

End to End Resilient Timing Architecture – Digital Substation with Process Bus



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Agenda

- **Digital substation with process bus - time synchronization requirements**
- **Time synchronization vulnerabilities and mitigation**
- **End to end resilient timing architecture**

Digital Substation with Process Bus

Time Synchronization Requirements

Digital Substation with Process Bus

Time Synchronization Requirements

- **Digital substation with process bus inter-substation protection typically requires IEC 61850-5 Time Performance Class T5 (<1 μ s)**
 - Substation merging units require master to be advertising PTP clock Class 6 or 7 with accuracy better than 250 ns
- **Time synchronization must be high availability**
- **Real-time monitoring of time synchronization assets**

Vulnerabilities and Mitigation

Vulnerabilities and Mitigation

Time synchronization vulnerabilities	Mitigation
GNSS jamming or interference	Holdover, alternate high accuracy sync sources
GNSS spoofing	Machine learning and signal characterization, multiband and multi constellation, alternate high accuracy sync sources
Poor antenna placement and urban canyons	Multiband and multi constellation, holdover
Lightning or other environmental events	Holdover, GM redundancy, alternate high accuracy sync sources
Erroneous data caused by third party subsystems	Machine learning, sanity checking and alternate high accuracy sync sources
Erroneous data broadcast through the constellations	Machine learning, sanity checking and alternate high accuracy sync sources
Hardware failure	GM redundancy, network redundancy, dual power supplies
Leap seconds, GPS week number rollover, epochs and eras, software arithmetic overflow	Machine learning, sanity checking and alternate high accuracy sync sources

Mitigation Techniques

- **Multiband and multi constellation (< 5 ns RMS)**
- **Alternate high accuracy sync sources**
 - Optical networks (DWDM, OTN) PTP Telecom Profile ITU-T G8275.1 < 100 ns from core to the network edge
- **Enhanced holdover through high grade oscillators**
 - OCXO, Rubidium
- **Machine learning, Sanity checking and signal characterization**
- **PTP grandmaster redundancy**
- **Dual power supplies**
- **Network redundancy**
 - IEC 62439-3 Parallel Redundancy Protocol (PRP)

End-to-End Resilient Timing Architecture

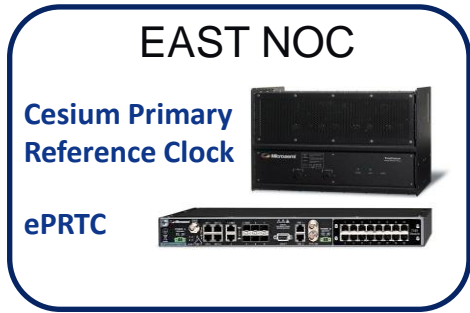
Communications Network – Timing Requirements

Communications

Substation

Core to the Edge - ePRTC to HP BC PTP Output ≤ 100 ns

Digital Substation Clock
PTP Output ≤ 250 ns

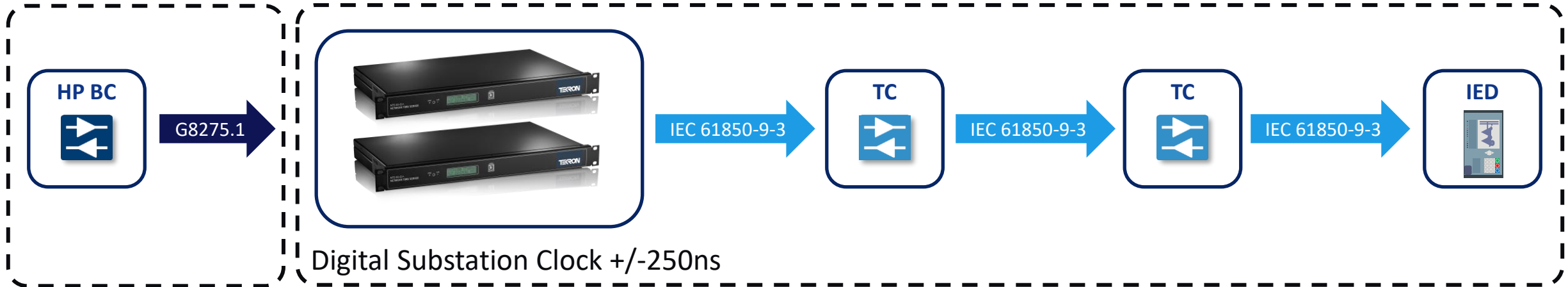


ePRTC = +/-30 ns



Source of Time	Transport BC Class	Edge Timing Requirement
PRTC A: < 100 ns	A: cTE < 50 ns	< 100 ns
PRTC B: < 40 ns	B: cTE < 20 ns	
ePRTC: < 30 ns	C: cTE < 10 ns (HP BC)	
	D: cTE For further study	

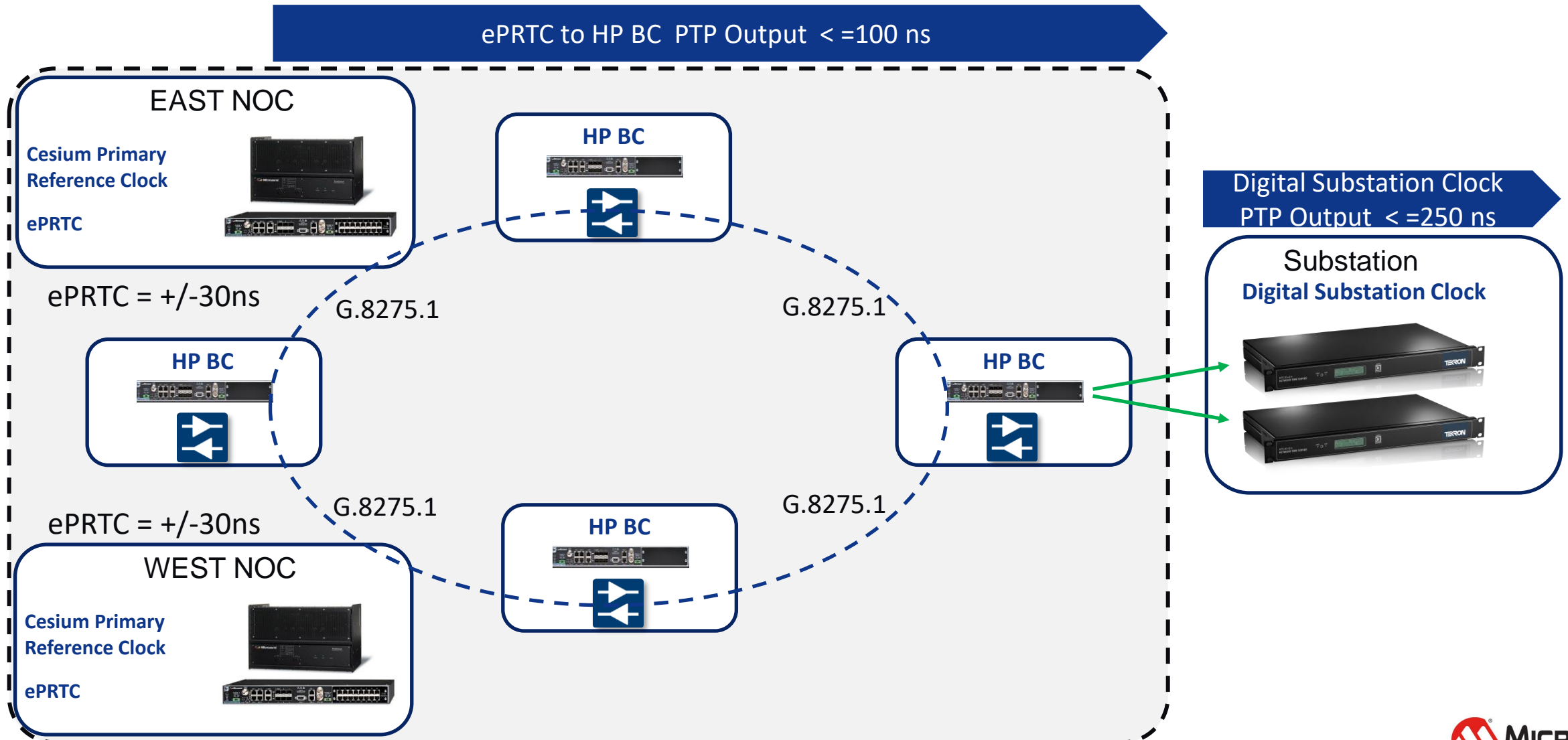
Substation – Timing Requirements



Clock Type	IEC 61850-9-3 Time Inaccuracy
Grandmaster Clock (GM)	< 250 ns
Transparent Clock (TC)	< 50 ns
Boundary Clock (BC)	< 200 ns

Resilient Timing Architecture

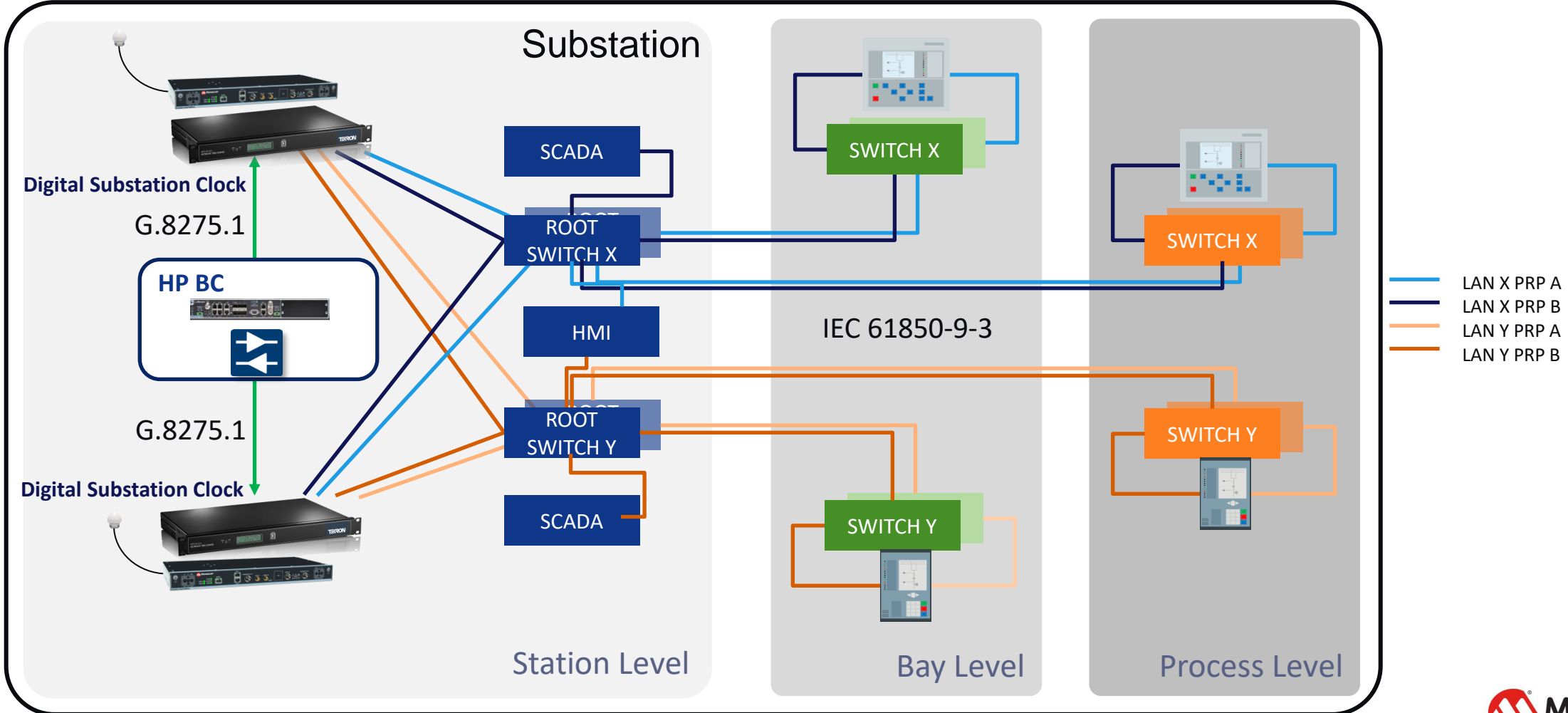
Communications Network



Resilient Timing Architecture

Substation Protection and Control System Network

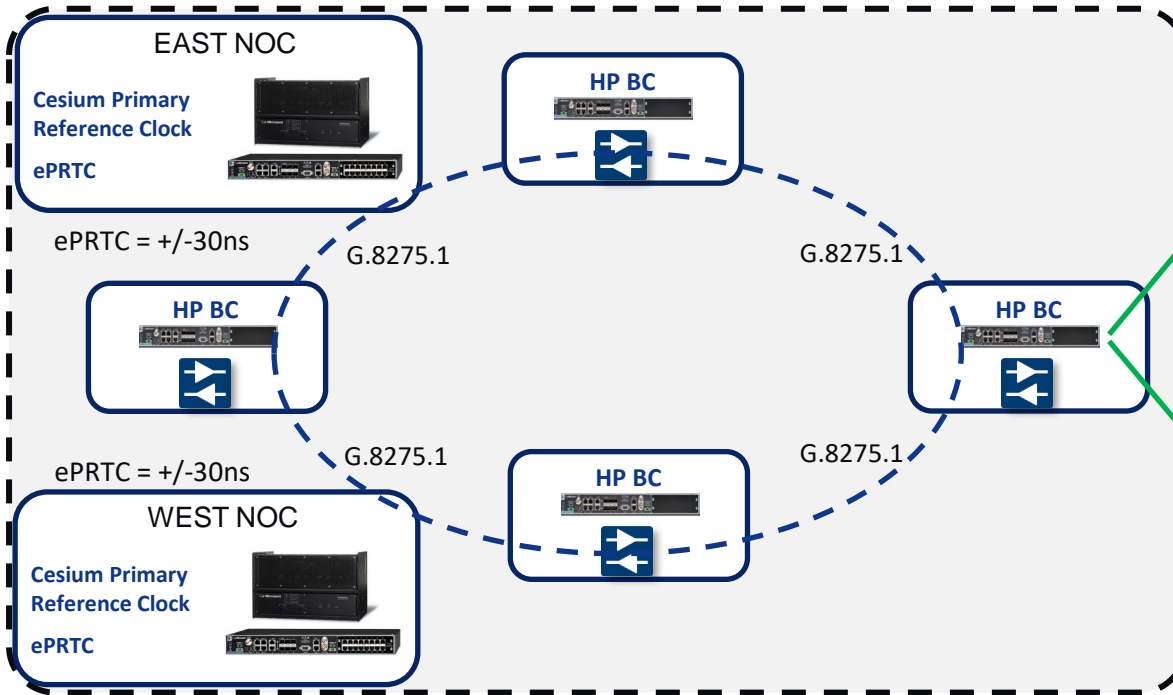
Digital Substation Clock PTP Utility/ Power Profile Output to SS IED $\leq 1 \mu s$



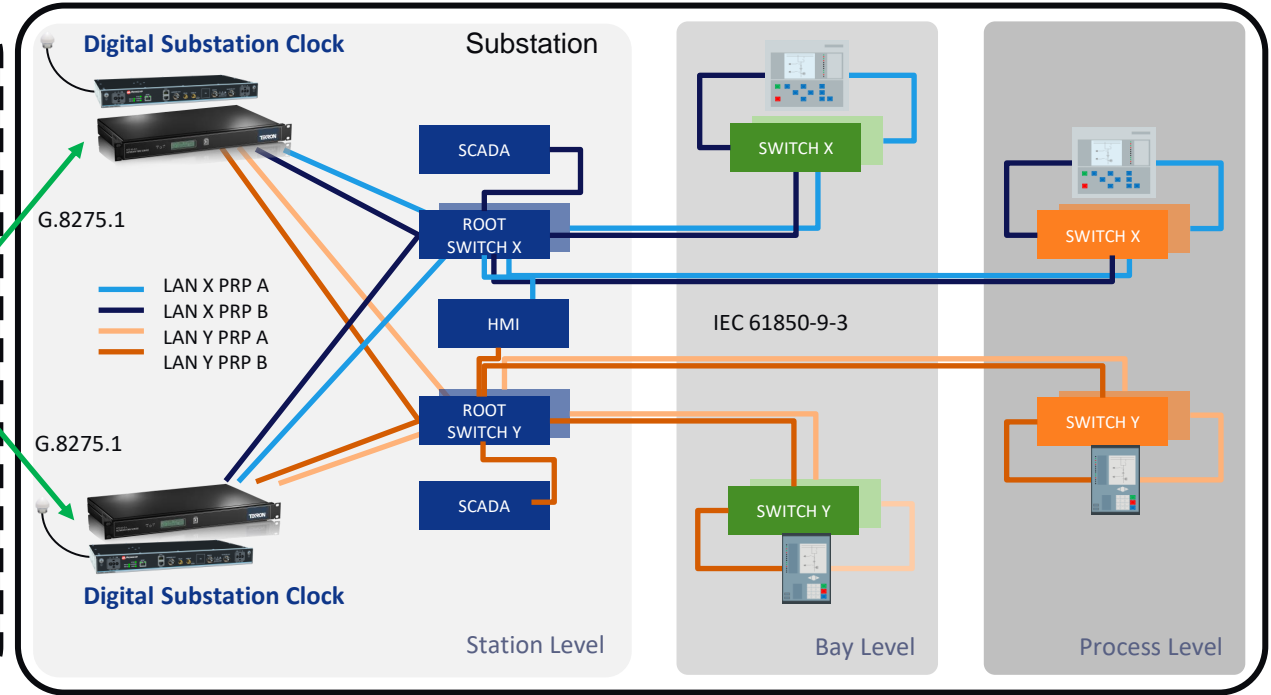
End-to-End Resilient Timing Architecture

Consolidated Solution

ePRTC to HP BC PTP Output $\leq 100\text{ns}$



Digital Substation Clock PTP Utility/ Power Profile Output to SS IED $\leq 1\mu\text{s}$



Thank You!

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