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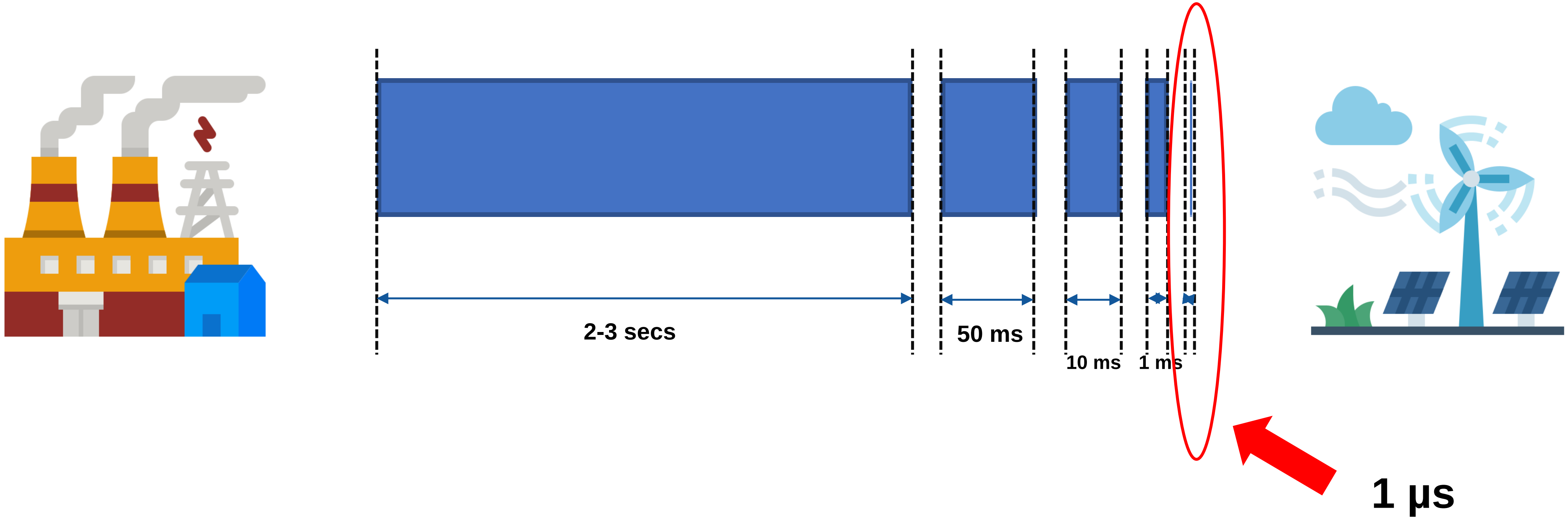
The Importance of Time in Digitalization of Power Systems

Fred Steinhauser, Digital Substation Evangelist, OMICRON

(Real) Time

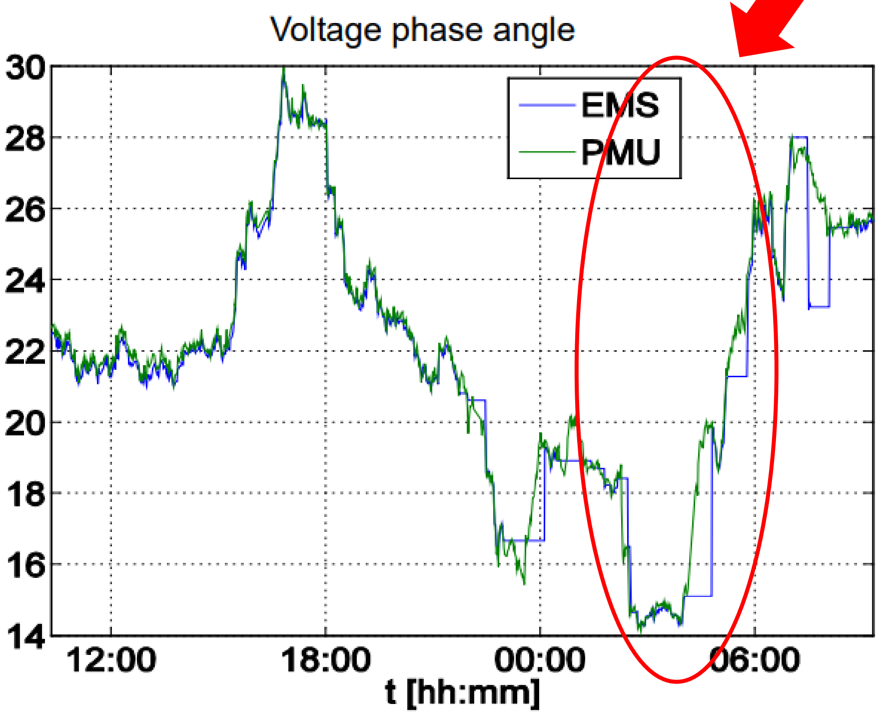
Real time is shrinking



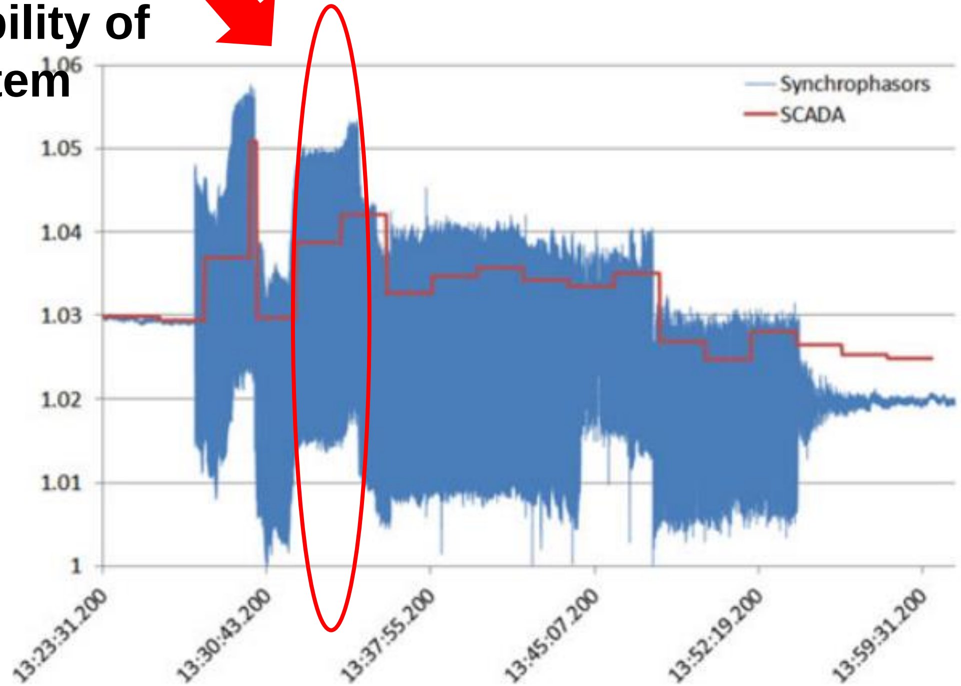
- Decarbonization of power systems with intermittent renewable generation with different operating characteristics requires more granular visibility of power systems, thus driving digitalization.

- Digitalization of power systems with digital measurements and digital protection, control and automation signals require precise time references for accurate and performant operation.

Real time is shrinking



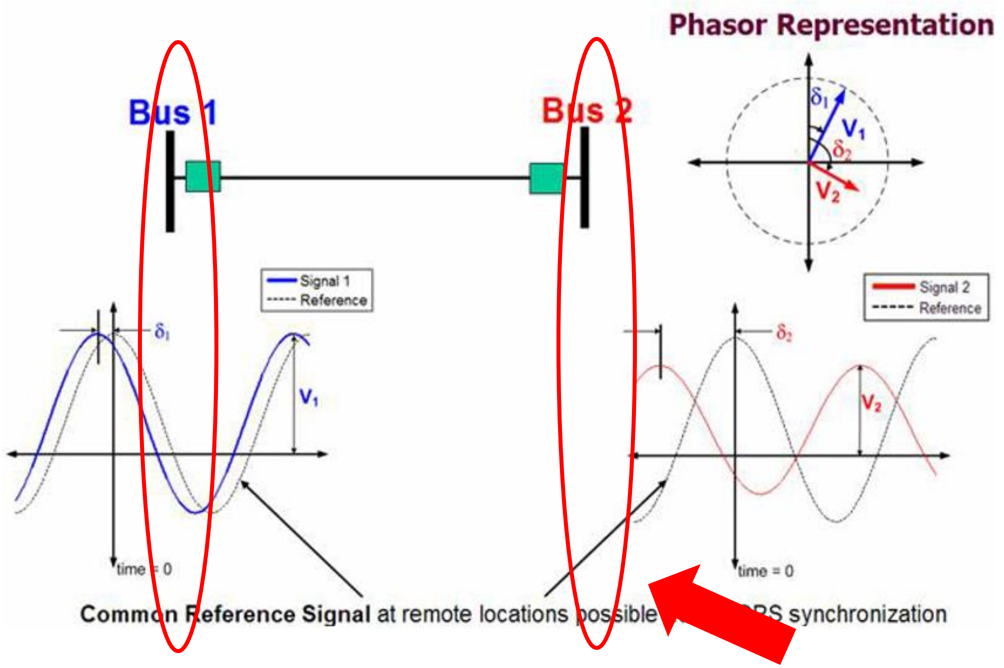
High resolution sampling enables better visibility of power system

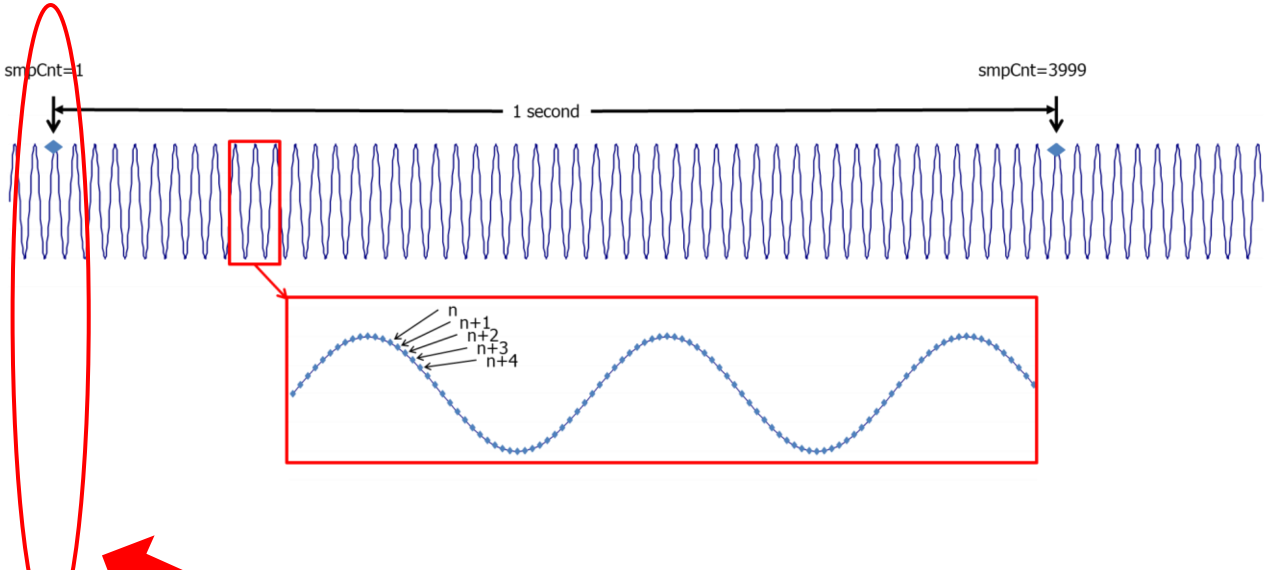


- Conventionally timestamped SCADA measurements do not capture and analyze power system oscillations and disturbances sufficiently.

SYNCHROPHASORS DEFINITIONS, FUNCTIONALITY AND STANDARDS – Hitachi ABB, Galina S. Antonova
A Phasor Measurement Unit Based Fast Real-time Oscillation Detection Application for Monitoring Wind-farm-to-grid Sub−synchronous Dynamics - Luigi Vanfretti, Maxime Baudette,Jos´e-Luiz Domınguez-Garcıa, Muhammad Shoaib Almas, Austin White and Jan Ove Gjerde

Precise time synchronization is crucial





Accurate time reference ensures that sampling times are within 1 µs

- Wide area measurements which need to be superimposed to make accurate phase angle calculations rely on reference signals time synchronized across the network.
- A/D converters in digital protection systems time-tag the samples (using a sample counter) within a few **microseconds** of each other.

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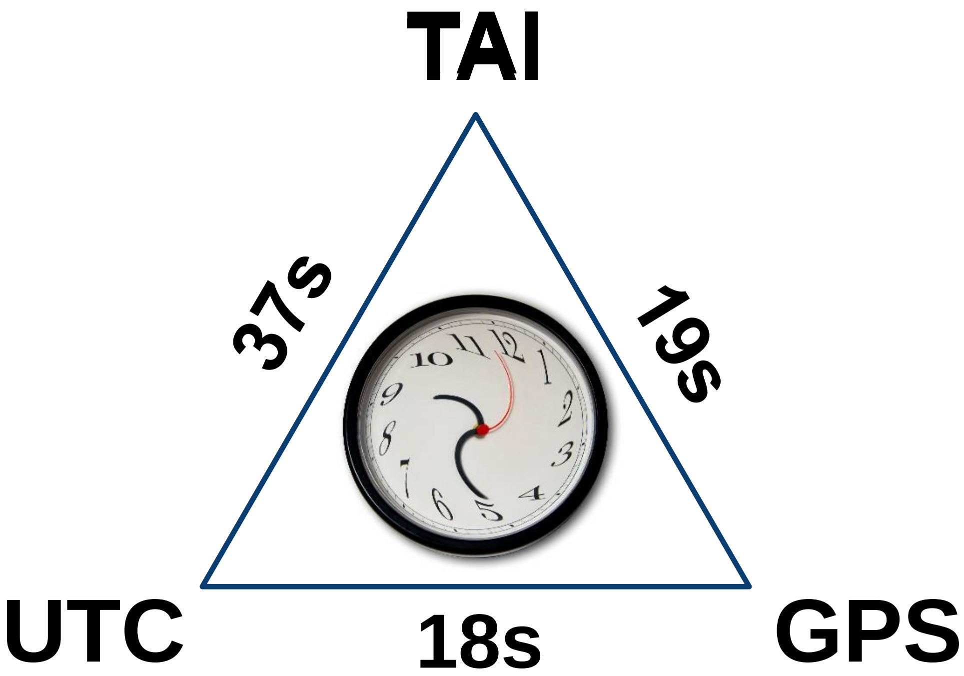
Time Systems



Precise relative time synchronization is the top priority.
Local time and time zones are not relevant.

Commonly used time protocols

Time Synchronization System	Typical Uncertainty	Uses Ethernet Network	Ambiguity
IRIG-B	10 µs - 1 ms	No – own wiring needed	1 year (extension available)
1PPS	1 µs	No – own wiring needed	1 second
Serial ASCII	1 ms	No – own wiring needed	None
NTP	1 ms - 10 ms	Yes	None
PTP (IEEE 1588)	1 µs	Yes	None

The new state-of-the-art: Precision Time Protocol (PTP, IEEE 1588)

- "µs accuracy“
- What we need in Digital Substations!

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Precision Time

Precision time for the electrical power industry

- **P**recision **T**ime **P**rotocol (PTP) is what we want and need
- IEEE 1588 uses „**profiles**“ to define **default settings, methods** and **adaptations** for different industries.
- "Power Profile" – IEEE C37.238
- "Utility Profile" – IEC 61850-9-3
  - Base profile – simple but good enough
  - Adaptations to IEEE 1588 – 2019 ongoing

Applications

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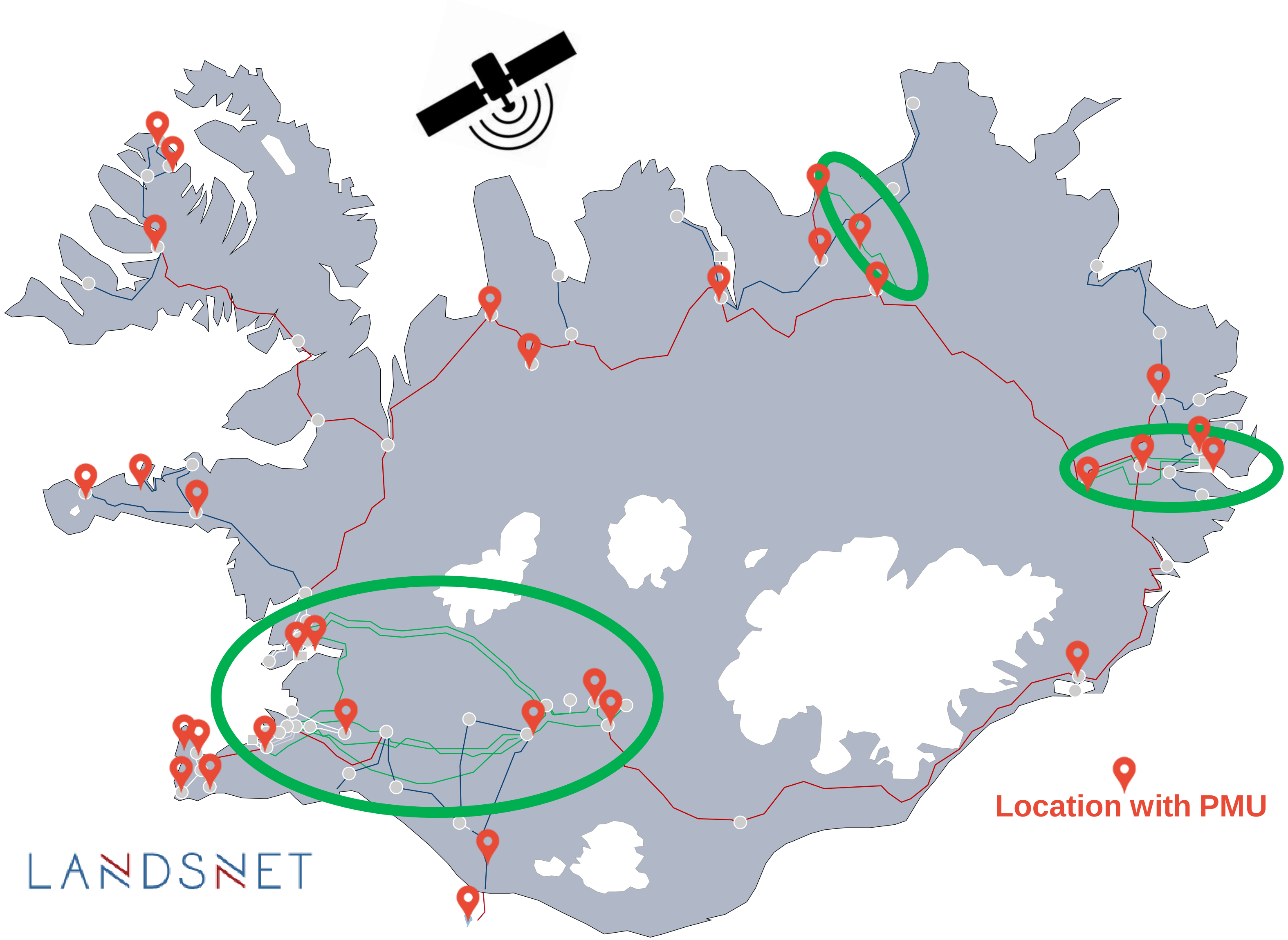
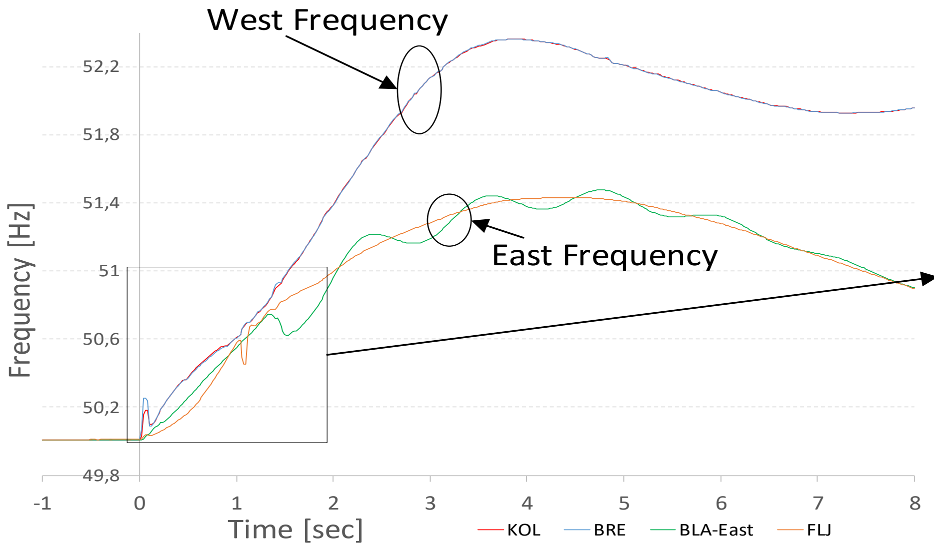
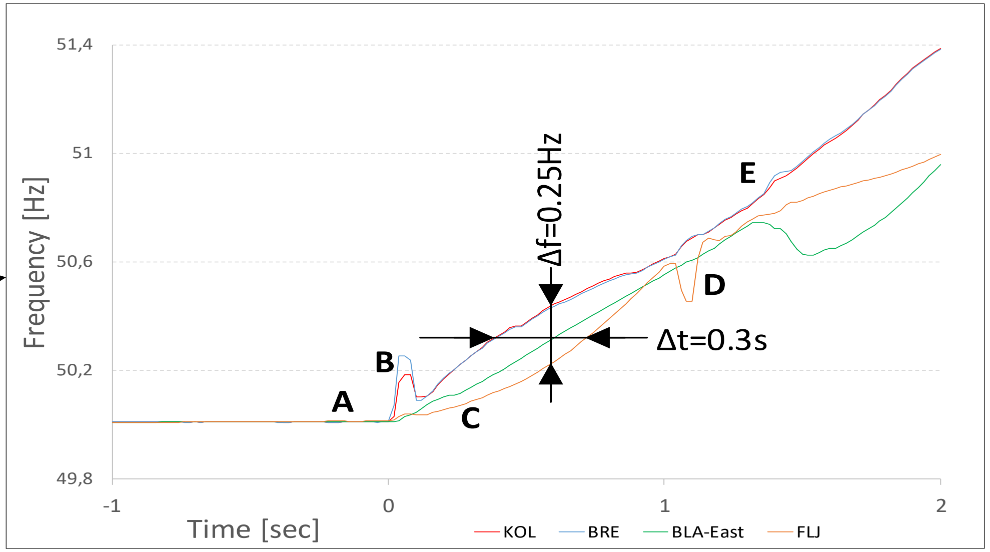
Application 1 – Wide Area Monitoring Systems

- LANDSNET Iceland is the transmission network owner and operator in Iceland.
- LANDSNET has deployed an extensive WAMS monitoring network (~60 PMUs) over good quality communications network.



Islanding event captured with synchrophasors

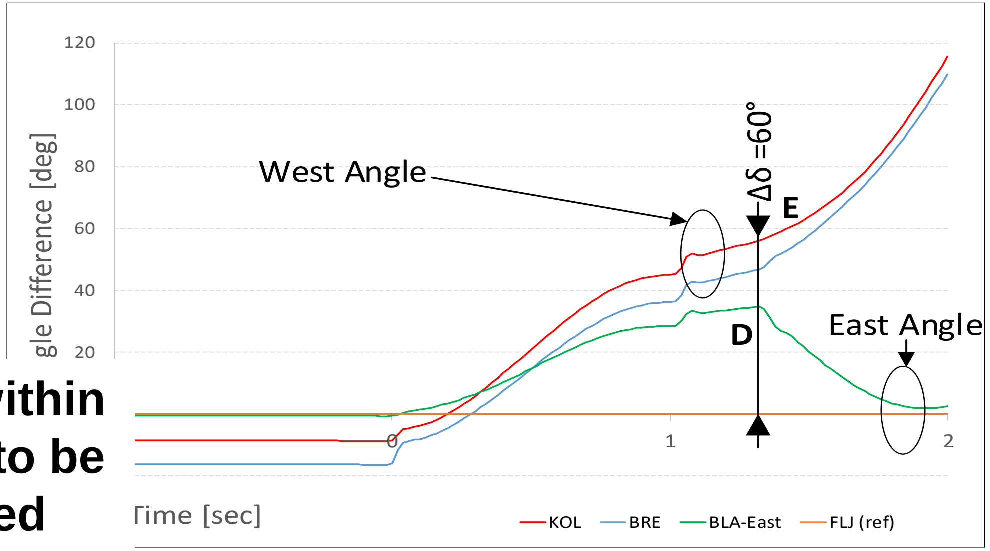




1.2s to Islanding

4s to Frequency Peak

A	T=0s	Industrial load #1 reduction (first stage)
B	T=0.2s	Industrial load #1 reduction (second stage)
C	T=0.36s	Industrial load #1 trip
D	T=1.1s	Area angles separated by 60°, result in high E-W power. One route opens by special protection
E	T=1.2s	A… eler… synchron… m



Events occurring within milliseconds need to be accurately monitored

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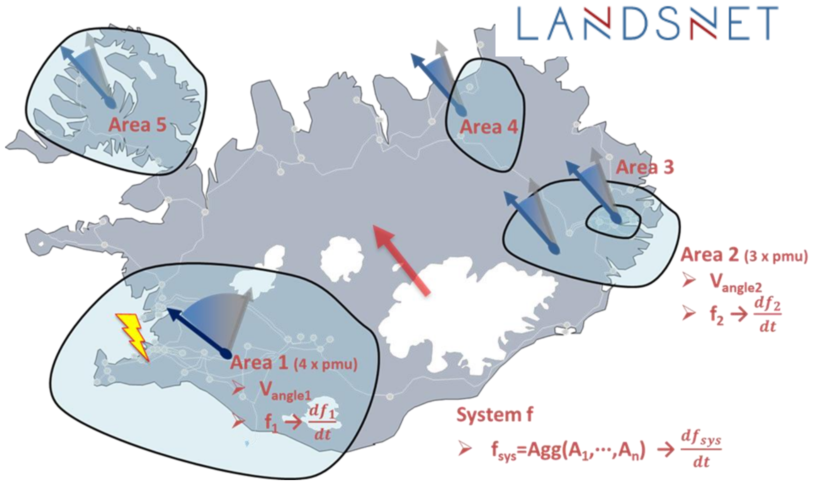
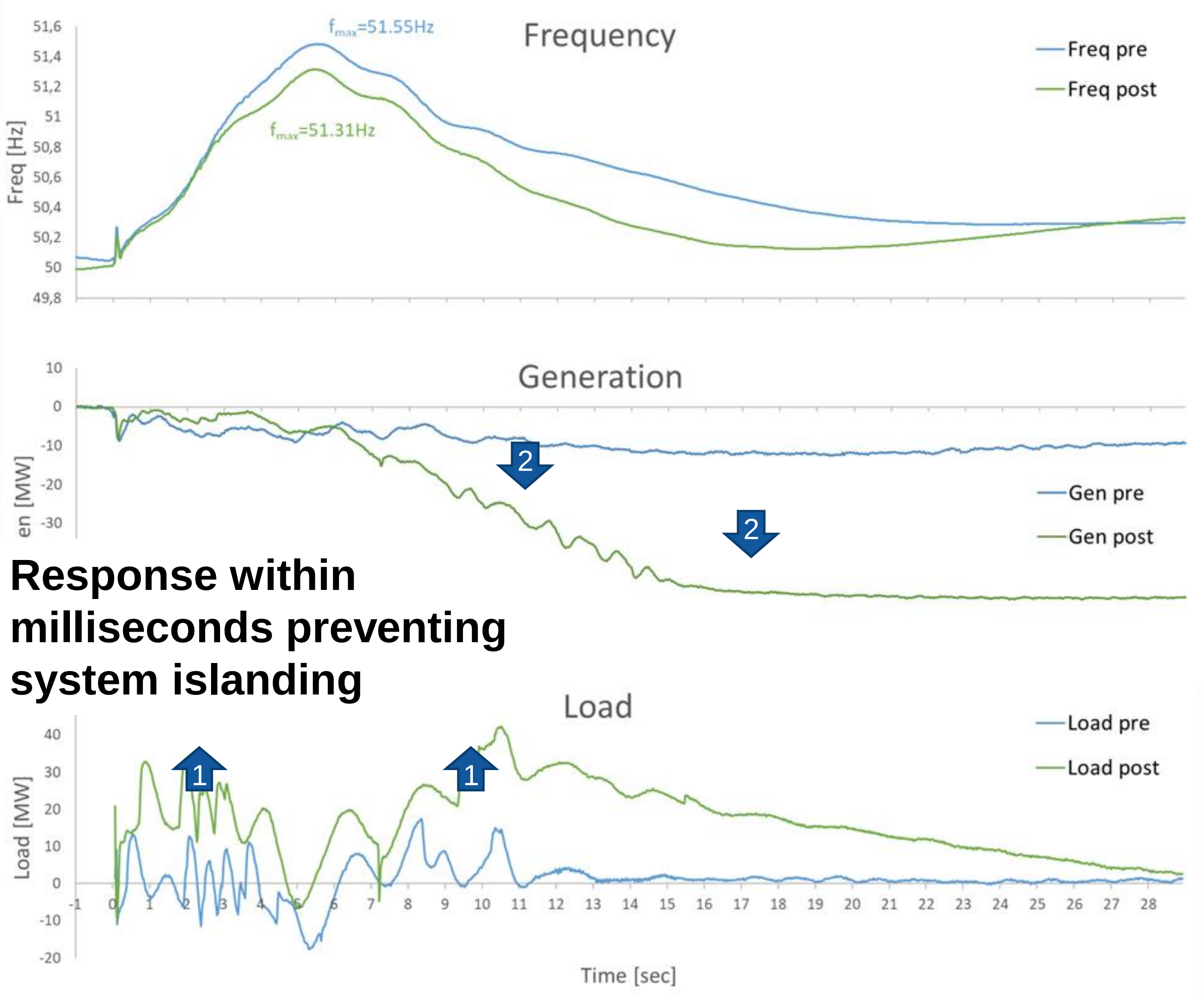
Wide area control using synchrophasors



1. Load response in < 0.5 s, reduces frequency peak.
2. Hydro fast ramp start at 3.5 s, replaces fast temporary load response. Rate & volume greater than primary control

<u>Islanding avoided!</u>

Response within milliseconds preventing system islanding



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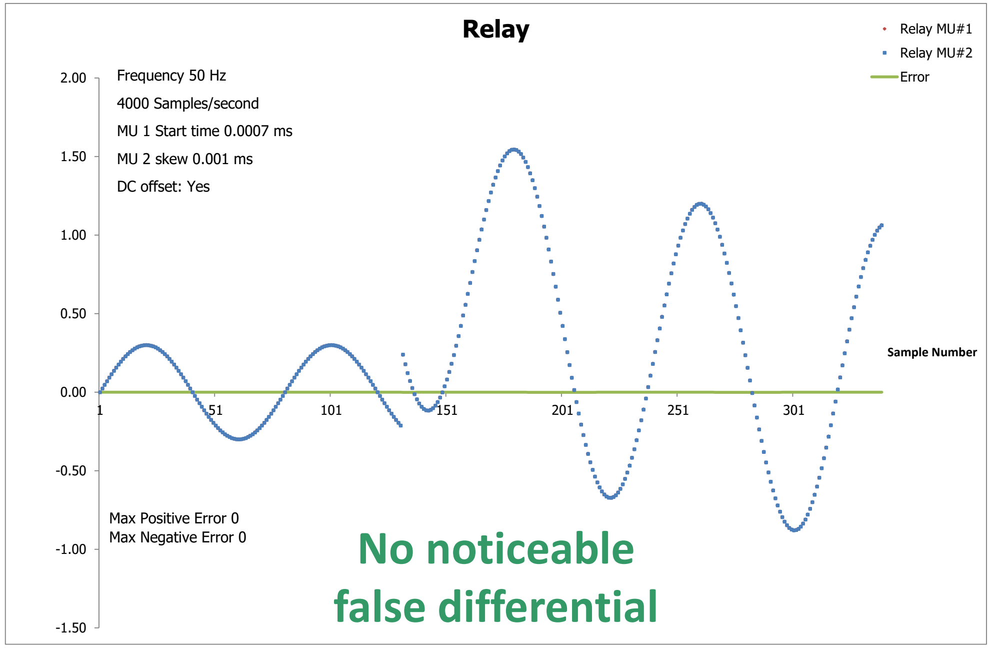
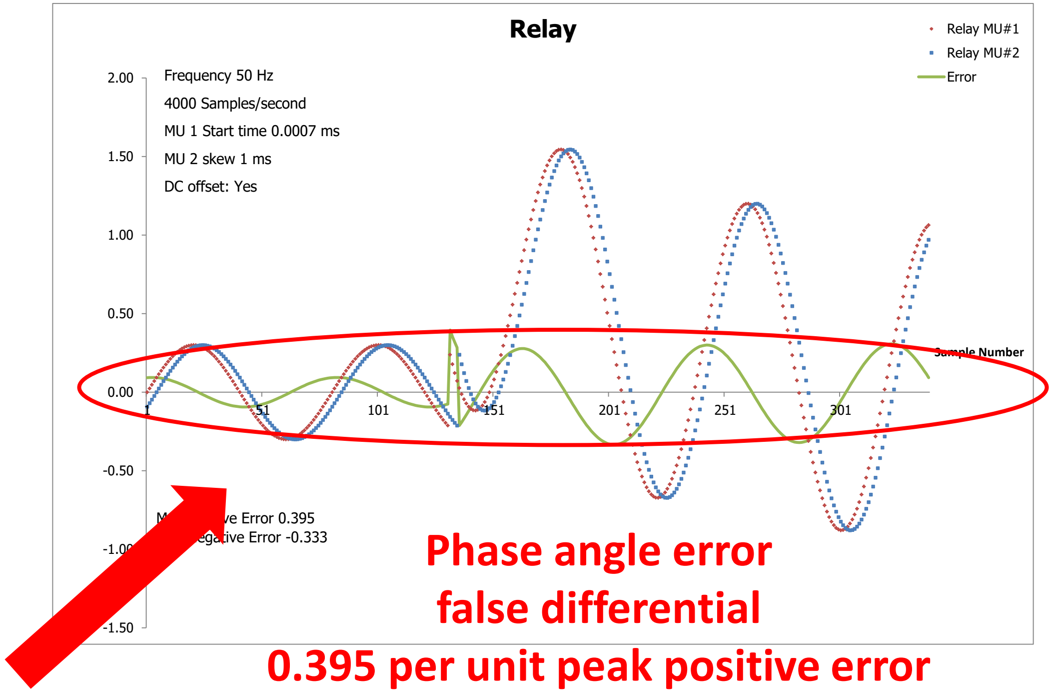
Application 2 - Digital Substations – Sampled Values

well synchronized



1 ms time difference



1 ms timing error leads to false operation

0.395 per unit peak positive error
-0.333 per unit peak negative error

- Sampled Values are digitized Voltage and Current measurements in digital protection systems
- Sampled Values from different A/D converters must be well time synchronized to avoid phase errors and maloperations.

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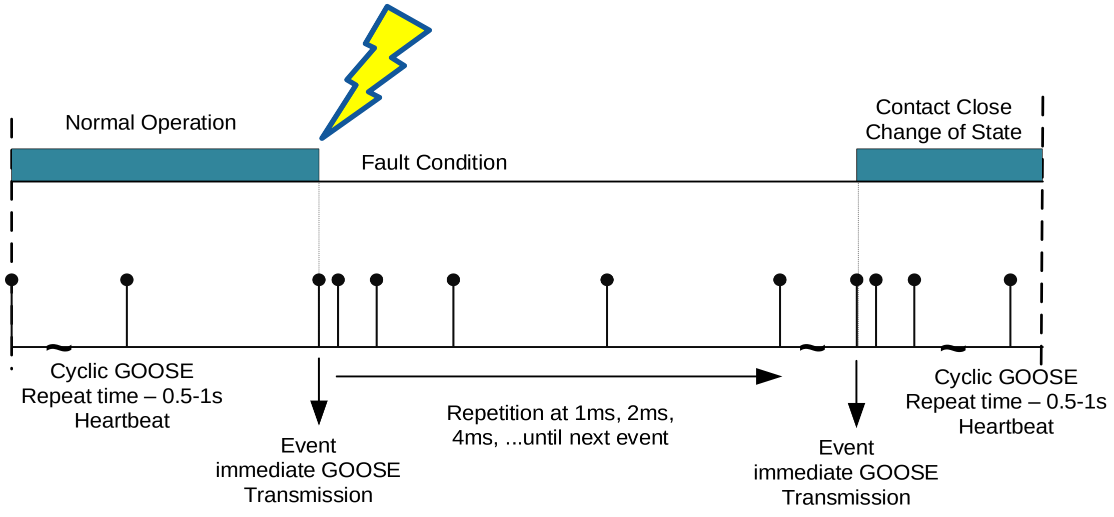
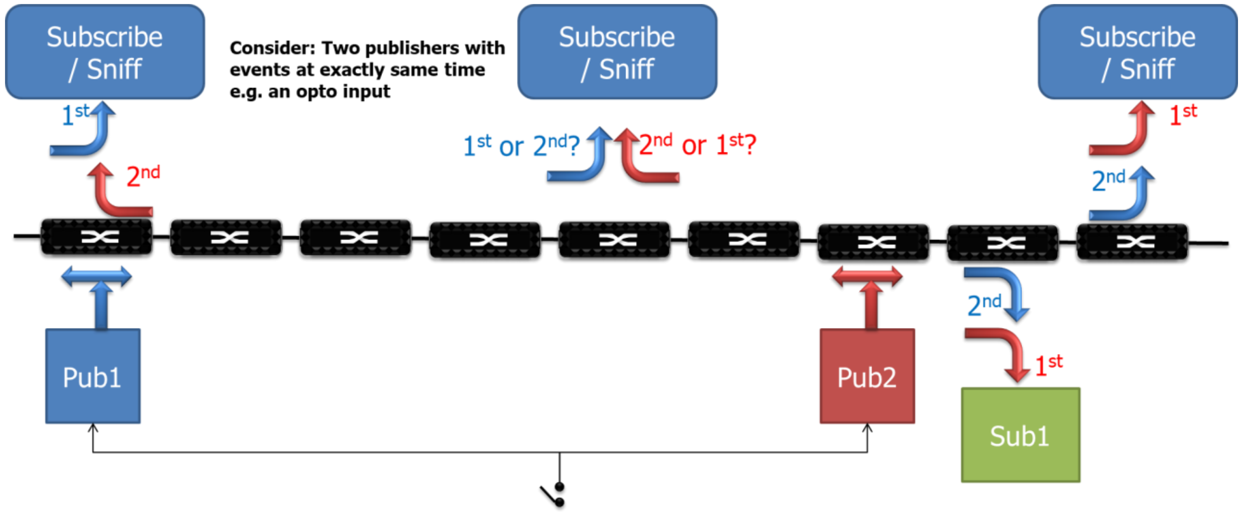
Digital Substations – GOOSE timestamping





- GOOSE communication carry system events such as status changes, trip signals, etc ...
- GOOSE messages are timestamped upon status change. The subscribing IED may receive the same status change from different publishers and may perform plausibility checks based on the timestamps. To properly derive the sequence of events, the publishers need to be time synchronized.

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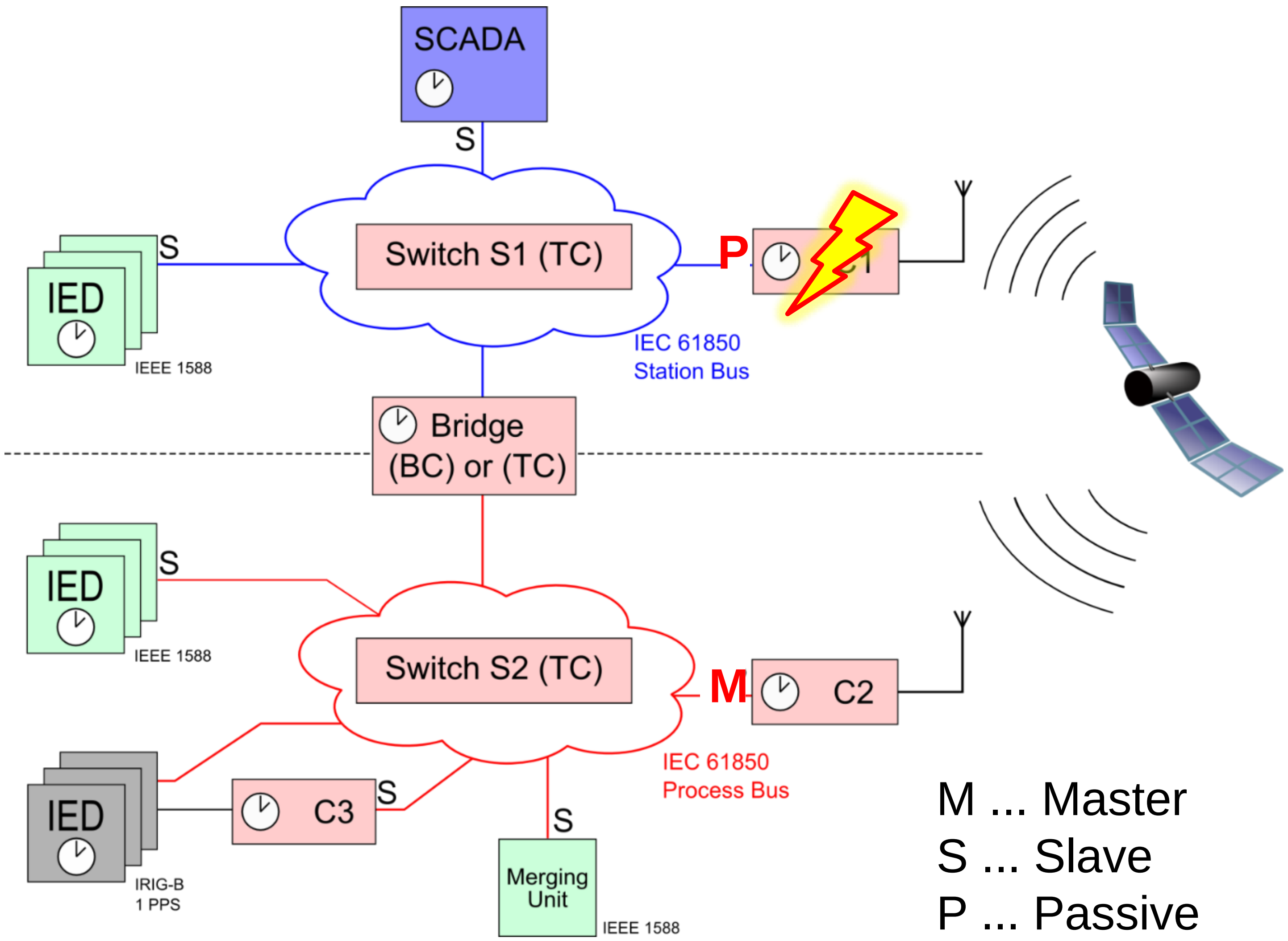
Application of PTP in Digital Substations



- **Use of a PTP profile,** e.g., IEC 61850-9-3
- **Layer 2, peer-to-peer**
- **Best Master Clock Algorithm** used

- Failure of GNSS reception is seen as a likely threat

- Holdover performance comes into the focus

Challenges

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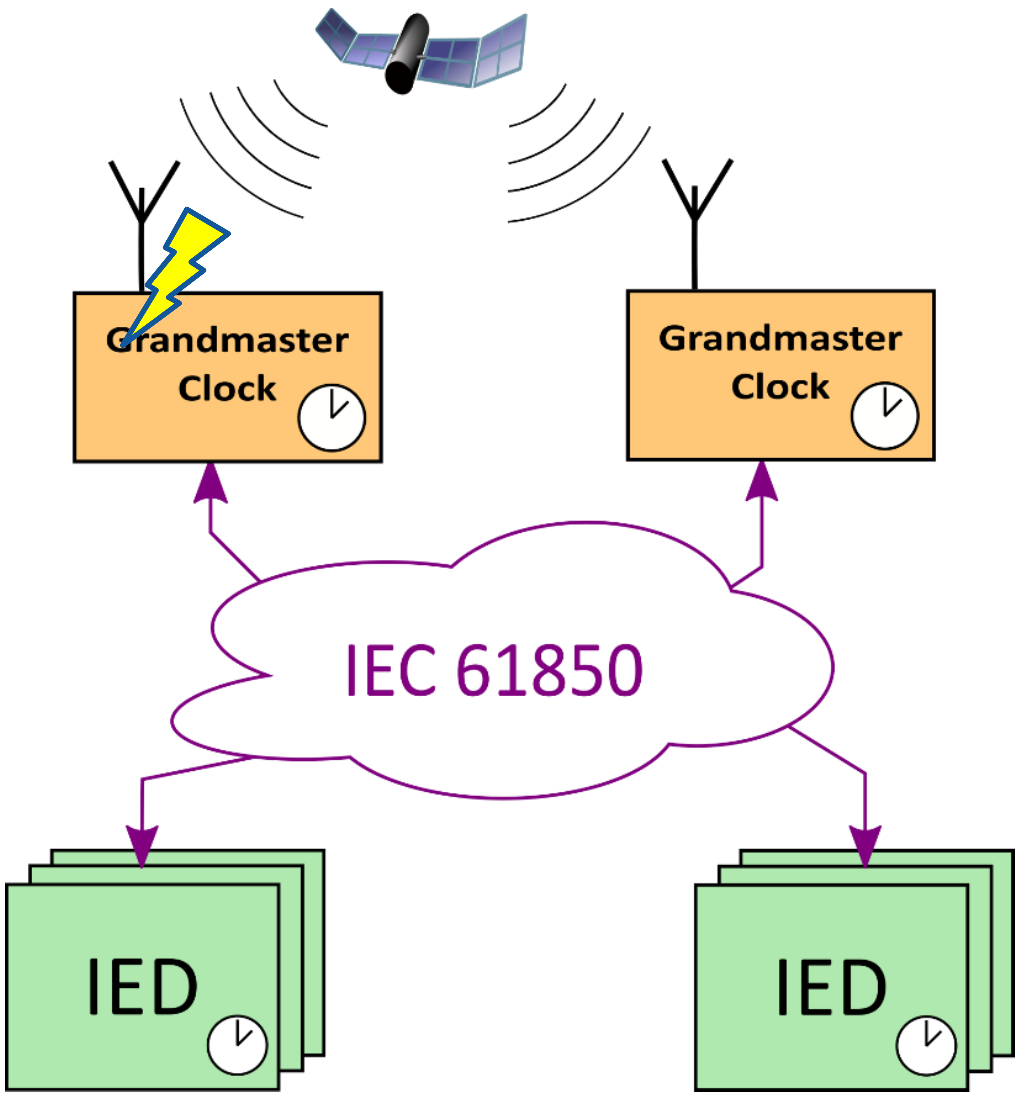
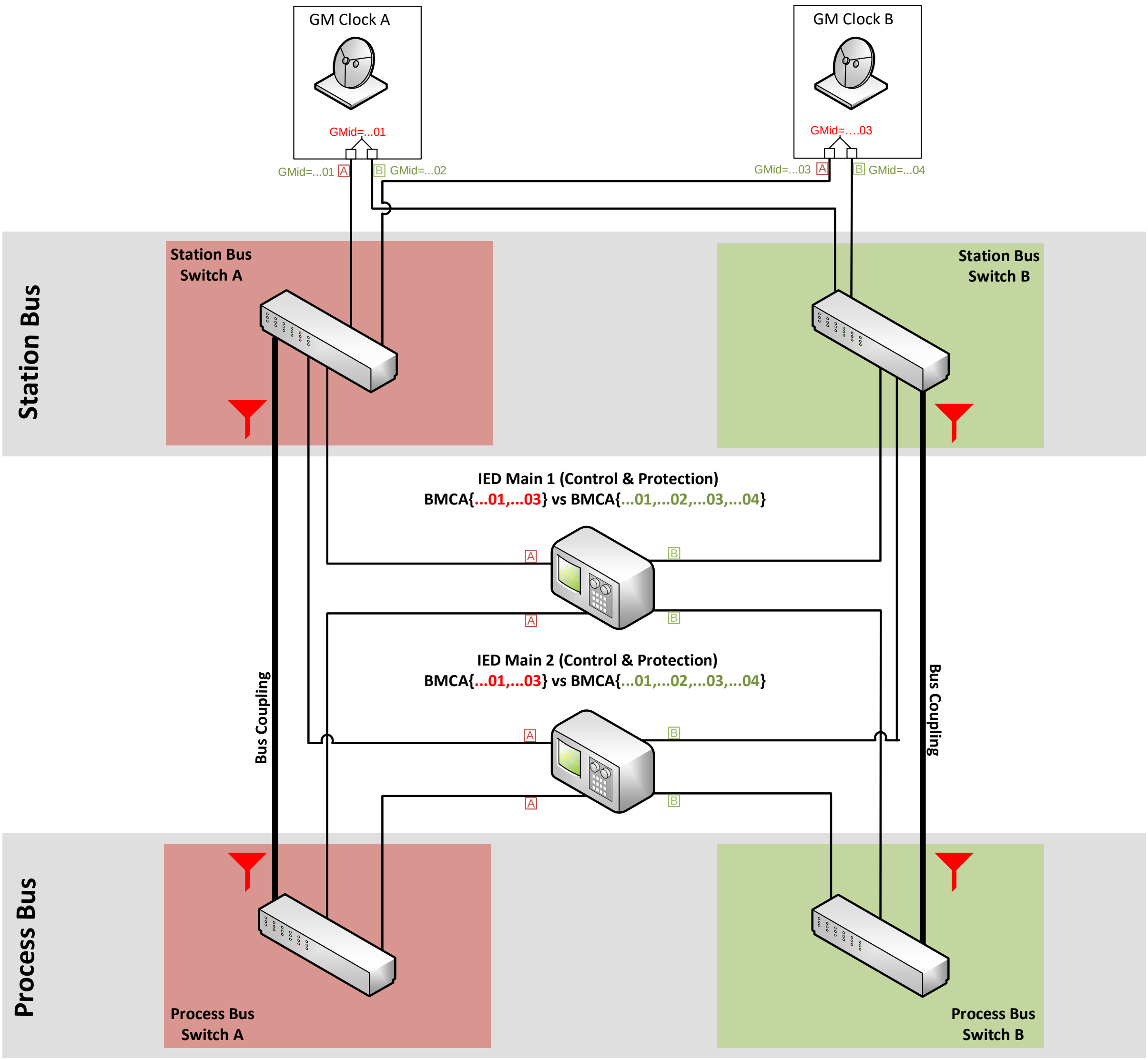
Dealing with failure modes

- Problem with the primary time reference
  - GNSS jamming / spoofing
- Malfunction of the station clock
- Failure of the synchronized IED
- Failure in the time distribution network

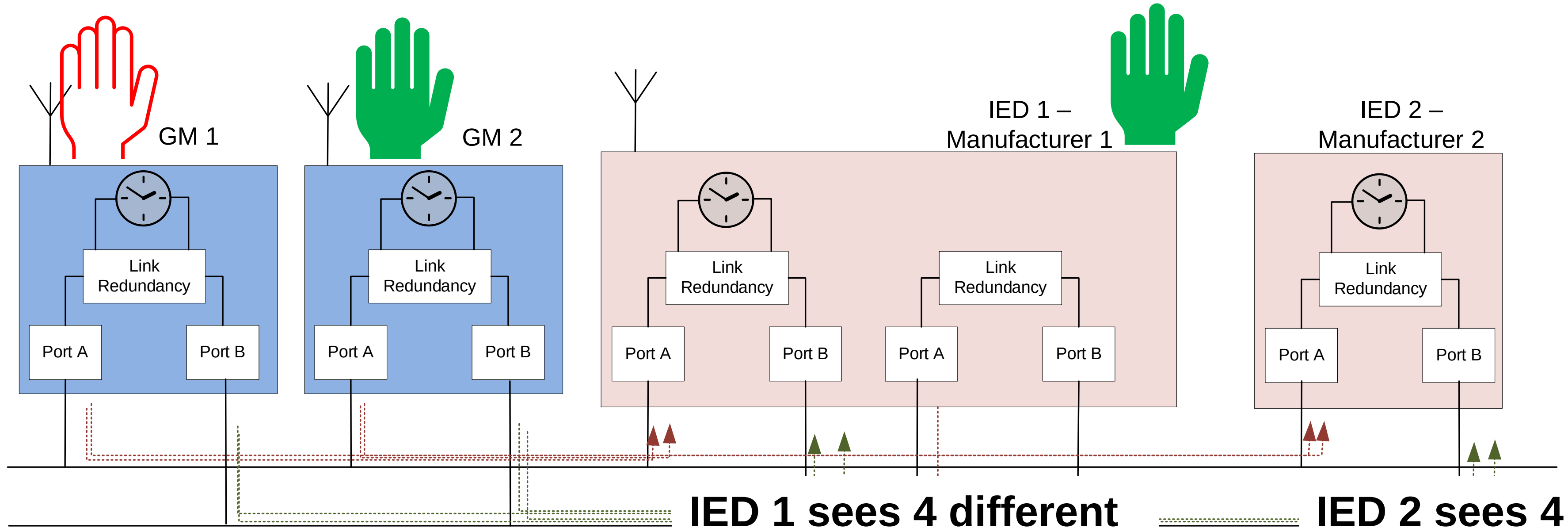


Agreeing on a common time reference



- Precise time synchronization is crucial for the functional substation automation and protection systems
- Redundancy of time sources is highly recommended in digital protection systems
- Redundancy requires IED to perform BMCA to select a time source. Ideally, all IEDs should be synchronized to same time source
- Less is more

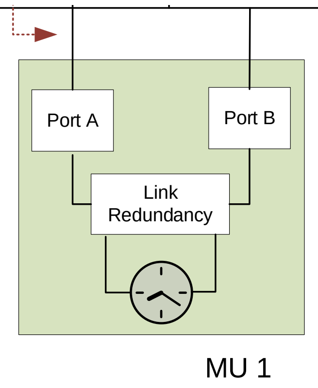
Presence of multiple master clocks



IED 1 sees 4 different clocks, 2 at each port and can self act as a master clock.

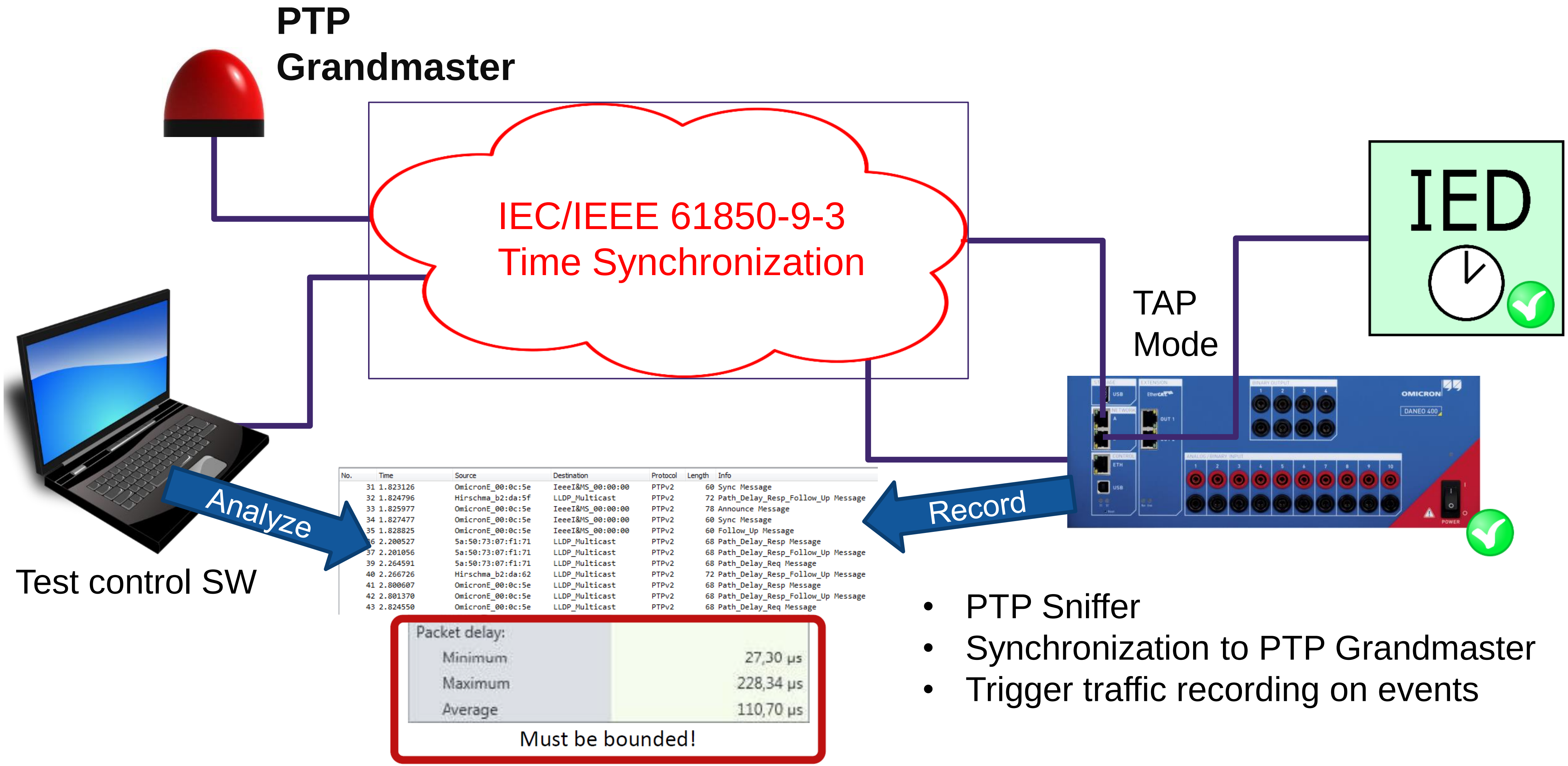
IED 2 sees 4 different clocks, 2 at each port and could also be synchronised by IED 1.

- Presence of multiple eligible time sources and different implementations of BMCA by IED manufacturers can make the whole system unstable.



MU 1 receives PTP frames cascaded through IED 1 acting as boundary clock.

Minimizing surprises through testing



- PTP Sniffer
- Synchronization to PTP Grandmaster
- Trigger traffic recording on events

Summary

- Precise time synchronization is crucial for digitalization of power systems.

- Potential to improve stability of time synchronization in redundant configurations
  - Should be jointly addressed by standard bodies, manufacturers and end users.

- Utilities should follow best practices, such as:
  - Use multi-system GNSS receivers, as they are more difficult to spoof
  - Use high stable oscillators with adequate holdover performance, to bridge temporary signal loss
  - Use atomic clocks as back up time sources
  - ...

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Thank you for your attention!

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