GOOSE Testing of Different Make IEDS: IEC 61850 Server Testing by UCAIUG Procedure

VATSAL PARMAR[1]

DR. SATISH H. CHETWANI[2]

MS. SHEFALI TALATI[3]

ABSTRACT

In today's modern Digital Substation Automation System Cyber Security is the utmost requirement. Presented work concentrates on IEC 61850 protocol standard supporting GOOSE messaging operation as per UCAIug procedure Edition 2.0 establishment for IEDs. ERDA's testing Laboratory setup with different manufacturers' two IEDs communicating with an Ethernet based IEC 61850 Test Environment network have been implemented & tested. GOOSE test of 1. IED REF615 & 2. IED REF620, & 3. IED L90 & 4. IED P345 as per UCAIug procedure was carried out. The objective of this study is to detect GOOSE operations as per UCAIug procedure for Multivendor IEDs installed in IEC 61850 Substation Automation System (SAS). One IED tested with the UniGrid SA (DNV Test Tool) and the results demonstrated that the proposed GOOSE operation of IED works satisfactorily as per standard IEC 61850-8-1 standard & UCAIug procedure. Thus paper aims at goose testing of IEDs with IEC 61850 protocols as per UCAIug procedure.

Keywords *: GOOSE, Automation, IEC 61850, UCA, IED*

1. INTRODUCTION

GOOSE is used in substation automation for fast horizontal communication between different manufacturers IEDs in IEC 61850. GOOSE can be used for direct data exchange, for example, of interlocking and blocking information between protection relays. As per IEC 61850-8-1 standard, GOOSE uses a publisher/subscriber profile in which information is shared from one device to one or several devices by using Ethernet multicast messages. By use of GOOSE and software interlocking will reduce the amount of copper wiring significantly. The status data response time, that is, the time it takes for the application to handle a received GOOSE message and to send the concerned data back to the network, is ≤ 3ms. The horizontal communication configuration consists of the protection relays' GOOSE control block, data set and GOOSE input configuration. UCAIUG test procedure UCAIUG is abbreviated as Utility Communication Architecture International Users Group. UCA test procedure is meant for conformance test procedure for Server Devices with IEC 61850-8-1 Edition 2 Interface (Author: Richard Schimmel – DNV GL Netherlands B.V.) published on December11, 2018.

Several researchers [1],[2], & [10] have carried out work with GOOSE Testing. [3] to [9] have done Sample value testing with IEC 61850 protocols and Goose messaging for Substation Automation System (SAS). Some of the research work has proposed GOOSE testing of IEDs with IEC 61850 protocols as per UCA procedure. Paper has obtained inter-operability with GOOSE testing of IEDs with IEC 61850 communication protocols as per UCA procedure

2. GOOSE TESTING

The GOOSE Configuration module configures the mappings and sets up the test set for communicating with the GOOSE messages on the substation network. As with any Secondary Injection Relay kit (IEC 61850 complied), it can be inserted multiple times in test plans to automatically configure the "wiring". To facilitate parameter entry and to avoid typing errors, the parameters can be imported from configuration files in the standardized SCL format.

Secondary Injection Relay kit (IEC 61850 complied) operate with status data in GOOSE messages as if they were "wired" to the binary inputs and outputs of a Relay test set. Data attributes from received (subscribed) GOOSE messages actuate the binary inputs of the test set (for instance trip or start signals). Binary outputs actuate data attributes in simulated (published) GOOSE messages. By this generic approach as illustrated in below Figure-1, all test modules of the Test Universe software can be used with GOOSE.

1. UCA Tester, Assistant Manager & Act. Head – TM4, R&D, Electrical Research & Development Association, Makarpura, Vadodara

2. Director, Electrical Research & Development Association, Makarpura, Vadodara

3. Manager & Head – TM4 & DT, Electrical Research & Development Association, Makarpura, Vadodara

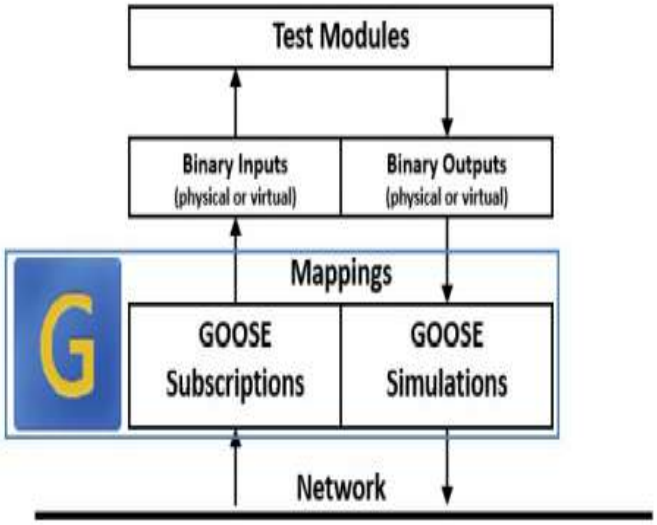


Fig. 1 : Test Universe software with GOOSE

All IEC 61850 types and structures are allowed in a GOOSE Data Set. Mappings are provided for Boolean, Bit-String, Enum, Integer, and Unsigned. The timing performance of the message exchange is according to Type 1A; Class P2/3 (IEC 61850-5, "Trip" – "most important fast message").

Users typically utilize GOOSE for unsolicited multicast message delivery in automation systems. The delivery of these messages needs to be high performance & reliable. Since GOOSE is a multicast, information that is needed by multiple subscribers can be published in a single message. Subscribers need to be able to be configured to understand which data from a specific GOOSE message is being utilized by the application.

A. Test Features in IEC 61850

IEC 61850 has standardized many different features that can be used for testing. These features include:

- The possibility to put a function in test mode;
- The possibility to characterize a control service or a data attribute sent within a GOOSE message as being sent for test purpose;
- The possibility to subscribe to GOOSE or sampled value messages from simulation or test equipment.

A logical device in an IED can be put in test mode using the data object Mod of the LLN0. In addition to that, any logical node can have its mode controllable by the operator using the Mod data object of the logical node. The final behavior of a logical node is represented by the data object Beh, which results from a combination of the logical node and logical device modes. (Table A)

The possible values of mode and behavior are: on = 1, on-blocked = 2, test = 3, test/blocked = 4 and off = 5. The maximum value between LLN0.Mod and LN.Mod wins and results in the final logical node's behavior (Beh).

There is a way to isolate the device under test (DUT) from the rest of the system is by setting the LN0.Mode to either test or test blocked at the highest level LN0 in the logical device hierarchy for purpose of "Device isolation". Mod can be set to the following values, which in turn become Beh states. The common values are: on, blocked, test, test/blocked, and off. Detail explanation is given below:

- On=1: The logical node has full operational capability, will ignore incoming data marked with test quality, and will

Table A : Processing of Incoming data in Logical Node

LD wide setting LLN0.Mod.stVal	LN specific setting e.g. XCBR.Mod.stVal	LN behavior result e.g. XCBR.Beh.stVal	LN quality result e.g. XCBR.Pos.q
on	on	on	
on	on-blocked	on-blocked	
on	test	test	q.Test = True
on	test/blocked	test/blocked	q.Test = True
on	off	off	q.Validity = invalid
on-blocked	on	on-blocked	
on-blocked	on-blocked	on-blocked	
on-blocked	test	test/blocked	q.Test = True
on-blocked	test/blocked	test/blocked	q.Test = True
on-blocked	off	off	q.Validity = invalid
test	on	test	q.Test = True
test	on-blocked	test/blocked	q.Test = True
test	test	test	q.Test = True
test	test/blocked	test/blocked	q.Test = True
test	off	off	q.Validity = invalid
test/blocked	on	test/blocked	q.Test = True
test/blocked	on-blocked	test/blocked	q.Test = True
test/blocked	test	test/blocked	q.Test = True
test/blocked	test/blocked	test/blocked	q.Test = True
test/blocked	off	off	q.Validity = invalid
off	<does not matter>	off	q.Validity = invalid

output signals to switchgear through I/O or other services. It will also process questionable quality as it would normally process such quality. It will not process incoming data marked with test quality.

- Blocked=2: The logical node will provide the functionality that it proxies. It will behave in a similar fashion to on except it will not generated output signals to switchgear.
- test=3: Similar to the on state except the logical node will process incoming information marked with test quality as valid and use that information in its function. Any values produced by the logical node will have test quality.
- test/blocked=4: It is a combination of the test and blocked state.
- off=5: The logical node will not be providing its proxied function. Any information that would typically be produced by the logical node will be marked with a quality of invalid. No output to switchgear will occur.

The definition of mode and behaviour is standardized and presented in Table A that shows how an incoming data will be processed. The incoming data may be from:

- A control service: commands from an operator that can be sent in normal operation or for test purposes by setting the service test flag to True;
- A GOOSE message: any data attribute within a GOOSE message carries, as part of its quality status (data attribute q), the information whether it is sent in normal operation or for test purposes.

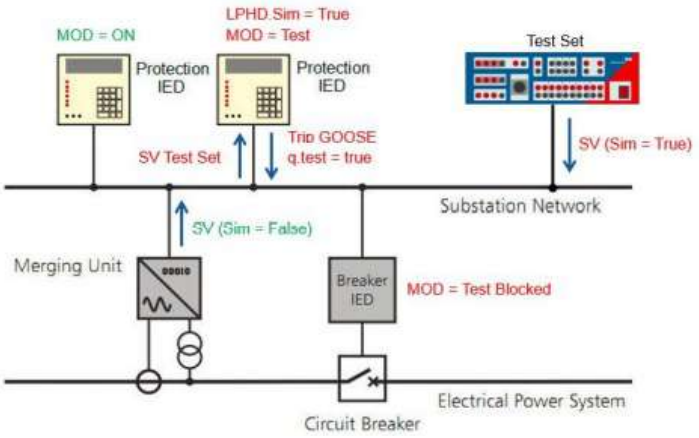


Fig. 2 : GOOSE operation in SAS

2. UCA TEST PROCEDURE

The purpose of UCAIUG test procedure document is to describe the conformance test procedure and results of the TEST SESSION concerning the IEC 61850-8-1 server implementation in the DUT.

The test results are the basis of the conformance statement.

A Components in the test environment

The test environment consists of the following components:

- DUT CLIENT SIMULATOR
- ANALYSER
- EQUIPMENT SIMULATOR
- Ethernet Switch
- SCL engineering tools
- TIME MASTER

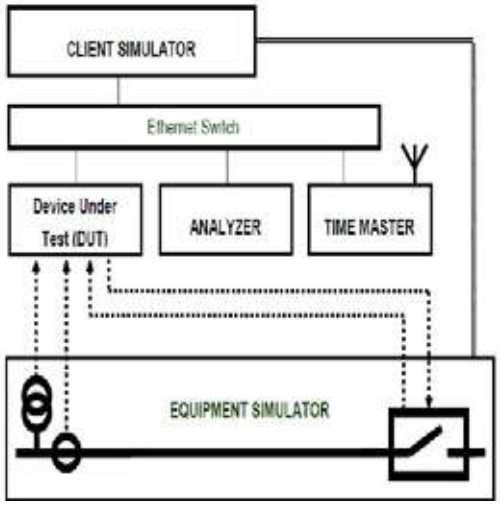


Fig. 3 : Components in Test Environment

B. Overview of the UCA Test Procedure

The server test cases are structured as follows:

- Documentation and version control (IEC 61850-4)
- Configuration file (IEC 61850-6)
- Data model (IEC 61850-7-3 and IEC 61850-7-4)

Mapping of ACSI models and services (IEC 61850-7-2 and IEC 61850-8-1)

Application association

- Server & Logical Device & Logical Node & Data
- Data set ▪ Service tracking ▪ Substitution
- Setting group ▪ Reporting ▪ Logging
- Generic object oriented substation events
- Control ▪ Time and time synchronization ▪ File transfer

4. TEST RESULTS FOR GOOSE TESTING

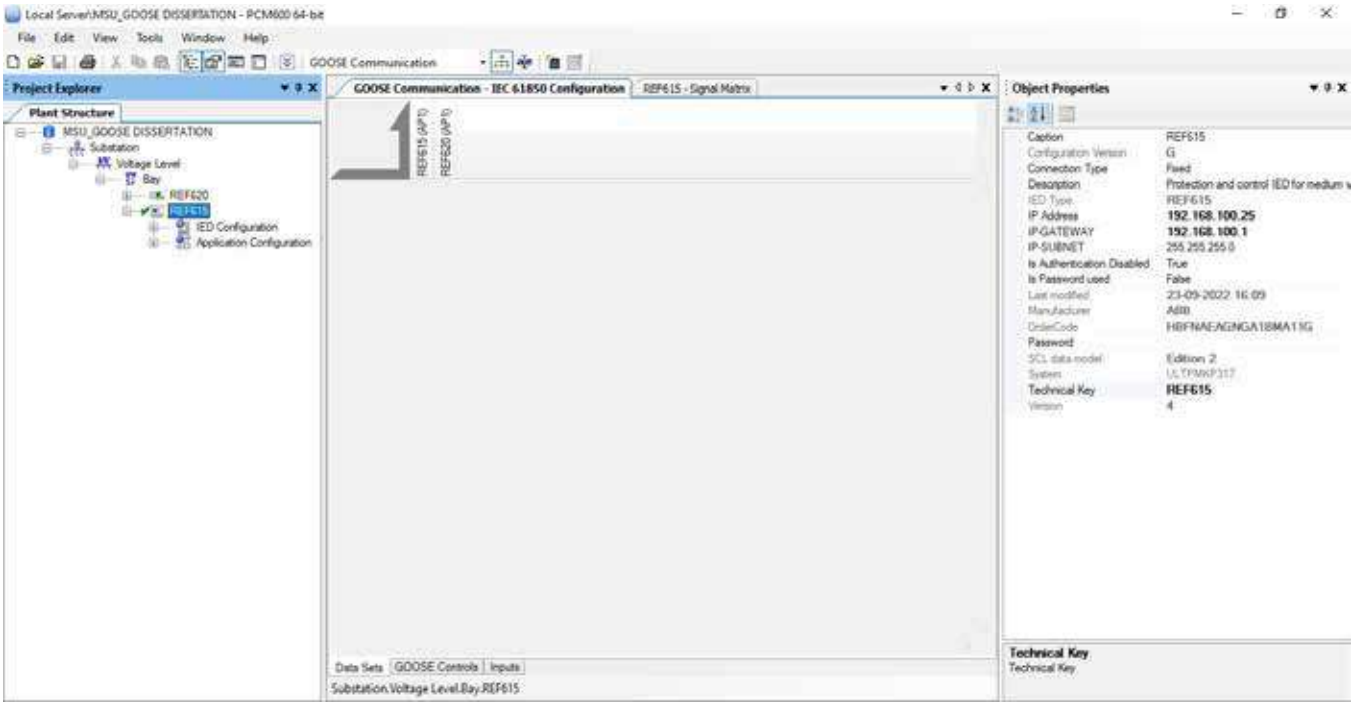
A GOOSE test of 1. IED REF615 & 2. IED REF620 as per UCA procedure Testing set up :

Testing set up:-

Fig. 4 : Test set up for GOOSE testing as per UCA procedure

During GOOSE communication configuration, the REF620 in PCM software has been configured with “REF615.AP.LD0. LLN0.REF615_DS” in IED REF615:-

Table B



During GOOSE communication configuration, the REF615 in PCM software has been configured with “REF620.AP1.LD0.LLN0. REF620_DS” in REF620:-

Table C

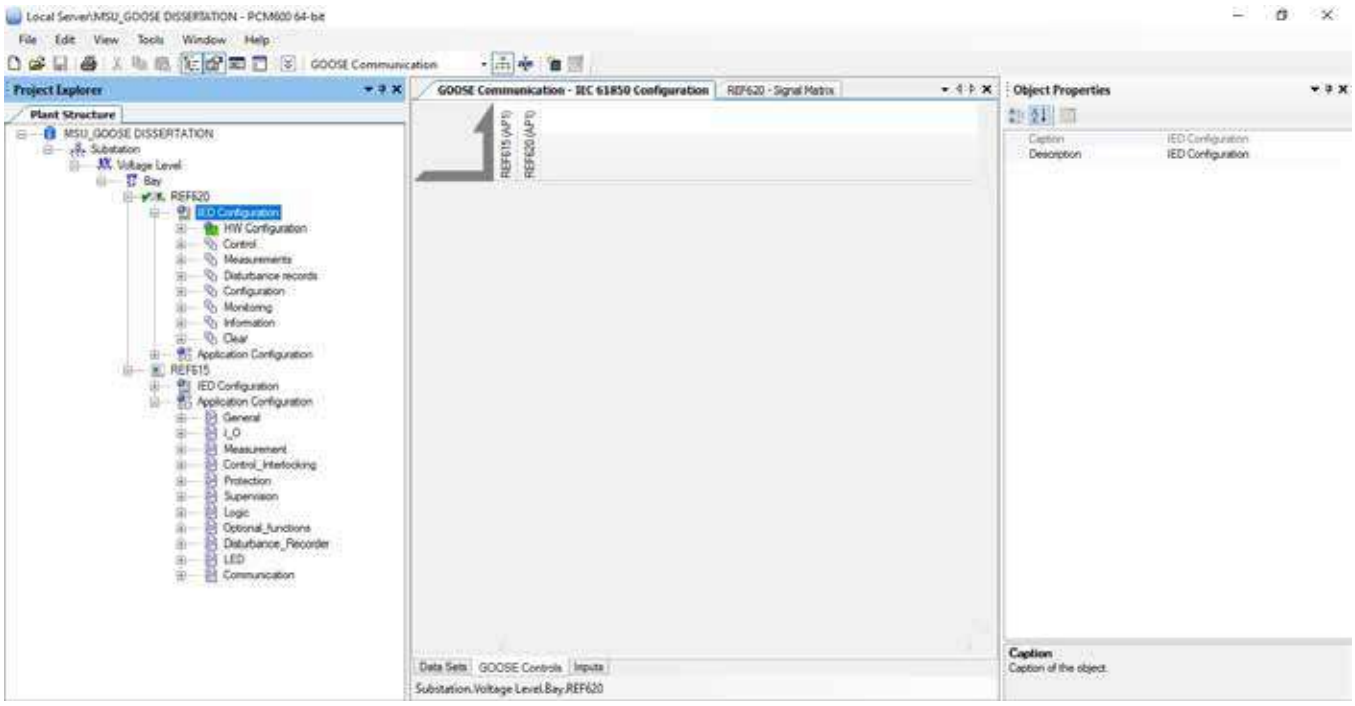
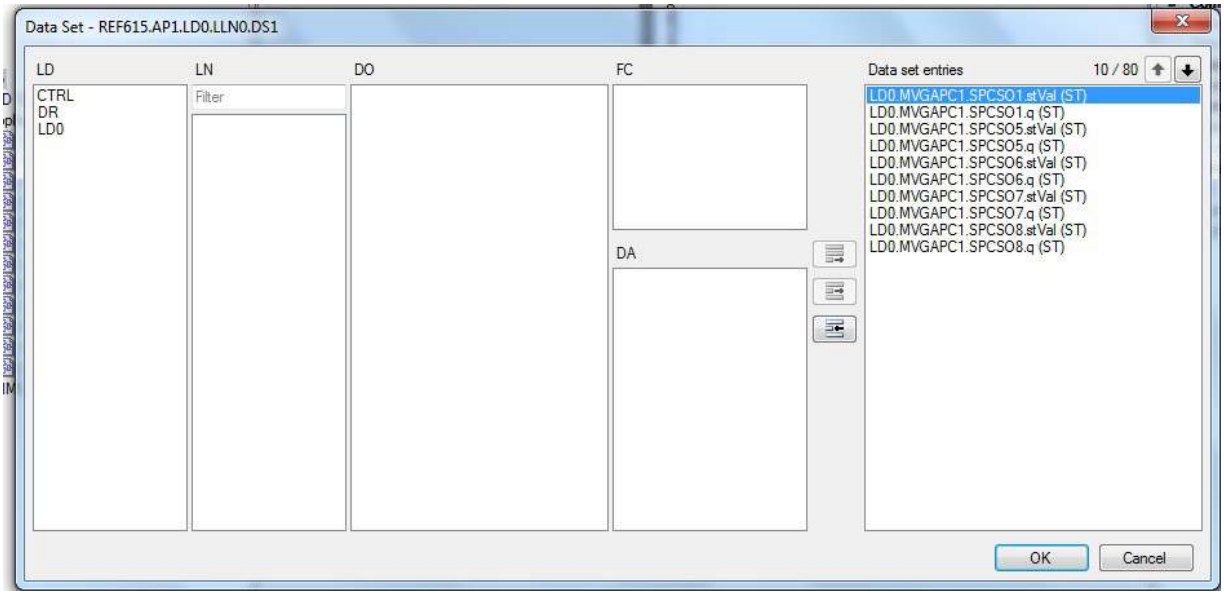


Table D



TEST RESULTS:

Expected Result	Obtained Result	Remarks
		Passed

B GOOSE test of 1. IED L90 & 2. IED P345 as per UCA

PROCEDURE TESTING SET UP:-

Fig. 5 : Test set up for GOOSE testing as per UCA procedure

TEST RESULTS:

Fig. 6 : sGos6 test as per UCA procedure

OBSERVED RESULT:

1 Project1.acc
Creation date/time: 2022-07-04 17:11:16.253+05:30

2 Test system
Device: AM033M
Software version: 2.10.0059
SCL files: P345_91A.iid

3 Test results

4 P345_91A - MiCOM P34591TF6S0910M

5 Test case Simulated GOOSE – Passed
Test type: Logic
Automated control: Off
Automated assessment: Off

6 Step 1 – 2022-07-04 17:10:10.278+05:30 – Passed

Control

Signal	Timestamp	Value	Expect value
Sim P345_91ASystem/LPHD1.Sim	2022-07-04 17:10:31.213+05:30	True	True
Signal assessment			
Signal	**Timestamp**	**Value**	**Expect value**
St P345_91ASystem/LGOS1.St	2022-07-04 17:13:05.150+05:30	True	True
SimSt P345_91ASystem/LGOS1.SimSt	2022-07-04 17:10:31.243+05:30	True	True

7 Step 2 – 2022-07-04 17:10:22.062+05:30 – Passed

Control

Signal	Timestamp	Value	Expect value
Sim P345_91ASystem/LPHD1.Sim	2022-07-04 17:13:30.327+05:30	False	False
Signal assessment			
Signal	**Timestamp**	**Value**	**Expect value**
St P345_91ASystem/LGOS1.St	2022-07-04 17:13:30.523+05:30	True	True
SimSt P345_91ASystem/LGOS1.SimSt	2022-07-04 17:13:30.327+05:30	False	False

8 Step 3 – 2022-07-04 17:10:41.563+05:30 – Passed

Control

Signal	Timestamp	Value	Expect value
Sim P345_91ASystem/LPHD1.Sim	2022-07-04 17:13:39.596+05:30	True	True
Signal assessment			
Signal	**Timestamp**	**Value**	**Expect value**
St P345_91ASystem/LGOS1.St	2022-07-04 17:13:50.390+05:30	False	False
SimSt P345_91ASystem/LGOS1.SimSt	2022-07-04 17:13:40.390+05:30	True	True

5. CONCLUSION OF TEST RESULTS

From above test results, it is concluded that proposed GOOSE testing is performed satisfactory between one manufacturer's IEDs – REF615 & REF620 which is the part of conformance testing with help of Unigrid SA software. Also test setup works satisfactory between different Manufacturers of IEDs namely IED REF615 & REF620 & as per UCA IUG test procedure version 2.0 with help of IEDScout software which is the part of Performance testing. Also IEC L90 & P345 were tested as per UCAIUG test procedure version 2.0 with help of Unigrid SA software which is the part of Conformance testing as per IEC 61850-10 standard.

6. CONCLUSION

In IEC 61850 protocol SAS, the Multivendor IEDs have to be interconnected. For the critical operation of Electrical signals like Circuit Breaker in Substation Automation System with fast messages like Circuit Breaker Trip, Circuit Breaker Close, Start, Block etc., is performed with Generic Object Oriented Substation Events (GOOSE) messages with the total transmission time of 3 to 10 milli second. The GOOSE messages are pear-to-pear data value published as per UCA test procedure falls under Conformance testing. Transfer of raw sample data were sent from Instrument Transformer to IEDs. Interoperability operation test between Multivendor IEDs was performed successfully as per UCA test procedure, falls under Performance testing. Paper has successfully developed Goose Testing of IEDs as per IEC 61850 by UCA Procedure.

Acknowledgement

The authors acknowledge the ERDA management for extending the laboratories facilities provided by Research & Development division of ERDA, Vadodara for their support for carrying out this test activity. Also we thank relay manufacturers for providing different categories of relays to ERDA.

REFERENCES

[1] Tanuhsree Bhattacharjee and Majid Jamil, “GOOSE Publishing and Receiving Operations of IEC 61850 Enabled IEDs” in 2019 IEEE 1st International Conference on Energy, Systems and Information Processing (ICESIP), pp. 1-6, Chennai, India.

[2] Apostolov Alexander, “Multi-agent systems and IEC 61850”, Power Engineering Society General Meeting 2006, IEEE, pp. 6.

[3] Amulya, Mayur Patil, S. R. Bhide, S. S. Bhat “Experimenting with IEC 61850 and GOOSE messaging” in 2017 4th International Conference on Power, Control & Embedded Systems (ICPCES), Allahabad, India.

[4] Mitalkumar G. Kanabar; Sidhu, Tarlochan S. Sidhu; Zadeh, Mohmmad R.D. Zadeh, “Laboratory Investigation of IEC 61850-9-2-Based Busbar and Distance Relaying With Corrective Measure for Sampled Value Loss/Delay” in 2011 IEEE Transactions on Power Delivery, pp. 2587-2595.

[5] Hussain, S. M. S., Farooq, S. M., & Ustun, T. S., “A Method for Achieving Confidentiality and Integrity in IEC 61850 GOOSE Messages” in 2020, IEEE Transactions on Power Delivery, pp. 2565 - 2567.

[6] Clavel, F., Savary, E., Angays, P., & Vieux-Melchior, A., “Integration of a New Standard A Network Simulator of IEC 61850 Architectures for Electrical Substations” in 2015, IEEE Industry Applications Magazine, pp. 41-48.

[7] Delavari, A., Brunelle, P., & Mugombozi, C. F., “Real-Time Modeling and Testing of Distance Protection Relay Based on IEC 61850 Protocol”, in 2020 Canadian Journal of Electrical and Computer Engineering, Vol. 13, No. 3, pp. 157–162.

[8] Hussain, S. M. S., Farooq, S. M., & Ustun, T. S., “Analysis and Implementation of Message Authentication Code (MAC) Algorithms for GOOSE Message Security”, in 2019, IEEE Access, Vol. 7.

[9] Hadbah, A., Ustun, T. S., & Kalam, A., “IEDScout software for managing multivendor IEC61850 IEDs in substation automation systems”, in 2014, IEEE International Conference on Smart Grid Communications, Venice, Italy, pp 67-72.

[10] Lee, N. H., Jang, B. T., & Song, I. J. , “The testing method of Data Transmission services of IEC 61850 based client”, in 2009 Transmission & Distribution Conference & Exposition: Asia and Pacific, Seoul, Korea (South), pp 67-72.

[11] Mekkanen, M., Virrankoski, R., Elmusrati, M., & Antila, E., “Analysis and methodology for measuring the IEC61850 GOOSE messages latency Gaining interoperability testing”, in 2014, 2014 World Congress on Computer Applications and Information Systems (WCCAIS), Hammamet, Tunisia, pp 67-72.

[12] UCA Test Procedures Server 61850-8-1 Edition 2 interface Revision 2.0 test procedure published on December19, 2018 [Author: Richard Schimmel DNV GL Netherlands B.V.], Copyright © DNV GL Netherlands B.V., Arnhem, the Netherlands. (10075662-INC 2018-v2.0).

[13] IEC 61850-8-1 Edition 2.0 2011-06 Communication networks and systems for power utility automation – Part 8-1: Specific communication service mapping (SCSM)– Mappings to MMS(ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3.

[14] IEC 61850-10 Edition 2.0 2012-12 Communication networks and systems for power utility automation – Part 10: Conformance testing.

[15] OMICRON ACADEMY BOOK ON “IEC 61850 Basics, Application and Testing” C.0055.AAX, v2.20 https://www.omicronenergy.com

[16] ISO 9506-2:2003 Industrial automation systems — Manufacturing Message Specification — Protocol specification.

[17] IED Manaual - RE_615_61850eng_756475_ENp.pdf http://www.abb.com/relion.

[18] EET&D Magazine: September/October 2018 Issue 5 , Volume 22

https://electricenergyonline.com/energy/137/magazine.

[19] IEDScout-Brouchure Versatile Software Tool for Working with IEC 61850 Devices https://www.omicronenergy.com