HAL
open science

Experimental Evaluation of an IEC 61850-Station Bus Communication Reliability

Ahmed Altaher, Stéphane Mocanu, Jean-Marc Thiriet

To cite this version:

Ahmed Altaher, Stéphane Mocanu, Jean-Marc Thiriet. Experimental Evaluation of an IEC 61850-Station Bus Communication Reliability. Journées Nationales des Communications Terrestres (JNCT 2015), Université de Grenoble 2; Laboratoire LCIS, Jun 2015, Valence, France. hal-01242280

HAL Id: hal-01242280

https://hal.science/hal-01242280v1

Submitted on 11 Dec 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Experimental Evaluation of an IEC 61850-Station Bus Communication Reliability

Ahmed ALTAHER[1], Stéphane MOCANU, Jean-Marc THIRIET

GIPSA-Lab, Univ. Grenoble Alpes, France

[1]ahmed.altaher@gipsa-lab.grenoble-inp.fr

Abstract **Recent improvements, in electrical power transmission and distribution, require considerations of existing regulations that enforce increasing of reliability and reducing of environment impact. Smart grids become industrial solutions that follow standardized development. These technologies are affected by international standardization in the field of power transmission and distribution.**

This study emphasis on modern SAS (Substation Automation System) communication standards, e.g. IEC 61850 GOOSE (Generic Object Oriented Substation Events), to present an experimental method to calculate End-To-End delay by utilizing monitoring capabilities and using network equipment such as SPAN and TAP devices.

Keywords: Monitoring, Ethernet GOOSE, ETE delay, Redundancy

I. Introduction

Modern electrical substations, i.e. electrical transmission and distribution stations, are part of smart grids. These substations follow new technological trends [1]. The IEC 61850 standard consists of 10 parts to enforce interoperability between different manufactured devices, e.g. intelligent electronic device (IED), in the substation communication systems either in station bus, bay level or process bus [2]. The standard enforces reducing of cabling complexity by using high-speed time-critical communications applying IT networking components to exchange events and states between substation devices. This standard sets a latency constraint to achieve a response time of less than four milliseconds for critical event communications, especially in the protection and automation fields [3]. This constraint is designed by many research studies providing different approaches to justify the matter of ETE latency.

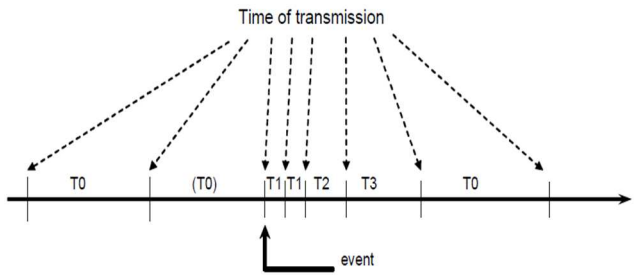
This paper is organized as the following: section II presents the IEC 61850 standards and GOOSE paradigm; section III provides an overview on the related work of IEC 61850 SAS communication latency calculation and analysis; section IV shows the modeling approach to understand the GOOSE mechanism; while section V introduces the GICS (GreEn-ER Grenoble Energy education and research Industrial Control Systems) platform with the experimental setup; section VI discussed the obtained results, and at the end, section VII concludes the paper.

II. IEC 61850 GOOSE event messaging

The IEC 61850 standard defines three communication application protocols which are GSE (Generic Substation Events), GOOSE and SV (Sampled Value). Among the benefits of this standard, reducing conventional wiring, high-speed ETE communication, high availability, and interoperability [2],

The SAS systems uses GOOSE publisher/subscriber mechanism to exchange status and events among IEDs in station bus and bay levels. GOOSE depends on Ethernet (IEEE 802.3) technology to embed its dataset (status and events) which encapsulated into the Ethernet frame payload. To improve communication reliability events and status are transmitted periodically within GOOSE messages. The standard sets retransmission intervals for a GOOSE message (Fig.1), this intervals are increased until reaching message expiration TATL (time allowed to live), new events will invoke immediately a new GOOSE messages (IEC 61850-8-1). To improve reliability, message frame includes fields such as sequential number, timestamp, state and specific Ether-Type field, i.e. two-octet field, used to indicate the encapsulated protocol in the Ethernet frame payload, IEC 61850-8-1 defined protocols uses Ether-Type value of 0x88b8 (hex) for GOOSE, and Ether-Type value of 0x88b9 for GSE management services. While SV, i.e. defined in IEC

61850-9-1 and IEC 61850-9-2, uses Ether-Type value of 0x88ba.



T0: Stable retransmission, (T0): invoked event, T1: shortest transmission time, T2 and T3: times until stable retransmission.

Fig.1 GOOSE Transmission Time (IEC 61850-8-1)

GOOSE Publisher/subscriber model is used to transmit event messages between SAS connected IEDs such as Feeder Protection, Breaker Protection and Control, station-bus level workstations, HMI monitors and etc. These messages uses a multicast address to transmit distributed datasets. Publisher will attach timestamp with increased sequential number, and also TATL field. After that transmission buffer would be used before sending the GOOSE for many subscribers via the SAS LAN. The interested subscriber will check the GOOSE message after receiving it in its buffer, in further, more checking is done at subscriber side against TATL confirming frame validity before analyzing and exhaustive processing [IEC 61850-8-1].

III. Related Work

Researchers have calculated communication latency theoretically by using Network Calculus with Algebra [4]. Other research works followed modeling and simulation approach by employing simulation software such as works conducted by OPNET Modeler in [5],[6], J-Sim in [7], and OMNeT++ in [8], while other researchers implemented a co-simulated technique to test Ethernet based IEC 61850 converter (gateway) beside legacy SAS systematic protocols to measure the communications latency[9].

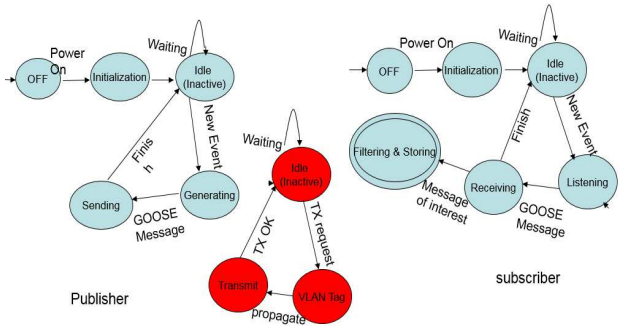


Fig.2 GOOSE publisher/subscriber model

IV. Modeling

In this research, modeling is done by employing a state machine charts. A model is therefore used to build and evaluate GOOSE real time communications (see Fig.2). The main components of the model are Ethernet network, publisher and subscriber IEDs. This model and its components are simulated to provide frame delays and to estimate the network latency in a station bus level.

The first model is used to model a simple GOOSE frame transmission in a 100 Mbps station bus architecture that gave interesting results for 16 frames with an average delay of 9.96 microseconds (fig. 3).

Since the current research objective is to analyze Ethernet based GOOSE communication pattern, i.e. time-critical messages, and to evaluate end-to-end transmission delay and message priority mechanism. In particular, to monitor, diagnose and evaluate theses parameters, especially when a network redundancy exists, a simulation model scenario is developed.

This model would be extended in future to represent redundancy mechanisms and to consider GOOSE frames sizes, contents and delays.

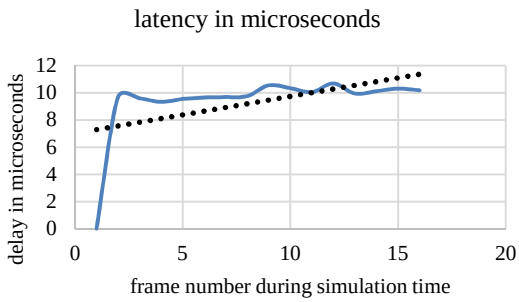


Fig.3 GOOSE Frames delay for 16 messages

V. GICS platform

This section presents the GICS platform, i.e. research and education platform, at GIPSA-Lab which is an industrial control systems platform that contains power SAS IEDs, i.e. microprocessor based physical device essentially includes logical objects and ability to communicate with other devices by standard protocols, from different vendors, process, station and bay communication networks, PLCs, protection and control devices, HMI (Human Machine Interaction) monitors and Ethernet switches with industrial features. This experimental platform is used for research studies in the field of automatic control and communications, especially for electrical power SAS systems. In particular, one of the research applications is capturing and to analyzing network communication traffic. IEC 61850-based communication implementation and testing is achieved by publishing GOOSE events in our substation platform, moreover three Siemens SIPROTEC 5 IEDs (Fig. 4-a) with network port capability are configured; i.e. 7SJ82 Feeder and overcurrent protection device, 7UT82 transformer differential protection device and 6MD85 Bay controller. In addition, to accomplish IEDs communication interoperability additional devices such as protocol gateways, IEDs from different vendors are installed and configured, e.g. ABB REF 615 (Fig. 4-b), feeder protection and control relay, many computer workstations are deployed to study the interoperability among the different devices.

Fig. 4-a Siemens SIPROTEC 5 IEDs, 4-b ABB REF 615 IED

To monitor the traffic, computer workstation is configured to capture network traffic through a physical connection attached to the network under study, furthermore, SPAN (Switch Port Analyzer) port is used to capture frames from a dedicated port in the station-bus network switch (Cisco Catalyst 10/100 Mbps with 24 ports). The captured frames is mirrored via an assigned port for more in-depth analysis. Measuring latency and bandwidth throughput is achieved by calculating time differences between captured frames in different points.

In more details the captured frames from two different nodes is performed to obtain timestamp changes between the considered protection IED and the ingress port of the switch. TAP (Test Access Point) is connected in both of nodes (Fig.5). Real-time capturing is performed at our SAS platform to guarantee precise analyzing and measurement of delay and jitter parameters.

Fig. 5 the SharkTap, Test Access Point sniffer from MidBit technologies

Captured GOOSE data frames are filtered and (Fig.6) saved in a file regarding a processing and parsing for a certain further processing, our purpose to sort and classify capture frames fields by merging the captured two-node frames and fields filtering with the required communication traffic.

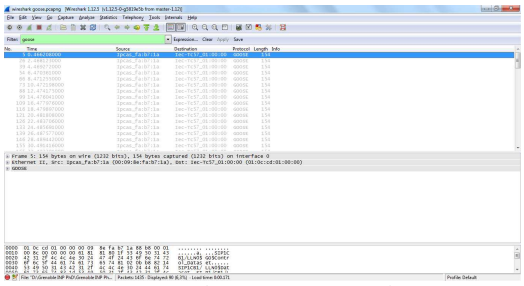


Fig. 6 captured frames with GOOSE filtering.

VI. Results and discussion

The protection and control response in time-critical environment requires rigid delivery of status and events, thus, the mentioned constraint of ETE delay in the standard [IEC 61850-7-1] should be fulfilled. The ETE delay, including propagation delay and hardware processing latency, should be less than 4 milliseconds.

In our experiment setup GOOSE frames were used as critical-time delivery mechanism in a switching LAN with 100 Mbps allocated bandwidth. The resulted GOOSE messaging average delay is conformed and satisfied according to the standard with different frame sizes, therefore, network redundancy effect should be studied in a further step to monitor double-path

messaging frames and to inspect and evaluate the time of recovery.

VII. Conclusion

In respect of the IEC 61850 standard, for critical time communication (type 1-1A), satisfied results are obtained.

Since the aim of this research is to evaluate SAS safety-related functions and their reliability, i.e. protective relay response. Hence that, current work will require further expansion to simulate the functional safety with the network redundancy. Perspective work, consisting of hardware network redundancy, will be implemented to study the effect of messaging repetition technique with different protocols.

REFERENCES

[1] ALSTOM, Network Protection and Automation Guide, May 2011.
[2] IEC 61850: Communication networks and systems in substations, 2003.
[3] S. Choi et al, Communication Interconnection Network Architecture and Logical Devices Application, International Journal of Software Engineering and Its Applications, Vol. 6, No. 3, July, 2012.
[4] H. George et al, Performance Evaluation of Time-critical Communication Networks for Smart Grids based on IEC 61850, IEEE INFOCOM Workshop on Communications and Control for Smart Energy Systems, 2013.
[5] J. XIN et al, A Priority-Based Transfer Scheme Based on Information Models in Switched Ethernet For Substation Process-Level, journal of electrical and electronic engineering, Vol. 5, No. 2, 2005.
[6] T. S. Sidhu et al, Modelling and Simulation for Performance Evaluation of IEC61850-Based Substation Communication Systems, IEEE Transactions on Power Delivery, VOL. 22, NO. 3, JULY 2007.
[7] Understanding and simulating the IEC 61850 standard, Y. Liang et al, May 2008.
[8] Simulation of IEC 61850-based Substations under OMNeT++, J. Juarez et al, 5th International ICST Conference on Simulation Tools and Techniques, P.P 319-326, Belgium, 2012
[9] M. Haffar et al, An extension to IEC 61850 for solving selectivity problem in electrical substations, 23rd IAR Workshop on Advanced Control and Diagnosis, Coventry, UK, 2008.