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An ANN based forecast for IED network management using the IEC61850 standard

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ABSTRACT

This paper presents the development of a forecast approach to manage IED networks using the IEC 61850 Standard. This is achieved by monitoring a special network occupancy parameter, which properly measures the traffic and behavior of Generic Object Oriented Substation Event (GOOSE) messages in the underlying network bandwidth. A small-scale station bus network was setup in a laboratory to test the proposed strategy. The tests revealed that IED functions may be deteriorated when the network parameter surpasses 5–15% of the available bandwidth, depending on the IED manufacturer and model. A piece of software was created to continuously calculate these parameters in the network, as well as a specially designed Artificial Neural Network, responsible for forecasting the bandwidth occupation. The software monitors and reports any possible changes in the performance of GOOSE messages, which makes it possible to use adaptive strategies in order to ensure the proper operation and performance of the protection and automation schemes.

1. Introduction

Since the IEC 61850 standard was published, a new design concept has been available worldwide for electric power substations [1,2]. The characteristics and benefits of the standard, such as seamless interoperability, high flexibility and scalability, as well as lower installation, commissioning and integration costs, make it very attractive to modern substation automation systems (SAS). In this new scenario, information such as tripping, blocking and other state signals (that once were transferred using dedicated electric channels) are now exchanged between Intelligent Electronic Devices (IEDs) using Generic Object Oriented Substation Event (GOOSE) messages in a common shared communication network infrastructure. This represents a major breakthrough for power engineers [3], since the underlying network is now a core element for protection and automation schemes considering a smart grid context [4].

Several authors such as, Ingram et al. [5], Manassero et al. [6], Matsuda et al [7], Apostolov and Tholomier [8], Sidhu and Yin [9], Ozansoy et al. [10], have pointed out some key issues about the performance and use of the standard. The most common problems are related to the overload of the communication network capabilities, incorrect configuration of devices, external attacks and eventual defective Intelligent Electronic Devices (IEDs) or communication switches.

A network management policy is a regular strategy to address some of these issues. The aim of the network management is to ensure the quality of service that users expect. This is done by collecting system information from different devices in the network in order to measure and analyze their performances and states to properly trigger control actions and report the overall network conditions.

This paper aims to develop a forecast approach to manage IEC 61850 based networks. This is achieved by monitoring a network occupancy parameter, which properly measures and quantifies the behavior of the GOOSE messages in a particular system. The occupancy parameter was used to build a software prototype, which constantly monitors and reports the IED network conditions in order to avoid the automation and protection scheme degradation. The system is based on time series, Simple Network Management Protocol (SNMP) and Artificial Neural Networks (ANNs) and was developed with the help of a specially designed laboratory testbed.

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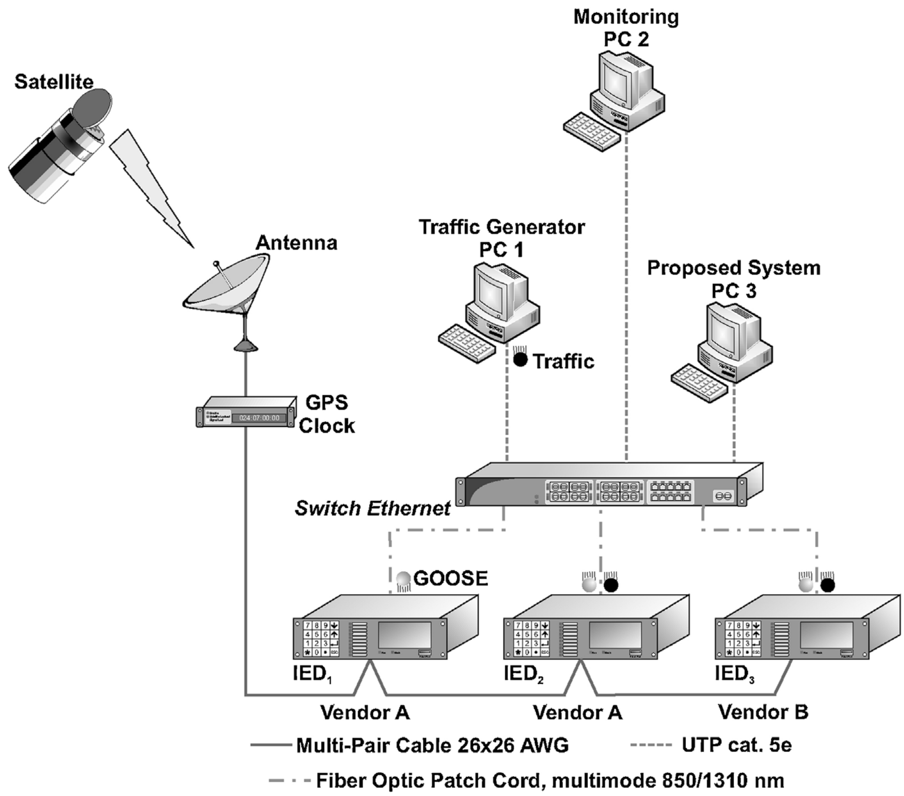

Fig. 1. Substation network testbed and its experimental apparatus.

2. Network occupancy parameter

The aim of the network occupancy parameter is to provide a discrimination point between proper operation and an unacceptable condition for transfer time of GOOSE messages considering the occupancy of the underlying network bandwidth. The determination of some performance metrics, such as mean transfer time, standard deviation, maximum and minimum transfer time, as well as the packet loss were used to find the network occupancy parameter.

2.1. Experimental procedure

In order to obtain the network occupancy parameter, an experimental apparatus was set up according to Fig. 1. This testbed mainly consists of three IEDs, an ethernet switch, three personal computers, a GPS (Global Positioning System) clock receiver and time server, optical fiber cables, unshielded twisted pair (UTP) cables, as well as support software. This structure represents, on a small-scale, an IEC 61850 station bus [11]. In this scheme, IED 1 acts as a controlled GOOSE packet publisher, while IED 2 and 3 acts as subscribers from IED 1 messages. All IEDs and the ethernet switch are commercial equipment commonly found in actual power substations.

The station bus network was set up considering a star topology, as it is easy to install, expand, reconfigure, troubleshoot and isolate problems [12–14]. The key components of this testbed are shown in detail in Tables 1 and 2. The IEDs' network interfaces were configured as 100 Mbps, full duplex, with timecode IRIG-B002, as well the ethernet switch and the personal computers, except the time code.

Table 1
General description of the equipment used in the testbed.

Equipment	Description	
IEDs	Multifunctional digital protection and automation relays, with an optical interface for communication (10/100 Mbps) and full support to the IEC 61850 protocols	
Managed switch	Interface 10/100 Mbps	14880/148800 pps
	Processing	Store and forward with IEEE 802.3x full-duplex flow-control, non-blocking
	Packet buffer size	240 KB for 10/100 Mbps
	Network standards and compliance	*Ethernet* v1.0/v2.0 IEEE 802.3: 10Base-T
		IEEE 802.3u: 100Base-TX, 100Base-FX
		IEEE 802.1p: *Priority protocol*
		IEEE 802.1d: *Spanning tree protocol*
		IEEE 802.1q: *VLAN tagging*
		IEEE 802.3x: *Flow control*
	Approval	IEC61850 EMC and class C operating conditions for power substations
	Latency	5 μs
	Scheduling mechanism	Weighted Fair Queuing (WFQ) with two priority queues
PCs	Two personal computers (IBM PC) with network card (100 Mbps, RJ-45 jack)	
GPS clock	Time synchronization with IRIG-B002	
Fibre optic patch cord	Patch cords between the IEDs and Ethernet switch 850/1310 nm	
Wire cable	Unshielded Twisted Pair Cat. 5e; multi-pair cable 26x26 AWG	