The implementation of the Process Bus according to IEC 61850 represents a major advancement for PACS, offering several advantages, but also presenting some challenges that must be considered.

Deploying a digital substation with a complete solution involving IEDs equipped with digital process interfaces and all other functionalities defined by the IEC 61850 standard brings various benefits, including:

- Interoperability: due to standardized messaging and data models, devices from different manufacturers can exchange information with one another;
- Simplified connections by replacing rigid copper wiring with network cables;
- Financial savings: both from replacing copper cables with network cables and from structural simplification. Structurally, there is investment savings in foundations by replacing conventional CTs and VTs with LPITs (Low Power Instrument Transformers) at the process level. Additionally, there are savings from the reduced area required for substation construction;
- Safety: in this new context, electrical quantities (voltage and current) are no longer handled directly; instead, information is transmitted. Therefore, the inherent danger of an explosion caused by an open CT secondary is eliminated when working with Merging Units (MUs) in the substation yard and data traffic only.

Alongside these benefits, the IEC 61850 standard also introduces new challenges related to the paradigm shift it imposes. In a digital substation based on IEC 61850, the Process Bus stands out due to the critical nature of the communication protocols it carries, involving Sampled Values (SV), GOOSE messages with trip information, and time synchronization via PTP. In addition to technical challenges, economic challenges exist as well, requiring strategic planning for the effective implementation of the Process Bus.

In keeping with the technological evolution of PACS, test tools must be capable of performing tests in both analog and digital contexts, and with the full range of IEC 61850 functionalities.

Testing in the context of digital substations based on IEC 61850 is of vital importance and must be carried out with the same rigor as in conventional substations, as close as possible to real-world scenarios. Otherwise, if a failure occurs in the system and there is a real fault, the resulting cost could be exponentially higher.

IED failures can result from hardware, firmware, configuration, or even wiring issues, which can lead the IED to operate incorrectly or fail to operate at all, potentially causing millions of dollars in damages and even loss of human life. New operating conditions thus demand new conditions to be analyzed, that is, new testing procedures.

When analyzing only the IED itself within the context of IEC 61850 functionalities, the test device no longer needs to generate power, since it does not need to reproduce analog secondary voltage and current signals. It only needs to be capable of sending SV messages to the IED under test. However, to test other parts of the system such as the SAMU (Stand Alone Merging Unit) or the CT/VT, the test equipment must still be capable of injecting current and voltage.

Figure 1 illustrates, in a simplified manner, the various combinations of tests in which the test tool is essential to the protection system, involving both analog injections and GOOSE/SV publishing and

subscription.

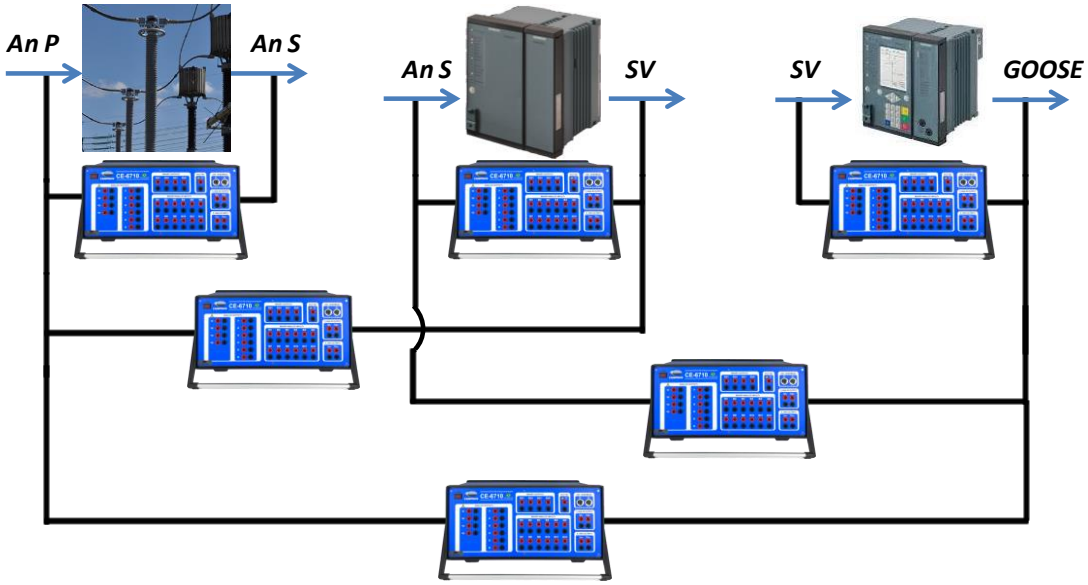

Figure 1 - Importance of the Test Tool in Various Test Combinations