EDGE DIGITAL SUBSTATION – A DISRUPTIVE AUTOMATION FIELD PROJECT

Aurélio BLANQUET
EDP Distribuição – Portugal
aurelio.blanquet@edp.pt

Bruno ESPÍRITO SANTO
EDP Distribuição – Portugal
bruno.espiritosantos@edp.pt

Hélder BARBOSA
EDP Distribuição – Portugal
helder.barbosa@edp.pt

Paulo SANTOS
EDP Distribuição – Portugal
paulo.costasantos@edp.pt

Bastian FISCHER
Locamation B.V. - Netherlands
bastian.fischer@locamation.nl

ABSTRACT

The constraints associated with most Substation Automation Systems (SAS) architectures used nowadays, can be overcome with a different approach. Dedicated platforms and hardware are more difficult to evolve than open platforms and standard hardware. The use of many different Intelligent Electronic Devices (IED) and sometimes with different versions and firmware, have higher operation costs and high value of spare parts' stock. Additionally, there are opportunities to design a more simple and flexible SAS architecture, allowing the development of new applications and solutions.
This paper intends to share the EDGE Digital Substation project approach, where the traditional Bay Level will disappear, centralizing protections and control functions in the Central Control Units (CCUs). For this case study document, it is proposed the following structure: introduction, current SAS architecture of EDP Distribuição, EDGE Digital Substation architecture, field project and future directions.

INTRODUCTION

The Digital Distributed System Operators (DDSO) are driven by the 4D Utilities Transformation, fueled by the 3rd technological platform and by the Industry 4.0 Accelerators. Following this reality, EDP Distribuição has taken the strategic decision to become a 4D utility, which means to be diverse, decentralized, decarbonized and digital. Through this, EDP Distribuição approaches the SAS architecture strategically by running the EDGE Digital Substation Project based on Locamation's *SASensor* solution. This base solution is a fully digital, software-defined centralized substation protection and control solution based on a redundant EDGE Controller. The separation of concerns isolates the acquisition of high-resolution data, from the application and from the data layer in order to provide an upgradable and extensible application platform.

CURRENT SAS ARCHITECTURE OF EDP DISTRIBUIÇÃO

The standard SAS Architecture of EDP Distribuição, as shown in Figure 1, relies on four different layers: Remote Management, Local Management, Bay Level and Process Level. The Remote Management layer hosts the dispatch and technical centers. The dispatch center is responsible for the optimization the grid's power flow and ensures the power supply delivery in compliance with Quality of Service (QoS) parameters, while the technical supervision center is responsible for the monitorization and maintenance of technical devices and systems. The Local Management layer is composed by two industrial computers, the CCU with SAS applications and the Human Machine Interface (HMI), both connected to a main switch integrated in the local optical fiber ring communication network. Attached to this network, there is a local GPS system that works as a time synchronization server. In the Bay Level, the IEDs receive information from the power equipment and communicate to the upper CCU through the secondary switch using the Rapid Spanning Tree Protocol (RSTP). The Process Level requires copper wired connections for the SAS interaction with the primary power equipment through digital I/O for signals and commands, and analog inputs for measurements.

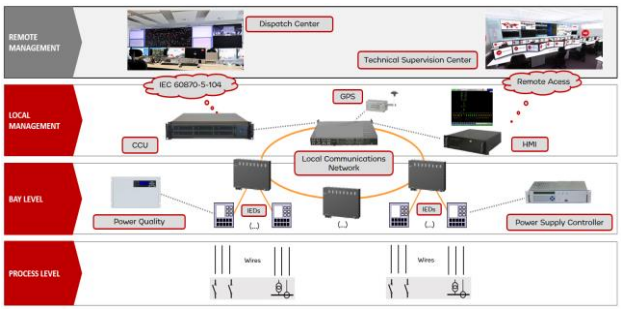

Figure 1. Standard Substation Automation System Architecture of EDP Distribuição.

With this architecture, proprietary software and hardware presents difficulties in terms of updates, expansions and renovations of the SAS compared to an open source platform were other suppliers can interact with the solution. The variety of existent IEDs, from different

suppliers, offer no interchangeability and interoperability between the bay devices and the local management software system. To overcome these constraints, EDP Distribuição is digitalizing the SAS architecture.

EDGE DIGITAL SUBSTATION ARCHITECTURE

The EDGE Digital SAS has the capability to reduce the number of discrete elements, with the exact same functionalities through centralization, standardization and simplification. This ensures a reduction in investment and operational costs for the initial SAS project and for future expansions while reducing the quantity and diversity of spare parts stock.

To better understand how the EDGE Digital Substation project is changing the actual SAS paradigm, it is imperative to understand how the functionalities are divided between the several layers in the current architecture. The Figure 2 simplifies what is represented in Figure 1 while listing the different functionalities for each layer.

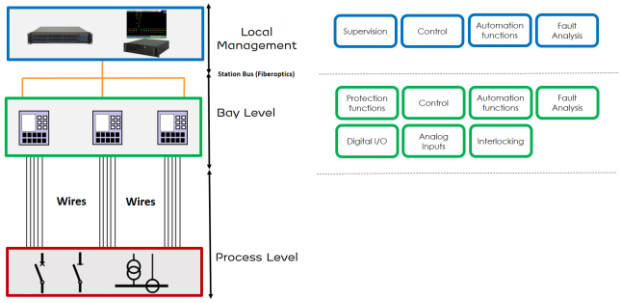

Figure 2. Standard Substation Automation System functionalities of EDP Distribuição.

In the new disruptive SAS concept, all the processing will become centralized at the Local Management, allowing the elimination of the Bay Level layer, while the digital I/O and analog inputs acquisition will be performed in the process level, as shown in Figure 3.

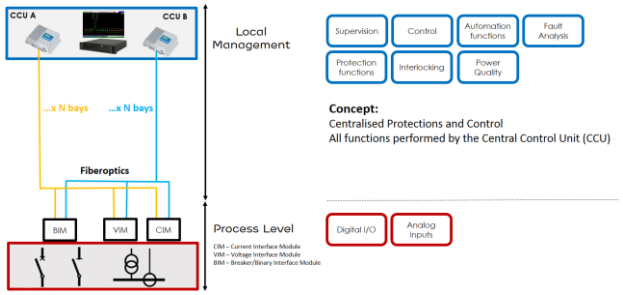

Figure 3. EGDE Digital Substation SAS System Architecture.

By design, this solution brings simplicity, longevity and integration of new features. The simplicity is met by hardware reduction (number and diversity of connected devices), easier engineering, installation, wiring and testing. The optical fiber based design, simplifies the commissioning of a substation while making it more environmental friendly, as it is expected to reduce up to 80% the use of copper wiring. In addition, it leads to a reduction up to 30% on installation times and uses up to 50% less implementation space.

The centralization of the functionalities separates the short-life devices, like the CCUs that are susceptible to several firmware and software upgrades, from the long-life devices, like the interface modules that are more robust. The process bus interface modules are designed for a life cycle of more than 30 years, that combined with the fully remote upgradable CCU ensures lower Total Costs of Ownership (TCO) over the entire life cycle of the SAS. This avoid technical or innovation obsolescence.

Therefore, centralized protections, automation and control functionalities offers the possibility to work in an integrated way in terms of software, firmware, hardware and *dataware* (data services). Since the SAS solution is based on an open-software platform, it is also expected to instigate a competitive market framework, considering the elimination of entry barriers for game changers.

The overall solution is expected to reduce the global investment costs up to 30% in comparison to the traditional architecture.

Functionalities

Regarding the protection, automation, command and control functionalities, the EDGE Digital Substation project will fulfil EDP Distribuição specifications. This means that the new digital substation must have at least the same functionalities as the classical one. The standard *SAsensor* solution from Locamation suffered updates to comply with these specifications, whose will be furthered developed and optimized along the project.

Success Indicators

There are three success indicators that must be fulfilled during the entire project. These are related to product development, system performance and supplier performance.

The product development indicator will evaluate the development of protection and automation functions according to EDP Distribuição specifications.

The system performance indicator is the result of the comparison between performance of the present solution and the new SAS solution during the Site Acceptance Tests (SAT). Until the observation period ends, the new solution will be running in shadow mode (assembled in parallel).

The indicator that evaluates supplier's performance is related to technical support, hardware shipment and both onsite and remote support during the project, accordingly to the Service Level Agreements (SLA).

FIELD PROJECT

The SAS system will be installed in a HV/MV Substation (High Voltage/Medium Voltage). The correspondent electrical scheme is shown on Figure 4.

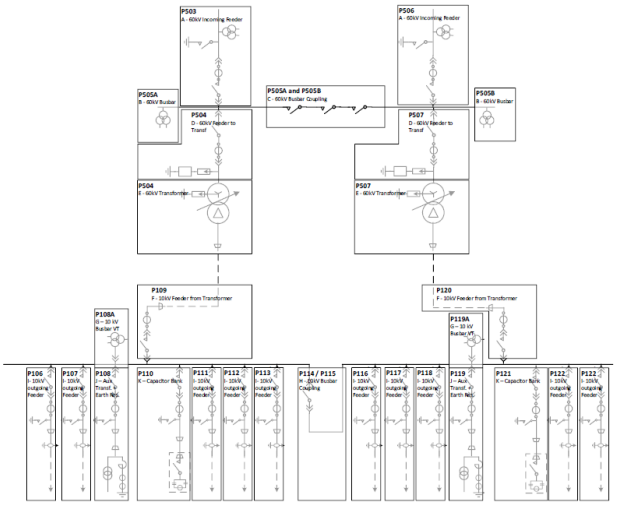

Figure 4. Substation electrical scheme.

The HV level operates at 60 kV and is composed by:

- 2 incoming line feeders;
- 2 busbars;
- 1 busbar coupling;
- 2 feeder-to-transformer bays.

The MV level operates at 10kV and is composed by:

- 2 feeder-to-transformer;
- 2 busbars;
- 1 busbar coupling;
- 10 outgoing feeders;
- 1 LV transformer plus neutral reactance;
- 2 capacitor banks bays.

This substation represents a standard EDP substation, since it has at least one bay of each type, allowing the analysis of the system performance between each different bay and the CCUs.
The SAS system will be installed and operated in shadow mode (Figure 5) and thus running in parallel with the currently installed equipment. Therefore, the new system will be receiving measurements and signals from protections, automations and communications equipment without being able to perform control commands because these will be physically disconnected. This methodology allows EDP Distribuição to acquire not only knowledge and operational experience but also to be less intrusive, since the old system will be fully operational while the new one is being tested. The new system can be put in service at any time.

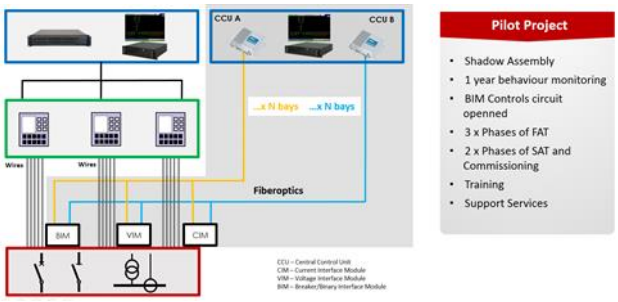

Figure 5. New SAS in shadow mode.

FUTURE DIRECTIONS

Looking forward to the future, this new project architecture paves the way from the present to an Automation Cloud. As shown in Figure 6, the EDGE Digital Substation is the first step towards this insight. The current architecture of this project is using two CCUs in the same substation to fulfil the needs of redundancy and resilience.

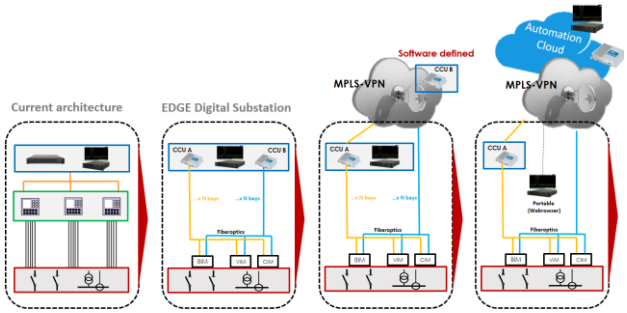

Figure 6. Substation Automation Control System Evolution Insight.

In a future step, together with the new IP-MPLS communications network (EDP Connect Program), it will be possible to use only one CCU per substation since redundancy will be accomplished by neighbor SAS.
These redundancy CCUs can also be installed in a data center, leading to a fully automation cloud concept. This will leverage a new SAS age, consisting in an electrical and communicational network of digital substations, which widely opens future possibilities to be explored (IoT, big data analytics, machine learning, artificial intelligence and blockchain).

REFERENCES

[1] Working Group on Centralized Substation Protection and Control, IEEE Power System Relaying Committee, 2016, "Advancements in Centralized Protection and Control Within a Substation", *IEEE Transactions on Power Delivery*, vol. 31, no. 4, 1945-1952

[2] Ratan Das, Mital Kanabar, 2015, "Centralized Substation and Control", *IEEE PES Power System Relaying Committee, Report of Working Group K15 on the Substation Protection Subcommittee*

[3] Adam Thompson, 2016, "The Future of Substations: Centralized Protection and Control", *Faculty of Virginia Polytechnic Institute*

[4] Jens Ljungberg, 2018, "Evaluation of a Centralized Substation Protection and Control System for HV/MV Substation", *Uppsala Universitet*

[5] Bastian Fischer, 2017, "TUA09 Software Defined Digital Substation Automation", *PACWorld*, Paper OP39

[6] Erin Spiewak, 2018, "PC37.300 - Guide for Centralized Protection and Control (CPC) Systems within a Substation", *H45 Working Group*