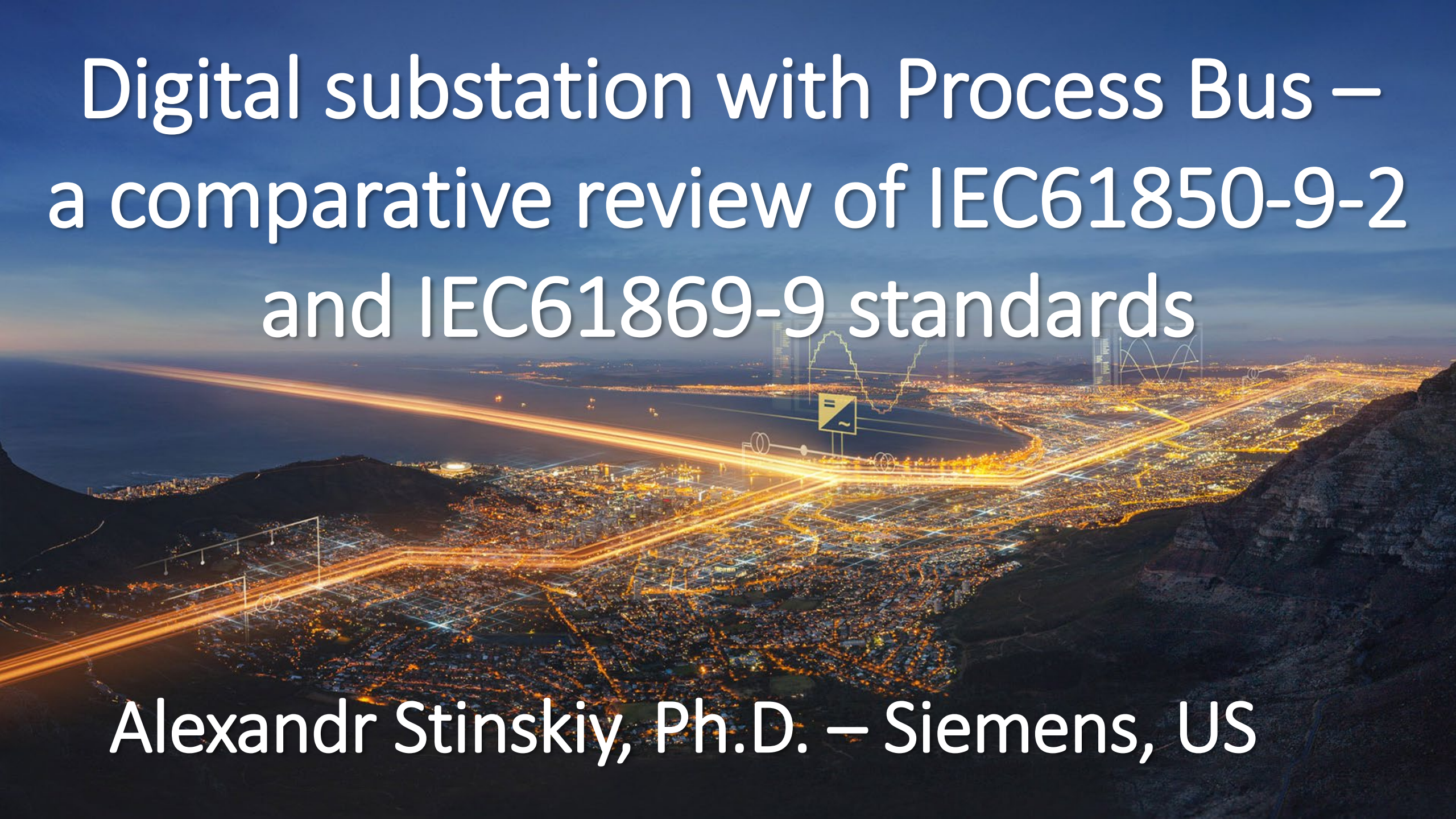
Digital substation with Process Bus – a comparative review of IEC61850-9-2 and IEC61869-9 standards



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Digital Substation and Process Bus benefits

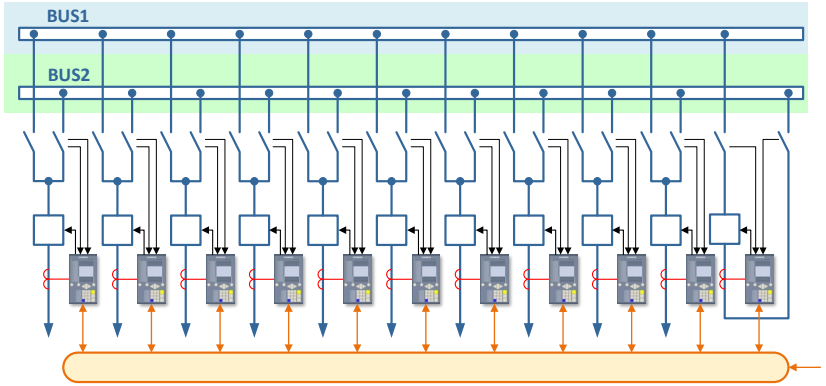
Primary Equipment

- Reduction of the CT burden can reduce the cost for the primary CT
- Operational safety – reduced danger of open CT circuits

Merging Unit

- Copper cable reduction, faster installation and commissioning
- Interoperable design enables multi-vendor solutions
- Improved safety – no CT/VT circuits in the control house

Process Bus implementation



- Control house space reduction
- Advanced functionality – allows centralized protection, PQ and IoT applications
- Flexibility and scalability – easier adaptation to future requirements and integration
- Storm hardening and EMP applications
- Gateway to PAC virtualization

IEC61850-9-2 Standard

- Historically the framework of digital substation architectures was built on the IEC61850-9-2 standard

- Standard was specifically designed for comprehensive substation automation systems requiring high-speed, precise communication of sampled values for critical tasks such as protection, control, and monitoring

- IEC61850-9-2 is focusing on data models, communication protocols, and performance criteria tailored for the unique demands of digital substations.

- The standard employs an abstract data model that represents electrical quantities as SMVs. These models are designed to be universal, facilitating interoperability among devices from different vendors. The data model includes attributes like magnitude, quality, and timestamp, ensuring comprehensive data for analysis and action

IEC61850-9-2LE

- The IEC61850-9-2LE (Light Edition) is introduced to simplify the implementation for digital substation systems that do not require the full bandwidth or performance capabilities of the original standard.

- The light edition is well suited for cost sensitive applications or digital systems with less demanding requirements. This standard requires less bandwidth compared to the original standard.

- Supports high sampling rates (typically 80 SPP for protection and 256 SPP for measurement or power quality applications) to ensure detailed waveform analysis and requires higher performance

- Sampling rate definition depends from the power system frequency, which leads to a wider range of sampling rates;

- Fixed data set of 4 currents and 4 voltages

IEC61869-9 Standard

- The IEC 61869-9 standard is introduced to define the digital communication of instrument transformers in electrical power systems
- Offers backward compatibility for devices using 61850-9-2LE
- Sampling rate definition independent from the network frequency. Utilizes 4800 Hz and 14400 Hz (vs. 80 smpl/cycle and 256 smpl/cycle for 61850-9-2LE)
- Uses IEEE 1588 as sample synchronization source, with IEC 61850-9-3 as PTP profile, besides PPS
- Flexible dataset in any mixture of current and voltage channels. Merging unit can publish up to 32 channels per data stream
- Better network bandwidth utilization for dataset compared to 4I and 4U of IEC 61850-9-2 LE

Technical specification comparison

- IEC61850-9-2 is designed for high-speed communication of sampled values, supporting advanced digital substation automation and protection applications.
- IEC61850-9-2LE provides a simplified version of the original standard above, suited for less critical applications where lower bandwidth and simple overall architecture are beneficial.
- IEC 61869-9 defines the digital output of instrument transformers, specifying the communication for accurate and efficient transmission of measurement data.
- All standards ensure interoperability through compliance with the IEC 61850 series. However, IEC61850-9-2 offers the most comprehensive support for advanced interoperability scenarios, given its detailed specifications and widespread adoption.

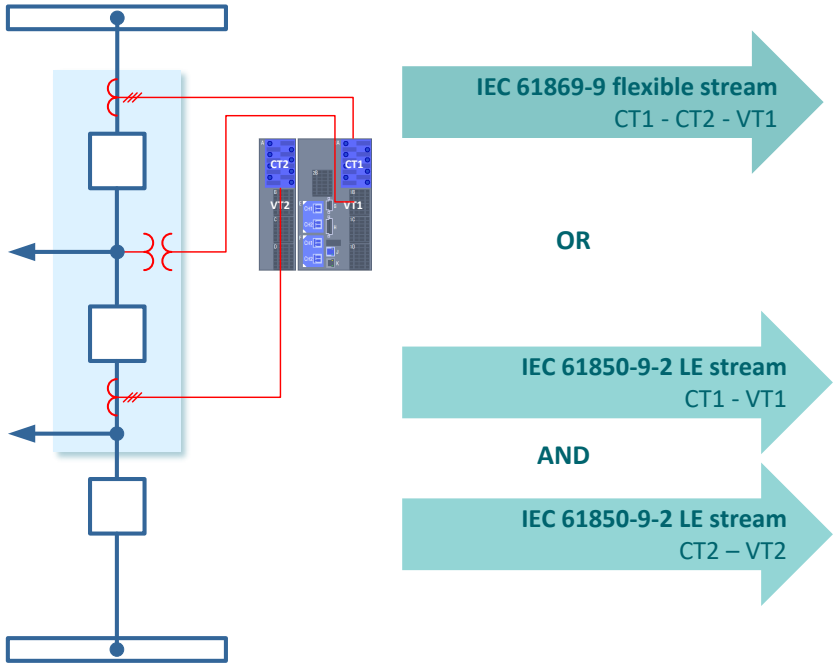
Data handling

- IEC61850-9-2 and IEC 61869-9 are similar in terms of handling of high-frequency SMVs, best suited for high precision applications.

- IEC61850-9-2LE, while still effective, handles SMV at potentially lower sampling rates, making it more suitable for applications with less stringent timing requirements.

Bandwidth requirements and performance

- IEC61850-9-2 demands higher bandwidth due to its higher sampling rates and more complex data models.
- IEC61850-9-2LE is optimized for reduced bandwidth consumption allowing more IEDs to share SMVs utilizing less complex network infrastructure.
- The bandwidth requirements of IEC 61869-9 can vary based on the specific application and configuration.



IEC 61869-9 flexible stream
CT1 - CT2 - VT1

OR

IEC 61850-9-2 LE stream
CT1 - VT1

AND

IEC 61850-9-2 LE stream
CT2 – VT2

Stream Type	Required # of Streams	Network Load	Delta Network Load to 9-2 LE
IEC 61850-9-2 LE (4CT, 4VT, 4800 Hz – 1 ASDU)	2	12,98 Mbit/s	0 %
IEC 61869-9 (8CT, 4VT, 4800 Hz – 1 ASDU)	1	7,72 Mbit/s	-41 %
IEC 61850-9-2 LE (4CT, 4VT, 12800 Hz – 8 ASDU)	2	23,32 Mbit/s	0 %
IEC 61869-9 (8CT, 4VT, 12800 Hz – 8 ASDU)	1	14,94 Mbit/s	-36 %

SMV Datasets

- SMV data sets in IEC61850-9-2 are detailed and designed for high performance, supporting complex applications.

- IEC61850-9-2LE offers a simplified SMV data set structure, reducing the complexity and size of the data. Both have fixed number of current and voltage channels (four currents and four voltages).

- IEC 61869-9 SMV data sets are tailored for the digital output of instrument transformers, focusing on measurement accuracy and efficiency. This standard provides flexibility in dataset configuration, allowing for any combination of current and voltage channels. Merging units can support up to 32 channels in the single stream, making IEC61869-9 standard ideally suited for modular MUs with multiple CT/VT connections.

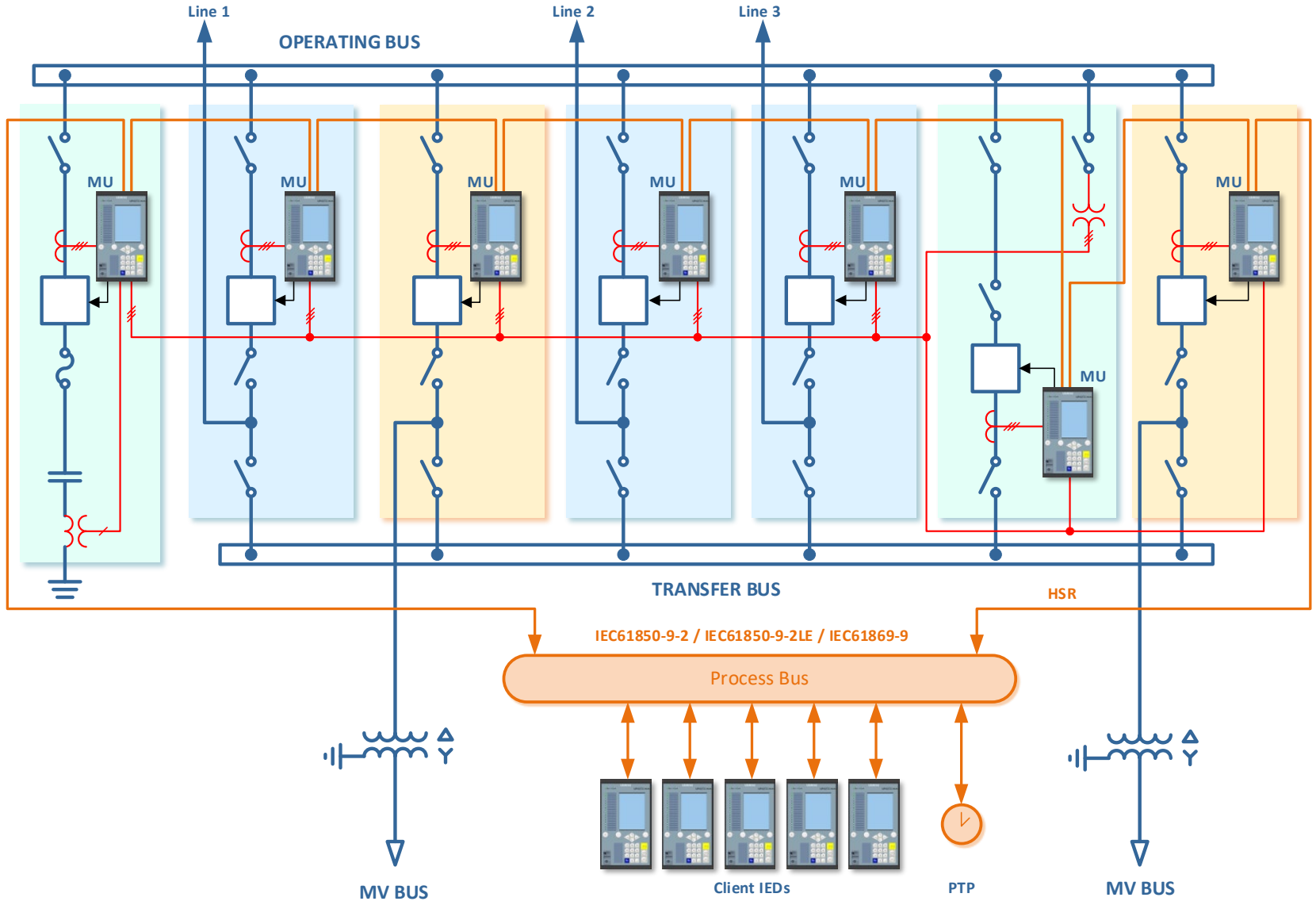
Challenges and limitations

- Ensuring adequate bandwidth for IEC61850-9-2LE and IEC 61869-9 applications requires careful planning and investment in network infrastructure
- Despite the focus on interoperability, real-world applications may encounter challenges due to variations in device implementations and configurations
- Adapting existing systems to comply with these standards, especially in older substations, can pose scalability and integration challenges with IED fleet from multiple generations.

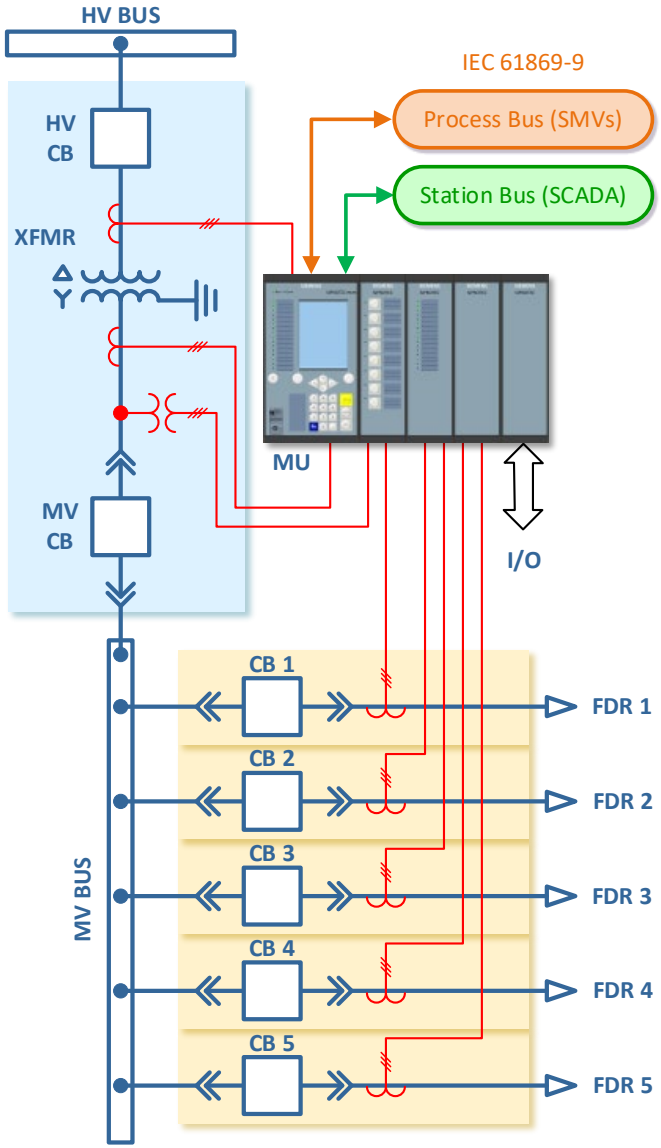
Sample Rate (Hz)	ASDUs	Payload (Bytes)	Frame Size (Bytes)	Transmission Rate (Mbit/s)	Max possible streams for 100Mbit network
4000	1	121	169	5.408	11
4800	1	121	169	6.490	9
4800	2	227	275	5.280	11
12800	8	863	911	11.661	5
14400	6	651	699	43.421	4
15360	8	863	911	13.993	4

Process Bus application example

- Each merging unit provides ASDU with 4I and 4V channels
- HSR network redundancy supports up to 15 MUs in the ring
- Either IEC61850-9-2LE or IEC61869-9 are applicable



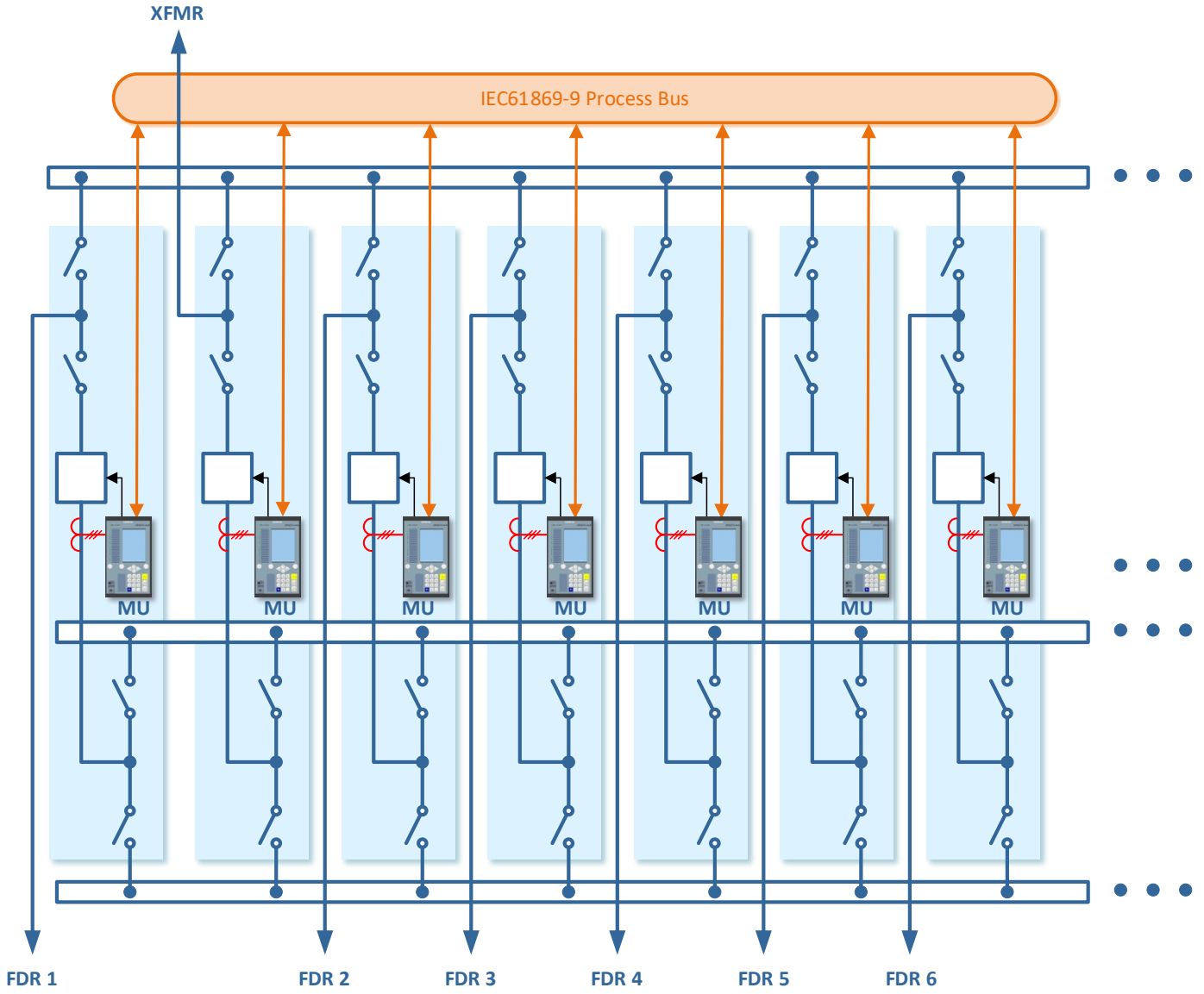
Application example with modular MU



- Application with modular MU (multiple CT and VT inputs)
- Applications with strict space limitations, such as data centers or mobile substations
- The IEC61869-9 standard allows to publish multiple analog channels in a single data stream (up to 32 channels in modern IEDs), mixing current and voltage signals as needed
- MU can also broadcast the same data at different sampling rates, serving protection and power quality monitoring systems
- Employing IEC61850-9-2LE for such applications is not desirable, since each MU current input would necessitate a corresponding voltage input, resulting in more data streams and ineffective MU hardware utilization.

Distributed Busbar Protection

- Distributed busbar protection
- Protection relay requires currents from every circuit within the protected zone(s)
- Applicable for large distribution substations with numerous circuits
- Busbar protection IED can subscribe to currents from up to 45 merging units
- The IEC61869-9 standard facilitates the most efficient implementation



Conclusion

- The IEC 61850-9-2 and IEC 61869-9 standards play a pivotal role in digital substation environment
- IEC61850-9- 2LE, with its reduced bandwidth requirements, offers a cost-effective alternative for less critical applications
- Meanwhile, IEC 61869-9 focuses on the digital output of instrument transformers, providing more flexibility and better network bandwidth utilization