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Q2.01: What are the challenges in the development of digital substations and how to address the problems caused by the digitalization?

Digitalization is the new era for the electric power industry around the word. Digital substations bring many benefits, including better measurement accuracy, higher system availability, remote monitoring, reduction of installation and commissioning time, functional integration and increased safety. Furthermore, Digital Substations could be continuously updated to meet new operating conditions and requirements.

Despite the benefits of digitalization, according to the authors' experience, there are still many issues to be addressed, as listed below.

Technological obsolescence: digital substations are affected by obsolescence, both at the station level (e.g., HMI workstation, station computers, RTU) and at the bay level (e.g., control, protection, and monitoring IED). Since the commissioning of a digital substation, the performance of the hardware devices can be reduced due to their age and the amount of required operation; this could result in an increasing number of failures that can affect the quality and security of supply and can increase the maintenance cost.
Furthermore, unavailability of spare parts contributes to the obsolescence of hardware devices. In fact, some manufacturers could no longer produce spare parts for the specific older device, due to unavailability of its components, or could decide to upgrade the device project to gain better performances; this results in issues related to porting, licensing and increasing cost of the spare parts.
To mitigate technological obsolescence, it's possible to take inspiration from the concept of *Virtualization.* This solution is today mainly adopted in the IT environment (Data Center), but many utilities are exploring how to apply virtualization to PACS/OT environment without compromising performance, availability, and reliability of mission critical applications. Typically, in many digital substations a separate hardware device (e.g., station computer, HMI, RTU etc) is used to provide a specific typology of functions (e.g. devices dedicated to cyber security, other device dedicated to substation monitoring and remote control, condition-based maintenance functionality, and others). In general, each device is dedicated to homogeneous tasks. Virtualization could allow to optimize the hardware by integrating many functions, that could be even heterogeneous, into a fewer number of hardware devices. By using virtualization, each application, even if implemented on the same hardware, can be run and operated separately. This results both in a hardware reduction and in a greater level of decoupling between hardware and software so mitigating impacts related to the renewal of hardware platforms or to the issue of newer versions of operating systems.

Vendor dependency: digital substations imply higher levels of vendor dependency during its whole lifecycle. The main challenge here is related to company strategies: to dominate a certain digital technology, a deeper understanding and knowledge of its deployment is required; the definition of detailed technical specifications is an important step to control the first stages of the PACS lifecycle, but it is not enough to guarantee the independence from the vendor during the following stages.
There are different ways to face the dependence on manufacturers, such as:

- *adoption of international standards*;
- *promotion of the interoperability;*

- *increase of internal know-how.*

Each of them must be addressed in a proper way.
The adoption of IEC 61850 as reference standard is not enough to guarantee an effective interoperability between IED coming from different vendors. It's necessary to know the standard and to address the system integration by defining a detailed datamodel to which all vendors should be conformant. Despite this, even if interoperability and integration of additional devices should be possible, the dependence on the original manufacturer is still strong due to the adoption of proprietary software and configuration tools. It's then necessary to improve internal knowledge: this could be addressed by the development of in-house projects, staff training and the creation of company internal competence centres.

Need for specific skills: The rapid technological evolution and consequential obsolescence of PACS are commonly recognised factors that make knowledge management a critical matter in the digitalization era. To exploit the benefits brought by digital substation, it is necessary to go deeper into a more and more wide area of concepts and specializations such as data networks, communication protocols, system integration and configuration, cyber security and, last but not least, computer vision, virtualization and artificial intelligence. There is a continuous need for specific training of internal staff to maintain PACS along its whole life cycle. The main challenge here is that technology is constantly evolving; therefore, the required skill set consists of mixed generations and this knowledge must be retained. A full assessment is required to create a skills matrix which must then be maintained during the whole PACS life cycle. From this point of view, it is necessary to extend the knowledge and bridge the skills gap for the whole personnel involved in the maintenance and operation of digital substation. Moreover, digital systems become more and more complex and the efforts for testing communication, interlocking logics and proper operation of all configurations have grown exponentially; here digital technology offers the opportunity to develop engineering tools and automated procedures to simplify the factory acceptance test (FAT) and site acceptance test (SAT). Testing tools and procedures should be more and more user friendly and focused on the controlled process, to be useful for the technical teams involved in commissioning activities and not specialized on "digital" matters. This could result in a drastic reduction of time required for FAT and SAT without sacrificing high quality levels, even improving them.

Cybersecurity: The rapid evolution of communication and technologies applied to the process have made it possible to increment the monitoring of information flows made available from the station devices (e.g., IED, Station computer) to monitor the state of electricity grid and of its assets. Through remote access, the qualified personnel can evaluate the status of the equipment without physically accessing to the site, saving both valuable time and resources. Although remote access to information gives operators much more visibility of the system for diagnostic and maintenance purposes, it also introduces new concerns and challenges related to cybersecurity; in fact, cyber threats that can raise not only from voluntary external attacks, but also from inadvertent errors caused by technical personnel operating in the substation (often due to of the growing complexity of the digital PACS). Cyber security will be always a challenge on a global scale; no single solution can guarantee the system security, but it is necessary to apply an efficient and holistic security approach (e.g., adoption of one-way policies, whitelisting, patch management, hardening, firewalling etc) depending on the system architecture, software, hardware, operating system, and communication network.