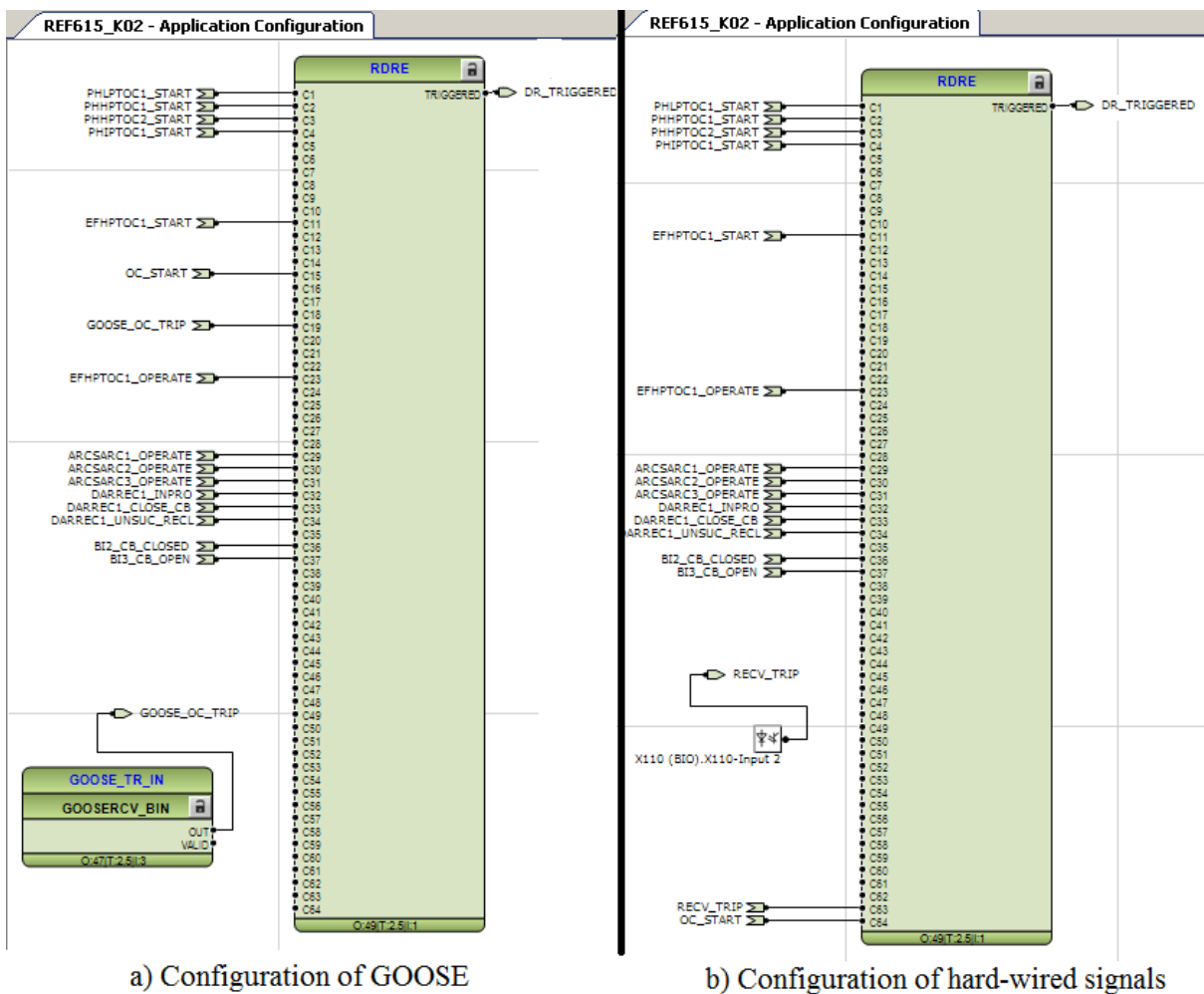


Fig. 2: Configuration of relay a) configuration of GOOSE, b) configuration of the signals

3) System Configuration for GOOSE

System configuration is the final and most important step that can be either via an independent IEC61850 configurator, or via the relay specific software (PCM600). In order to generate a (SCD) file and define GOOSE mapping, an independent system configurator can be used.

A simple verification test of GOOSE messages can be achieved using IEDScout. Local Area Networks (LAN) is used to interrogate and acquire the right GOOSE message during the testing processes.

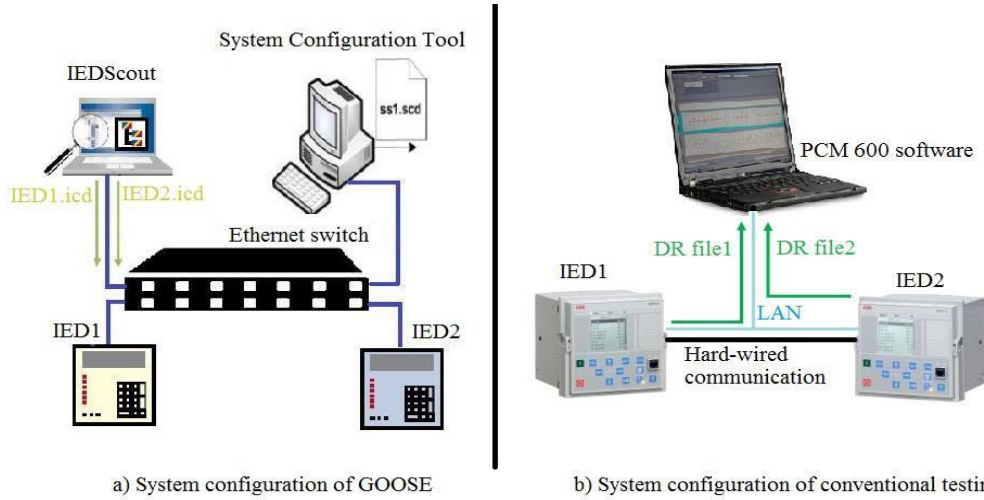


Fig. 3: System configuration a) System configuration for GOOSE, b) configuration for convention testing

From Eq. 1, the latency of the GOOSE messages for the tested device has been calculated t_{TD} as follows

$$t_{TD} = t_{RT} - t_{App} \quad (2)$$

where: $t_{TD} = t_{out.TD} + t_{in.D} + t_{out.D} + t_{in.TD}$

From Fig. 4 a) the round trip time is 5ms.

The outcome from Eq.2 has been divided by two given the above mentioned assumption that t_{in} and t_{out} for IED are symmetric, t_{App} is related to IED. We can accept $t_{App} = 0$ for REF615. Thus the latency for one GOOSE message is

$$t_{GOOSE} = 1/2(t_{RT} - t_{App}) = 5/2 = 2.5ms. \quad (3)$$

4. CONVENTIONAL TESTING OF PROTECTION FUNCTION

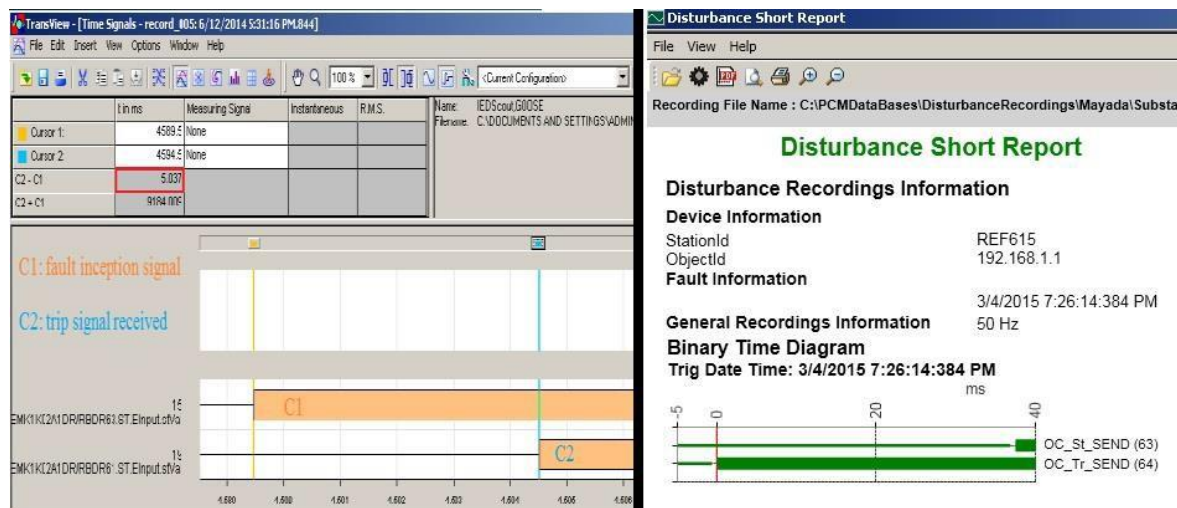
Testing of protection in automation systems is significantly necessary in order to guarantee the proper operation of the functions. The interconnectivity tests, which are included in the protection tests, can specify whether the devices are able to exchange information or not. Moreover, the overall performance tests are required to determine whether the components of the engineering solution meet the requirements defined during the design stages.

Fig. 3, b presents the conventional testing of hard-wired protection and automation systems. Laboratory setup testing consists of two protection relays REF615-ABB, PCM 600 software for configuration the relays and to demonstrate the measured results.

Fig. 2, b shows the function configuration of IED2 in which the function protection operates under abnormal system conditions (e.g. overcurrent) the output START signal will active to allow the device to carry out the protection action; But if the circuit-breaker of this protection device failed this relay send message to input of IED1 that will trip this fault by sending TRIP signal to IED2 due to the hard-wiring between binary inputs and outputs of IEDs.

Fig. 4, b is showing the round trip time from/ to IED2. Thus, the delay time of these signals is computationally using Eq.3 as

$$t_{signal} = 1/2(t_{RT} - t_{App}) = 40/2 = 20ms. \quad (4)$$



a) Testing results of GOOSE

b) Testing results of hard-wired communication

Fig. 4: Test results

5. CONCLUSION

Conventional testing methodologies are based on tests scenarios, selected equipment, and analysis tools, preferably executed in a laboratory environment, under well-controlled conditions.

Functional testing based on IEC 61850 has proved that GOOSE provides a very flexible and fast, high-priority and reliable method for the exchange of substation events among IEDs for interlocking and protection purpose.

Comparison between two methods illustrated that IEC 61850 can be successfully used to replace conventional substation control and protection systems without any degradation in the overall performance of the system. The successful measuring of the round trip time for the GOOSE messages for the tested device has proved that this device is compliant with the IEC 61850 criteria

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