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Key drivers of the energy transition that are surveyed across the globe are listed in Figure 2. A higher penetration of renewables at the transmission level with inverter-based resources (IBRs) and distributed energy resources (DERs) at the distribution level have started influencing not only T& D infrastructure planning, but also operational controls and maintenance decisions. There is also increasing demand due to electrification of other industries. The transportation industry for instance, is expected to integrate charging infrastructure to the grid for electric vehicles.

The microgrid real-time controller is responsible for maintaining the reliability of the system, while following the optimal dispatch plan generated by the optimizer. This is achieved through communication with various intelligent electrical devices (IEDs) and the onsite DERs.

Process interface units installed close to or as part of, primary equipment, are used to digitize the signal interface and communicate to process bus over interoperable IEC 61850-9-2 or IEC 61869-9/13 standards. The software and settings at the process level need to be minimal or, if possible, with minimum settings and segregated layer-2 (ethernet) level traffic. Easy-to-install hardware delivers higher reliability, and, with interoperable protocols, this data would be available to any application at the bay or station level.

Multi-speed of Technologies for a Substation: The historical evolution of protective relaying technology has been significantly influenced by electronics and communication developments. The next generation of digital protective relaying is also receiving direction from evolving technology trends of the industrial internet of things (IIoT), virtualization, digital interfaces of combined optical CT/VT and circuit breakers, as well as digitized primary equipment. Figure 9 illustrates the differences in various technological evolution cycles related to the substation PAC system.

Software-Defined System with Flexibility and Fast Innovation integration: Figure 10 presents innovation driving software-defined grid automation and control platforms. The virtualized architecture may have the potential to migrate non-mission-critical substation automation from native specific hardware platforms to virtual machines or even cloud-native containerized applications.

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