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S3N - Smart Solution for Substation Networks, an architecture for the management of communication networks in power substations

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Abstract. Today, the communications network has become an essential element to the operation of any type of organization or infrastructure, such is the case of the electrical power substations. Such networks in particular, demand high levels of availability and reliability, as the substation is a key element in the chain of energy generation and distribution. However, although recent network modernization introduced new features that allow to optimize the operation of the substation, the variety of devices that integrate it (Intelligent Electronic Devices - IED: breakers, switches, Protection and Control, Merging Units - MU, Network Switches, IEEE 1588 Master Clock) and the huge set of application-level protocols (SMV - Sample Measure Value, GOOSE - Generic Object Oriented Substation Event, MMS - Manufacturing Message Specification, PTP - Precision Time Protocols, among others), increase the management complexity. In this context, the Applied Telecommunications Research Group (GITA), has decided to propose the development of S3N - Smart Solution for Substation Networks. S3N is defined as a network architecture that introduces the novel Software Defined Networks (SDN) and virtualization technologies, in order to simplify the management of communication networks in power substations.

Keywords: SDN, network, architecture, substation, power, communication, IEC 61850, virtualization

1 Introduction

Smart Grid is a concept that aims to provide mechanisms for the generation and consumption of energy in a more efficient and intelligent manner. This concept proposes the appropriation of data networks advantages to the grid operation in the area of control, communications and monitoring [1]. To reach this purpose, the modernization of the infrastructure that supports the generation, transmission, distribution and consumption of power has caused the emergence, within the communication network, of a variety of IP compliant devices that are interconnected through a network based in Ethernet technology [2]. Currently, the automation process substation is oriented by the IEC 61850 standard [3], which covers almost all aspects of substation automation

system (SAS), providing communication specifications for operations monitoring, control and protection real time. However, this process of modernization has caused that the communication network management, in power substations, has become complex due to the large number of elements that comprise it (Intelligent Electronic Devices - IED: such as Breakers, switches, Protection and Control; Merging Units - MU, Network Switches, IEEE 1588 Master Clock), where each device is responsible for executing functions, with different requirements of connectivity, delay, bandwidth provisioning, synchronization and security [4].

Nevertheless, in recent years, the field of data networks has been permeated by two major trends aiming to facilitate the administration of complex networks: SDN and virtualization technologies, which make the network management more flexible and enable the rapid development and deployment of network services. SDN allow to provide programmability to the network infrastructure, considerably facilitating their management, while virtualization technologies allow, through software, to create a virtual version of a technological resource as an operating system, a storage device, a hardware component or a network resource, where and when it is needed [5] [6] [7].

In this area, we propose an experimental architecture for communications networks in substations, based in SDN and virtualization technologies, which is functional, secure, scalable and easy to manage by the energy operator.

This paper is structured as follows: Section 2 presents the research problem and Section 3 describes the methodology approach. Foreseen impacts are presented in Section 4, and the expected contribution and the conclusion are presented in Section 5.

2 Research Problem

Although solutions reached through SDN and virtualization technologies are positively transforming the way large datacenters, corporate networks and campuses have begun to operate their networks; it is also seen how gradually these concepts can positively impact the performance and management of the increasing complexity of communications networks in electrical substations [8] [9] [10]. However, as proposed in [11], communication networks involved in the operation of electric grid, must meet requirements that are not the same as a corporate network. For example, a substation may contain hundreds of IEDs generating and consuming critical information in real time with different requirements of connectivity, delay, bandwidth provisioning, synchronization, and security, according to its purpose or scope; not to mention, IEDs require proper maintenance and configuration.

According to the above, it can be said that the efficient, reliable and safe operation of power substation data networks, which is a critical infrastructure whose operation can significantly impact a highly energy-dependent society, is limited by the constraints introduced by high number of devices on the network (the order of hundreds, only mentioning IEDs), complex network configuration (each IED can count with 4 network interfaces to guarantee redundancy and his configuration is manual), and traffic management complexity (GOOSE is a multicast protocol that does not tolerate delays greater than 3 ms).

In this context, considering that [8] [9] [10] have only presented provisional solutions to the problem exposed through testbeds where: (i) performance evaluation was always emulated [8] [9] [10], (ii) network traffic was emulated and only limited to GOOSE and SV messages [9][10], (iii) SDN controllers based in Python were used in [8][10] (Python is a interpreted language with low performance compared to other languages), and (iv) no research proposes a complete architecture for management of substation networks, or introduces technologies virtualization as a facilitator in this type of environment, they only present as the application of SDN concepts can improve performance of different tasks on this type of networks. We consider that it is necessary to implement a complete testbed to improve the mentioned limitations, where the experimentation on real network topologies, with traffic conditions matching the wide variety of environment specific protocols (GOOSE, SV, MMS, PTP, FTP, RTSP, etc.). Besides, the use of robust (production capable) SDN controllers is required. In addition, a special interest in identifying the advantages and disadvantages that SDN can bring to communications networks into Smart Grid is growing [11] [12] [13] [14] [15]. Therefore, we have decided to propose the development of: S3N - Smart Solution for Substation Networks. A proposal with the aim of defining an architecture for the management of communication networks in power substations, with a high degree of self-configuration, availability, scalability and security; which will use the concepts proposed by SDN and virtualization technologies, for its conception.

3 Research Objective and Methodology Approach

The objective of this research is to propose an architecture for the management of network communications in power substations using the concepts proposed by SDN and virtualization technologies. In this sense, we propose the development of a methodology composed by the following steps:

1. To establish what operation requirements are more restrictive for communications networks in power substations, operating under the IEC 61850 [3].
2. To review the operating characteristics offered by SDN and virtualization technologies in order to define attributes applicable to the field of communication networks in power substations, meeting the restrictions defined under the IEC 61850 standard [3]. The study, of open standards and state of art review of partial solutions in this field, is proposed.
3. To propose models describing the features of the physical/logical elements that integrate the architecture, as well as their schemes of interaction, for the corresponding description of the architecture. For the development of this stage, it is suggested to follow the recommendations specified in the ISO / IEC / IEEE 42010 standard, System and software engineering - Architecture description [16]. This standard provides a foundational ontology to describe system architectures or software architectures. The recommendations of this international standard present a common terminology and a conceptual base that facilitates the specification of

requirements, as well as the definition, communication and review of architectures by using ADLs (Architecture description languages) .

4. To validate the functionality of the proposed network architecture by implementing use cases in a real testbed. To verify that the architecture meets the operational requirements defined by the IEC 61850 standard, compliance testing will be executed according to the guidelines of IEC 61850-10: 2005 Communication networks and systems in substations - Part 10: conformance testing. Likewise, use cases will be implemented in the following categories: Disaster Recovery, QoS Management and Security.

4 Foreseen Impact

The first impact of the project will be the formulation of an architecture for the management of network communications in power substations by using the concepts around SDN and virtualization technologies. This will provide the opportunity to obtain a communication network with a high degree of self-configuration, availability, scalability and security, which could be replicated in other scenarios of the smart grid.

Another important impact, on the level of technological development and innovation, will be the design and implementation of a proof of concept for the management of communications network in power substations, based on SDN. The possibility of implementing this technology offers enormous potential for development and commercialization, since it contributes to reduced operating and capital costs associated with management in this specific field.

5 Conclusions

The concept of automated substation, which led to the transition from traditional wired connections to an Ethernet-based network with IP support devices, introduced new features in the network, but there are still challenges to be overcome before its proper implementation in current systems.

With the development of this project, we expect to answer research questions such as: (i) can the proposed architecture deliver solutions that improve the management of the communications network in substations, ensuring existing levels of reliability and availability?, (ii) is it possible, using virtualization technologies, to transfer functions that now reside on different hardware equipments (IED's - Intelligent Electronic Device) to a virtualized environment with the aim of optimizing the operation resources (physical space, maintenance, computing capacity)? (iii) can the experimental architecture proposed, contribute to the advancement of Smart Grid concept, in line with the standards and requirements set by the sector?

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