International Timing & Sync Forum 2021

#ITSF2021

The Importance of Time in Digitalisation of Power Systems

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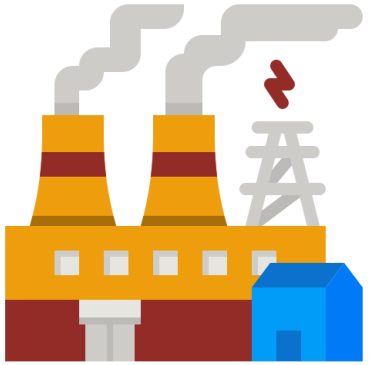
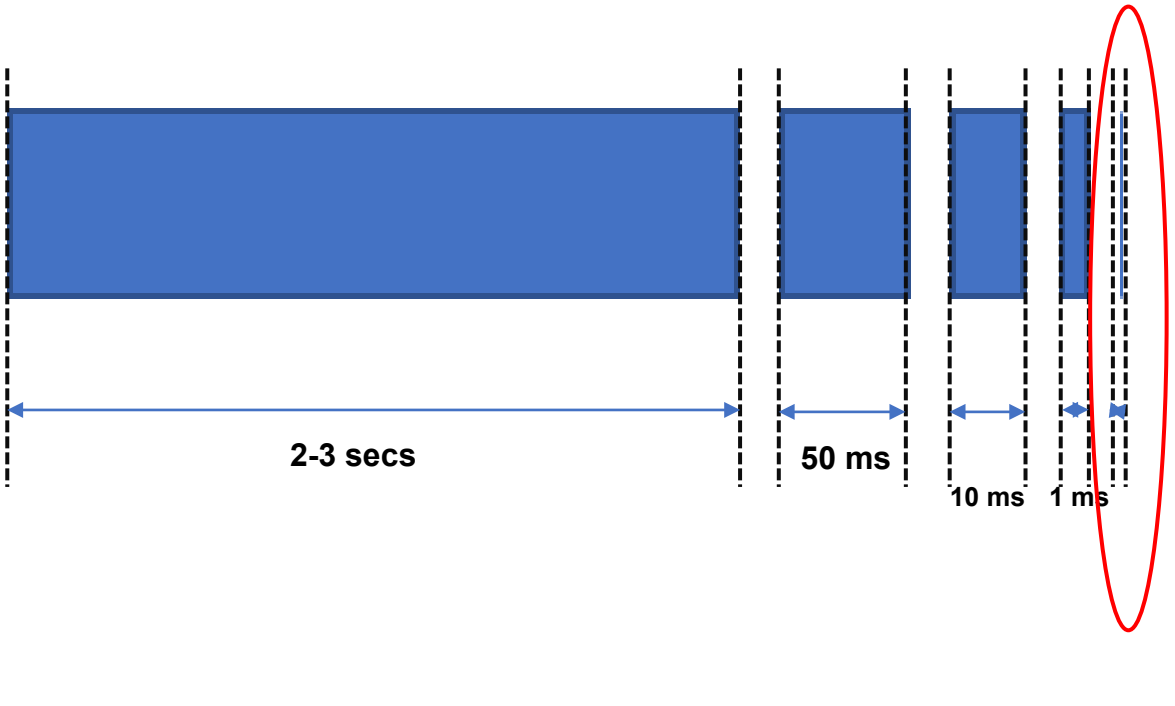
(Real) Time

Real time is shrinking

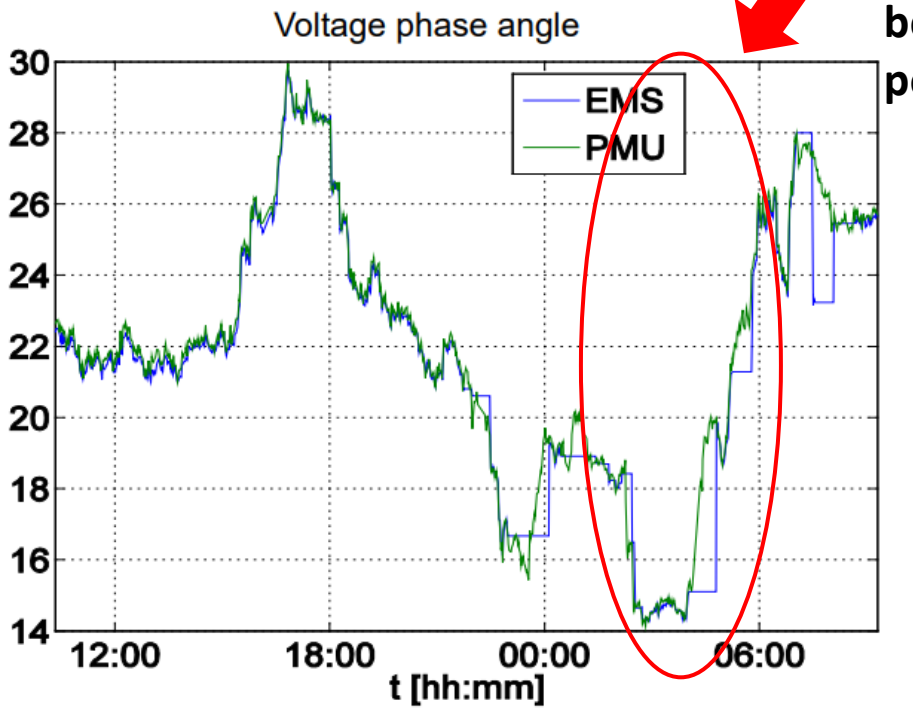




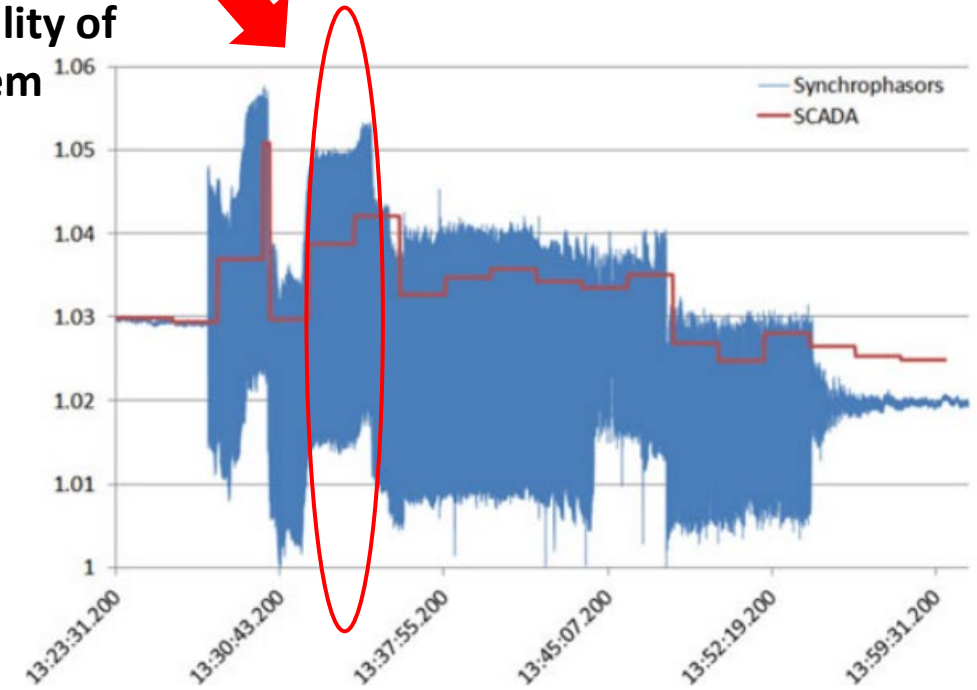
- Decarbonisation of power systems with intermittent renewable generation with different operating characteristics requires finer visibility of power systems, thus driving digitalisation.

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

Real time is shrinking



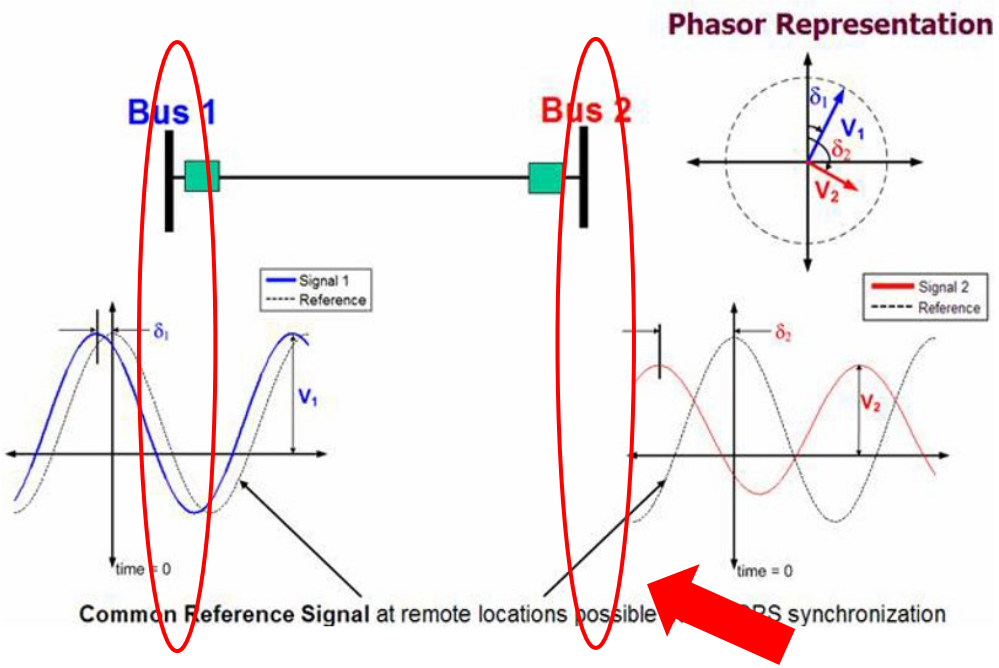
High resolution sampling enables better visibility of power system

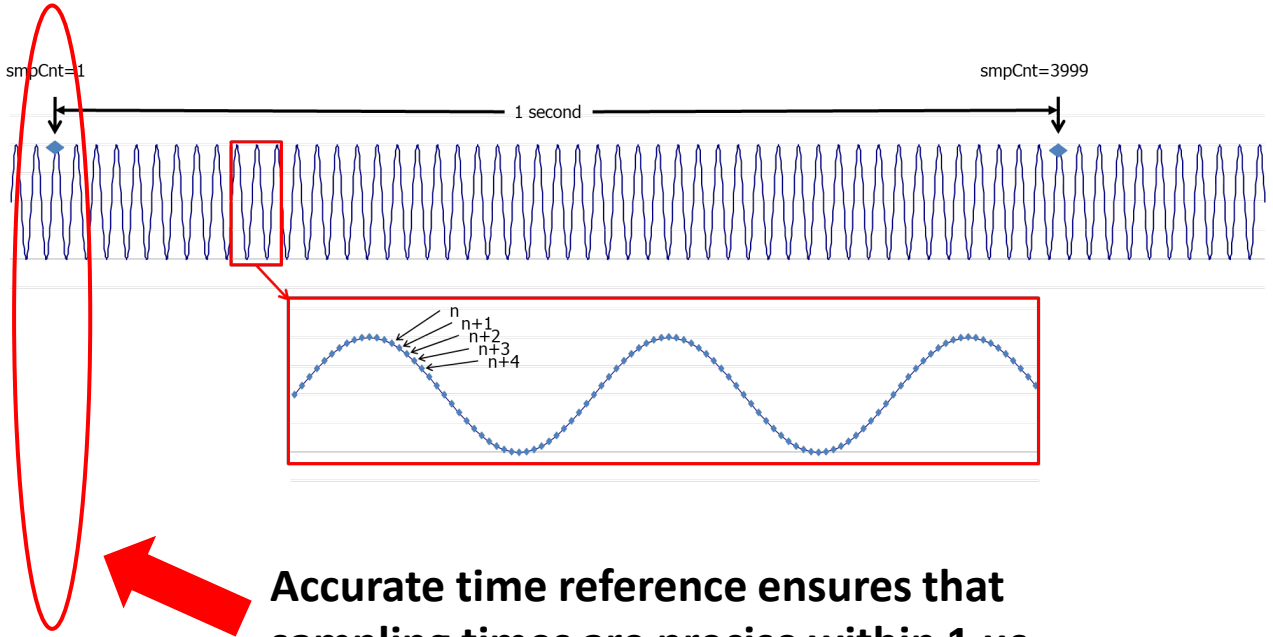


- Conventionally timestamped SCADA measurements do not capture and analyse power system oscillations and disturbances.

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

Synchronised time reference is crucial

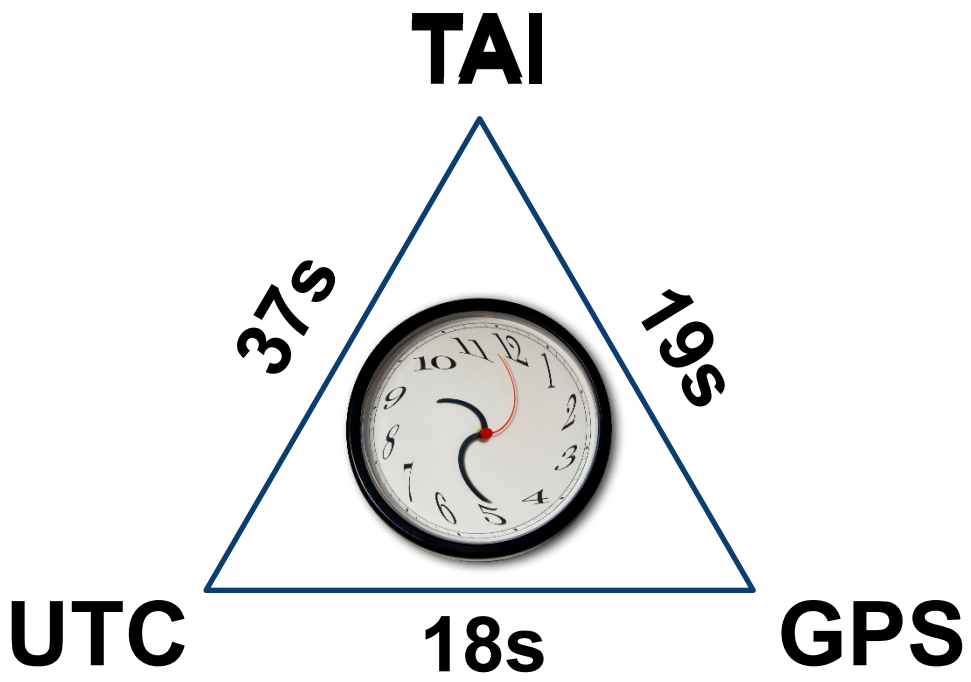




Accurate time reference ensures that sampling times are precise within 1 µs

- Wide area measurements which need to be superimposed to make accurate vector angle calculations rely on reference signals time synchronized across the wide area network.
- Analog to Digital converters in digital protection systems must be “aligned” start and reset the sample count “SeqNr” to zero within **1 microsecond** of each other.

Time Systems



Real time in power systems does not need to be absolute time, just precisely referenced to each other under the shrinking definition of real time!

Commonly used time protocols

Time Synchronization System	Typical Accuracy	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

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

- "µs accuracy“
- Essential in Digital Substations!

Precision Time

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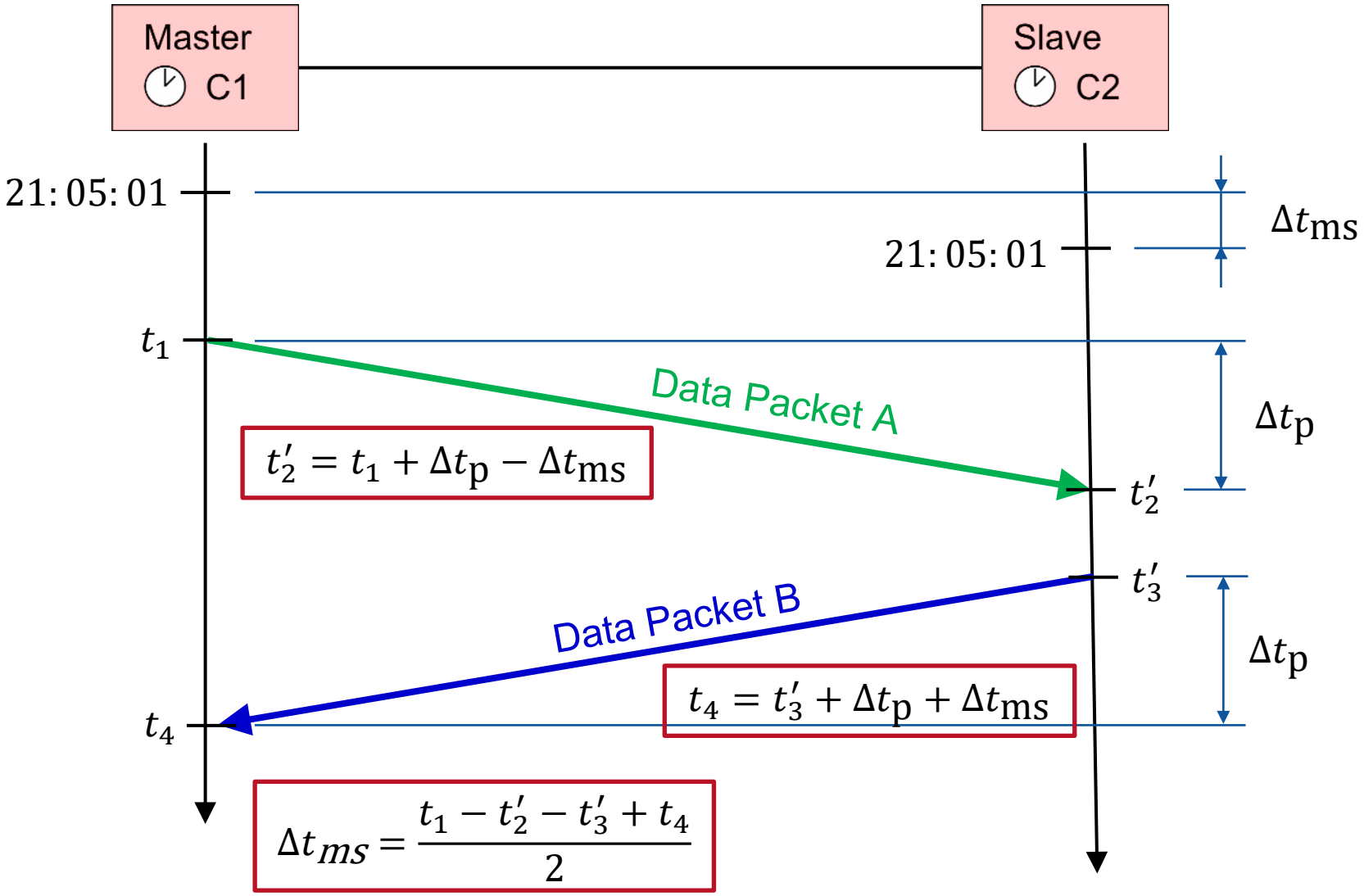
Precision time in a nutshell

- **P**recision **T**ime **P**rotocol (PTP)
- The IEEE 1588 standard defines the **most accurate** method to **synchronize clocks** over computer networks.
- IEEE 1588 uses „**profiles**“ to define **default settings, methods** and **adaptations** for different industries.
- Three versions of the standard so far
  - IEEE 1588 – 2002 (v1) – incompatible
  - IEEE 1588 – 2008 (v2)
  - IEEE 1588 – 2019 (v3)

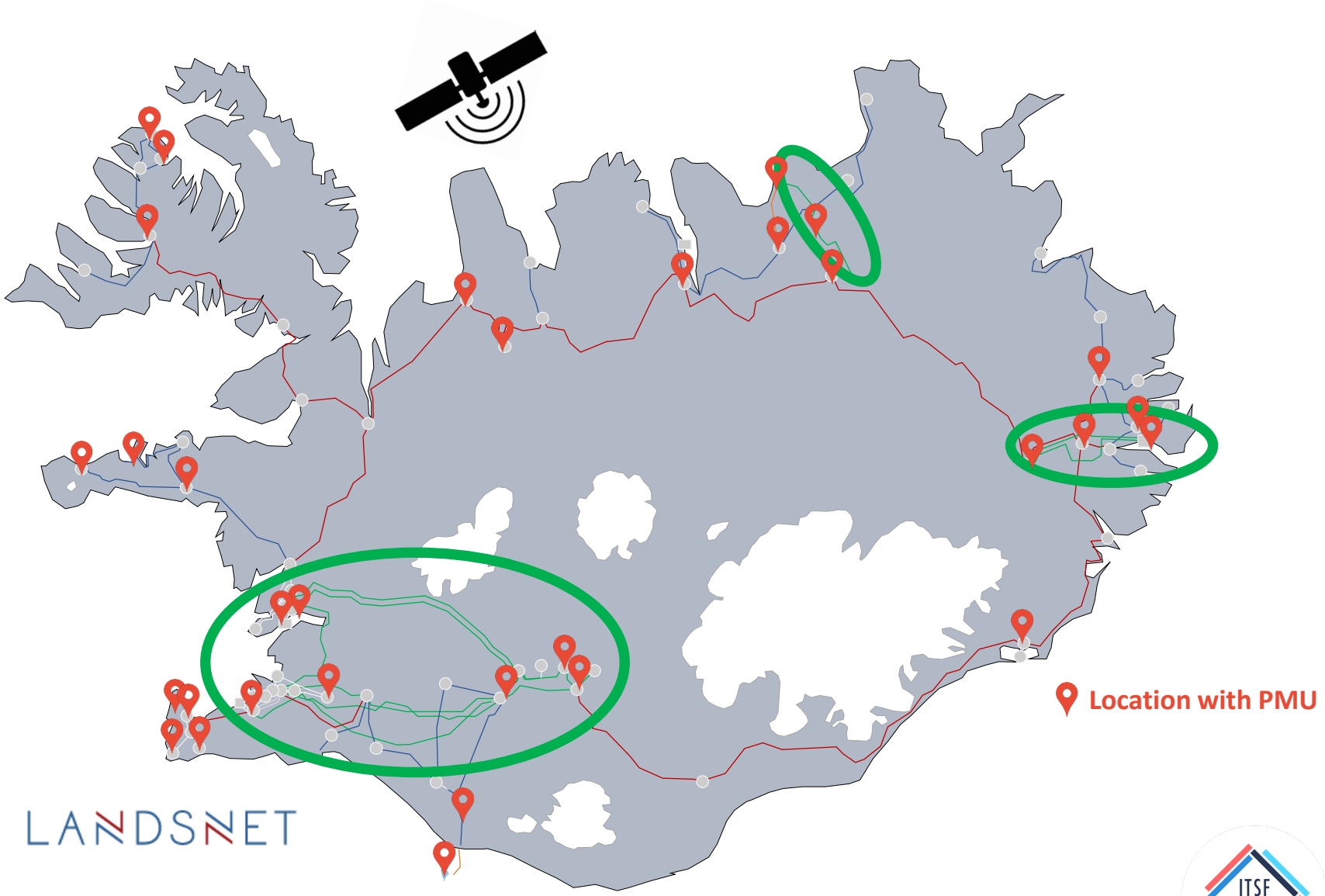
Propagation delay compensation



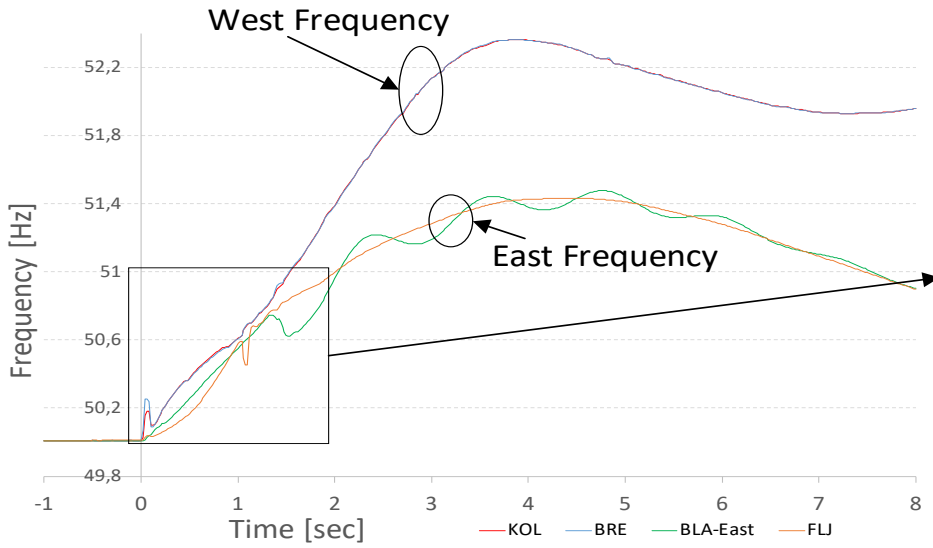
Applications

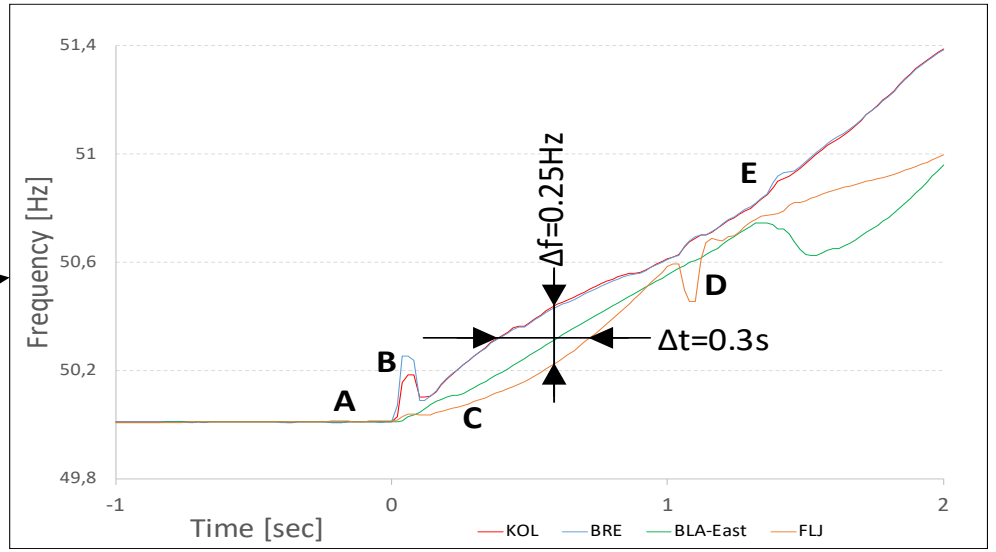
Application 1: Wide Area Monitoring Systems

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



System Islanding event captured with synchrophasors



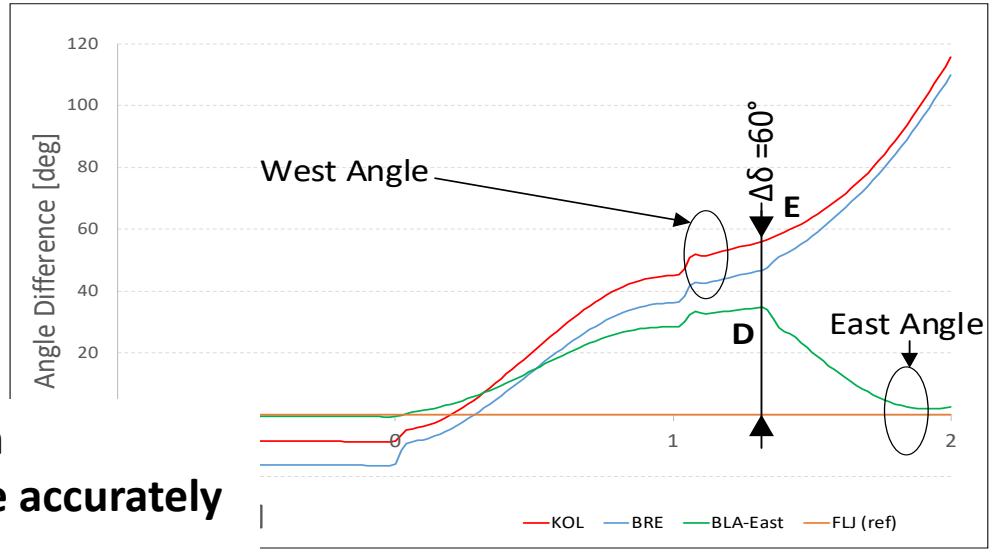


1.2s to Islanding

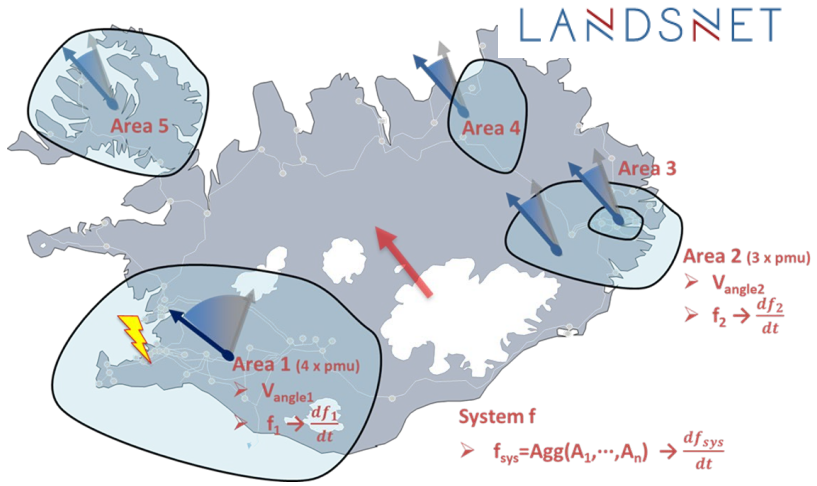
4s to Frequency Peak

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	Areas acce chronis

Events occurring within milliseconds need to be accurately monitored



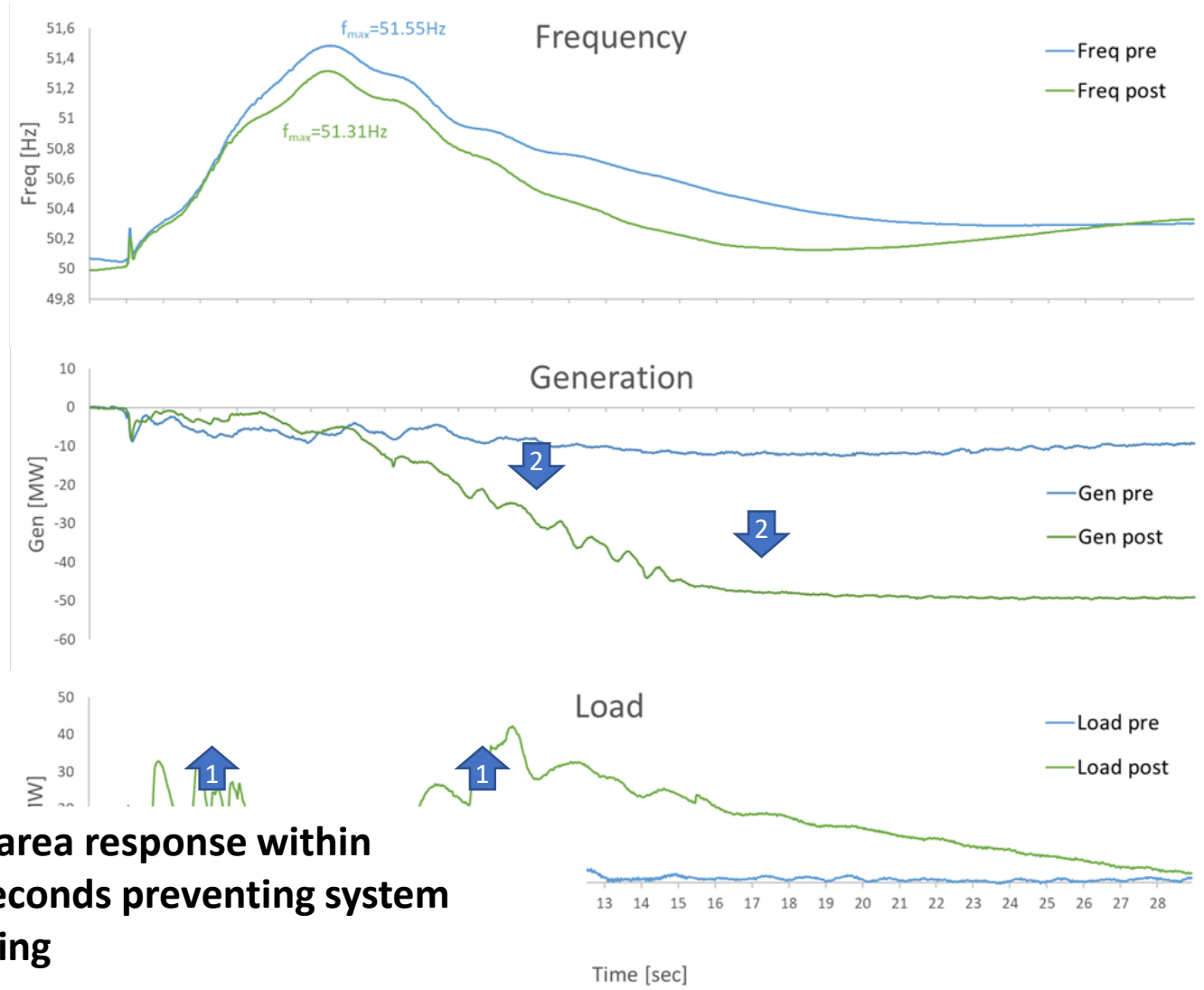
Wide area control using synchrophasors



1. Load response in <0.5s, reduces frequency peak.

2. Hydro fast ramp start at 3.5s, replaces fast temporary load response. Rate & volume greater than primary contro

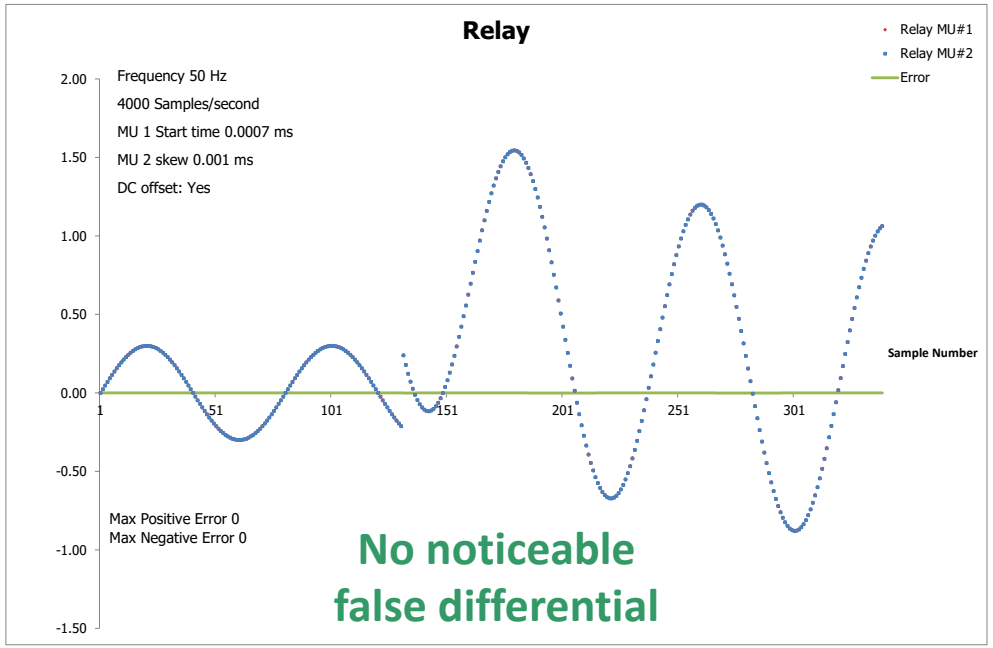
<u>No Islanding occurs!</u>



Wide area response within milliseconds preventing system islanding

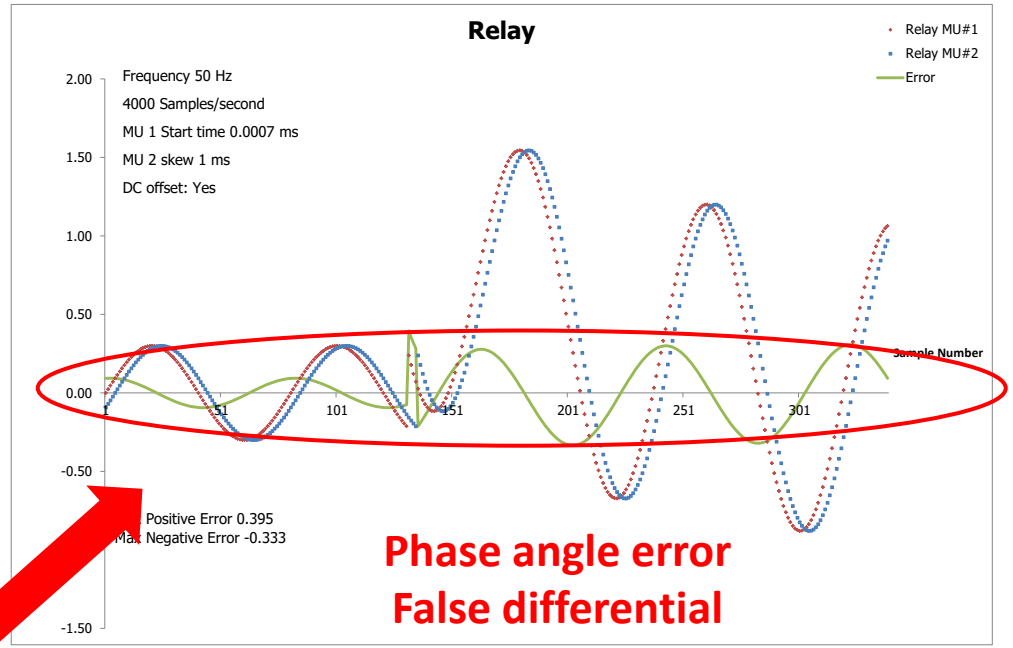
Application 2: Digital Substations – Sampled Values

0.001 ms + Offset



No noticeable
false differential

1 ms + DC Offset



Phase angle error
False differential

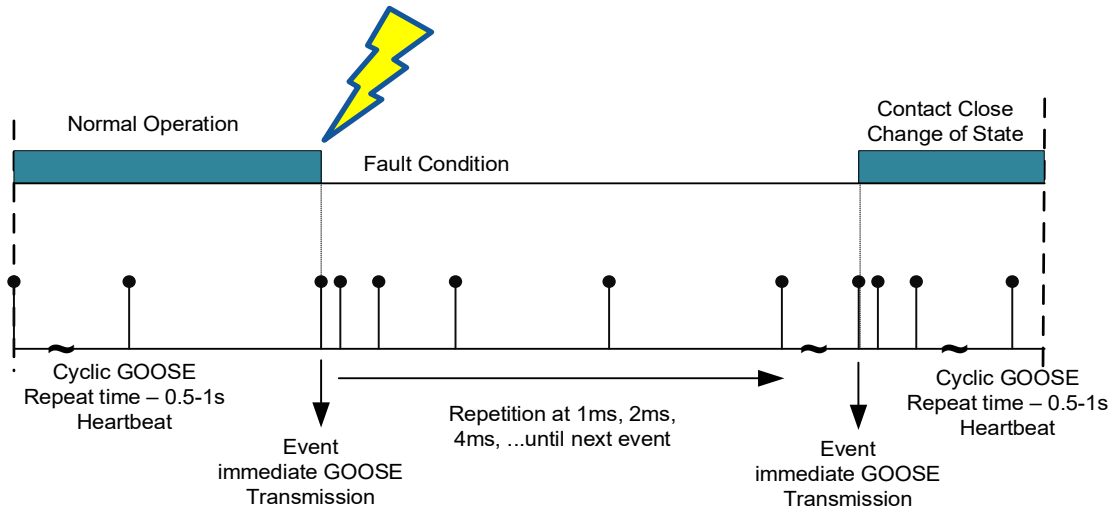
1 ms offset leads to false operation

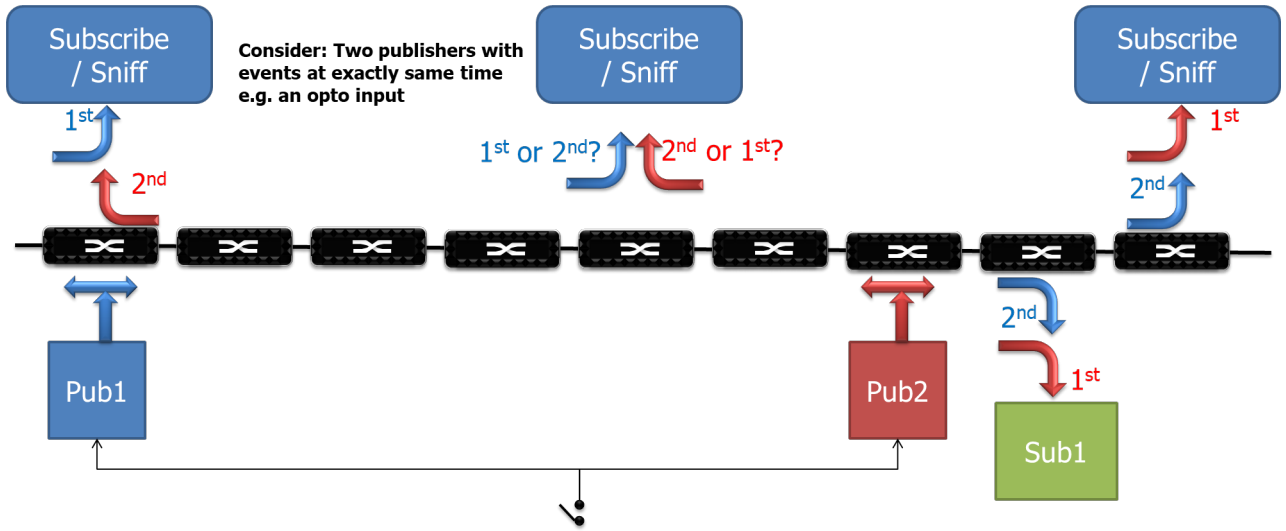
0.395 per unit peak positive error
-0.333 per unit peak negative error

- Sampled Values are digital representation of analog Voltage and Current measurements in digital protection systems

- Sampled Values from different analog to digital converters must have 1 microsecond coherency to avoid phase errors and maloperations.

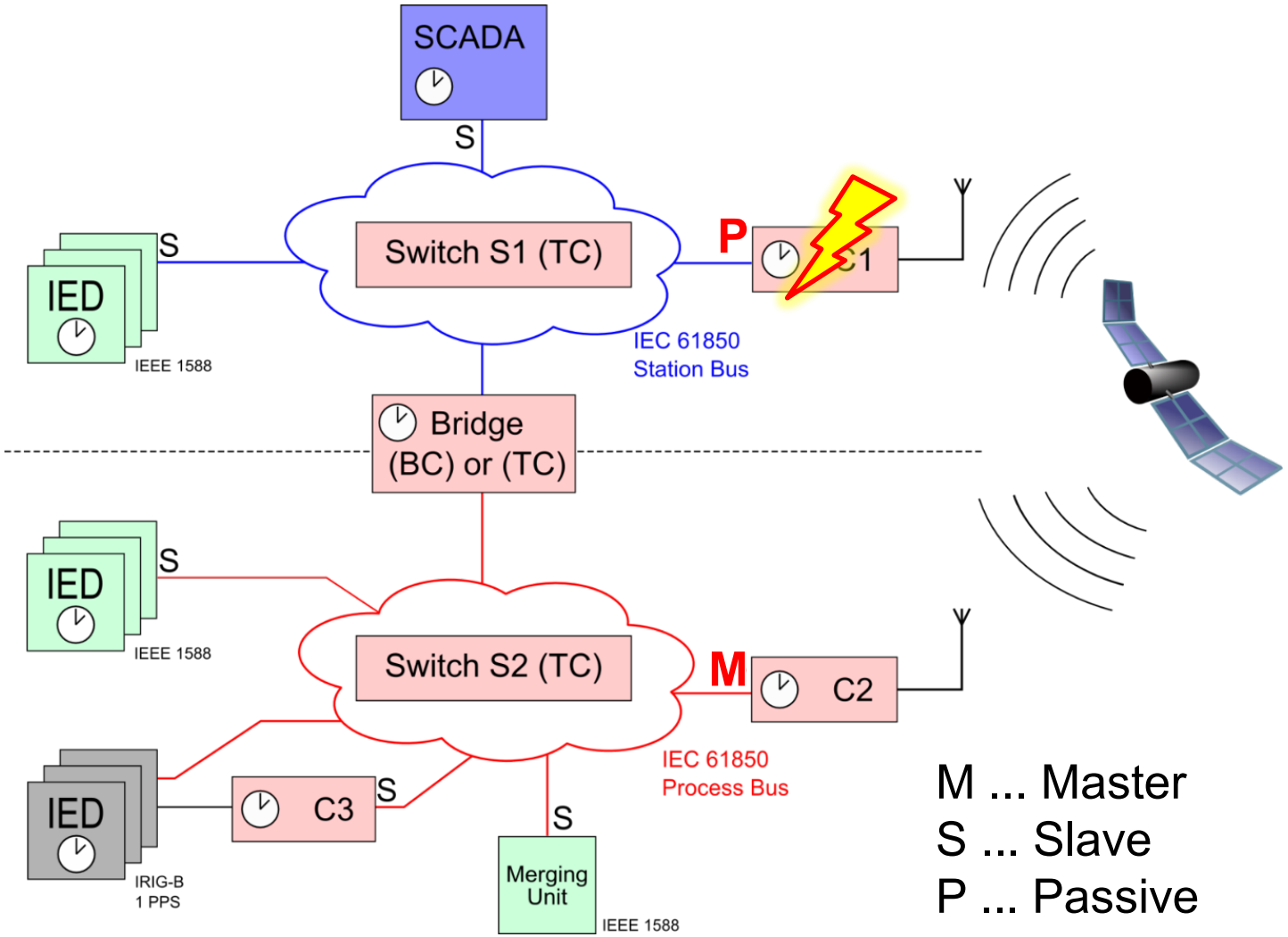
Digital Substations – GOOSE timestamping





- GOOSE communication carry system events such as status changes, trip signals when power system fault occurs.
- Each GOOSE message is timestamped at the start of a new sequence upon status change. The subscribing IED may receive the same status change from 2 different publishers, all IEDs need to be time synchronised to same time reference to interpret the sequence of events.

Application of PTP in Digital Substations



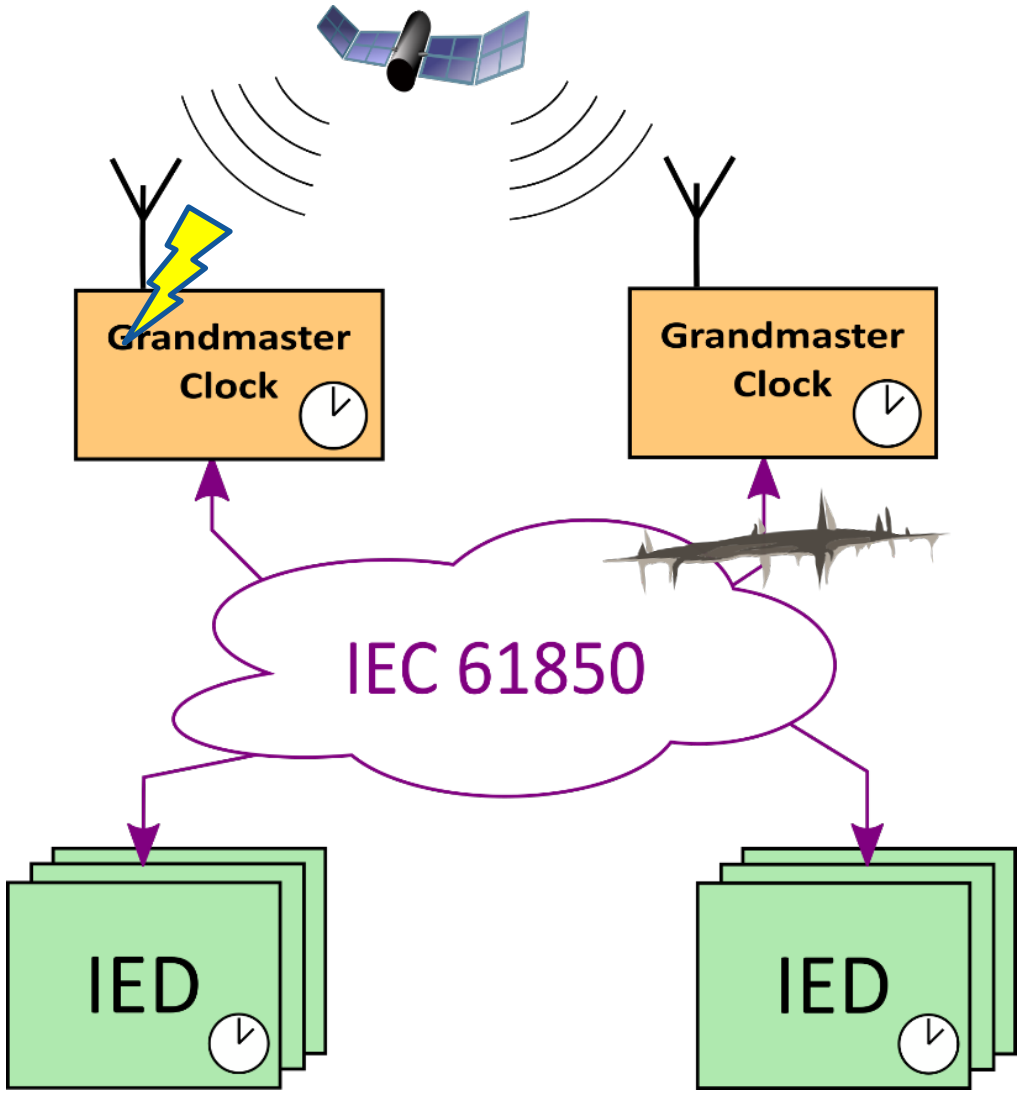
- **IEC 61850-9-3, PTP power utility profile.** Selection and switchover of Grandmaster Clock is done using **Best Master Clock Algorithm**.

- Failure of satellite connection or receiver antenna is quite common – hence a robust oscillator is required to maintain accurate (within microseconds) local time synchronisation (for 2-12 hours).

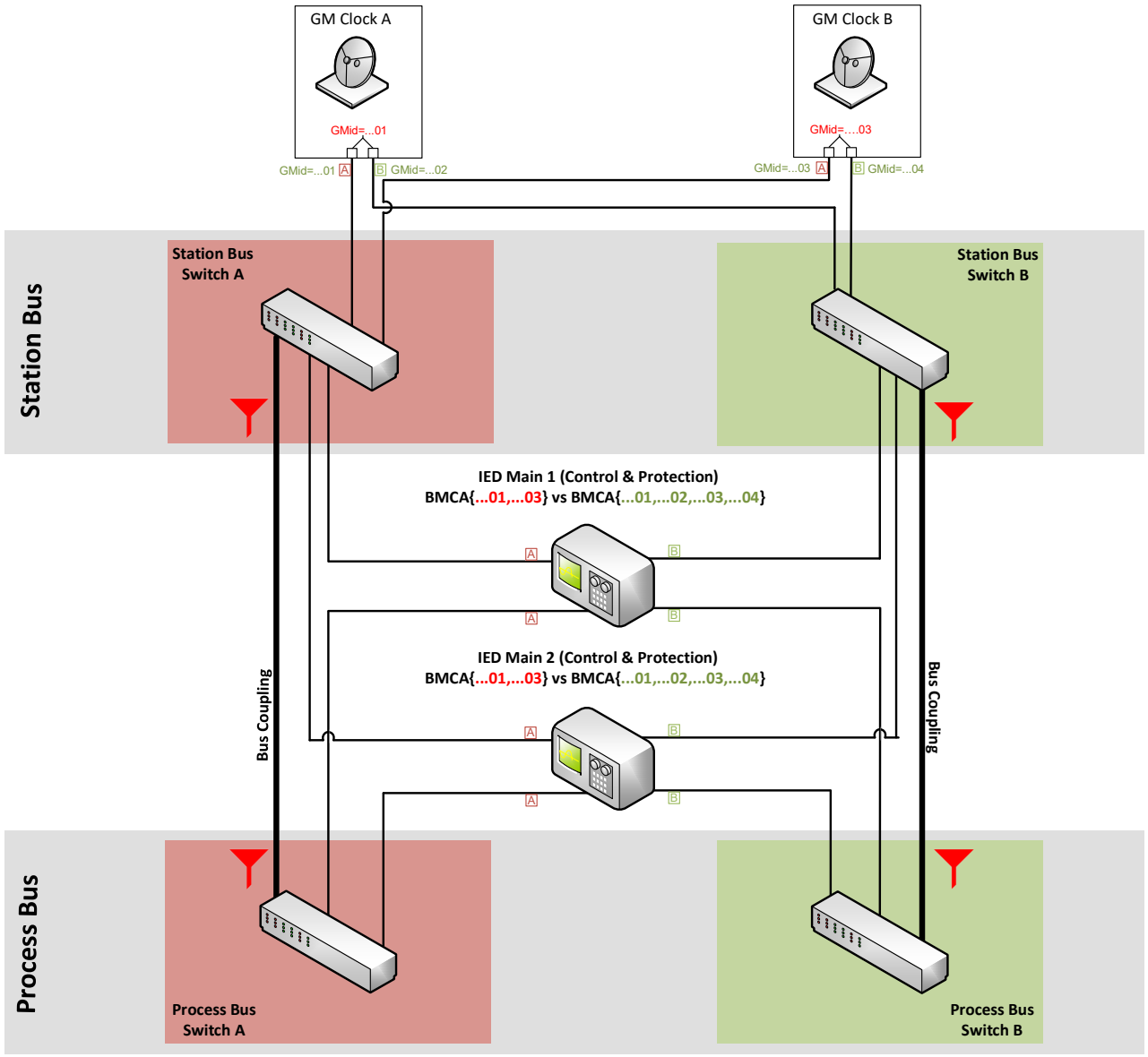
Challenges

Failure Modes

- Problem with the primary time reference
- GPS Spoofing
- Malfunction of the station clock
- Failure of the synchronized IED
- Failure in the time synchronization distribution network

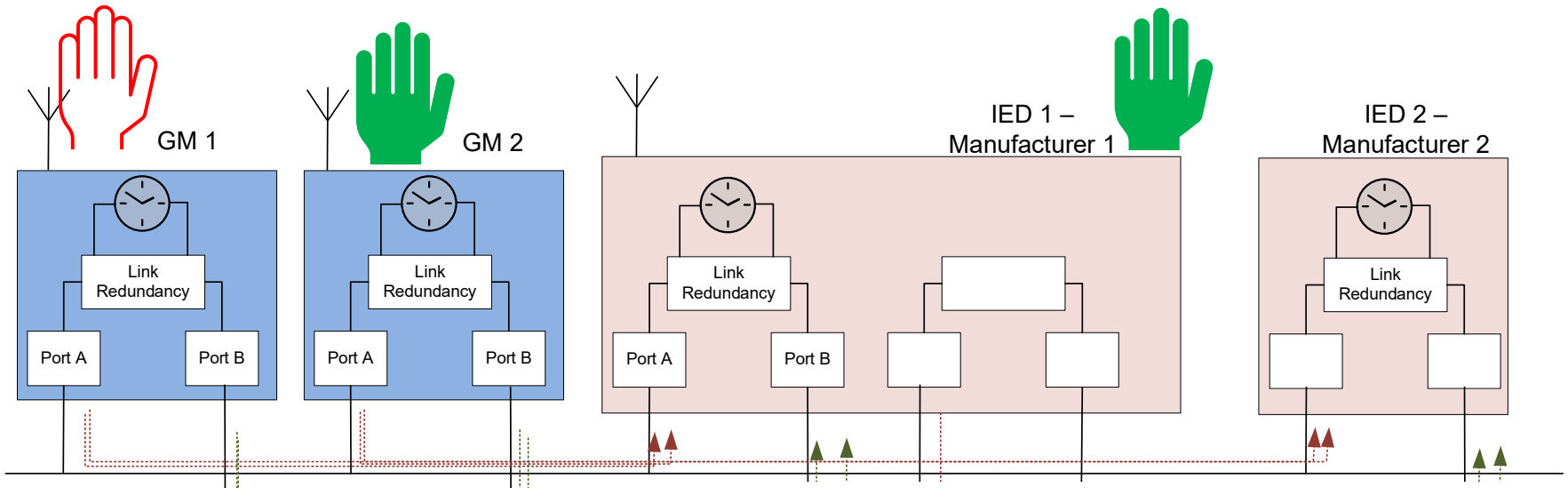


Maintaining common reference



- Precise time synchronisation is crucial to functional availability of digital substations which protect power systems against faults and blackouts.
- 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 synchronised to same time source.

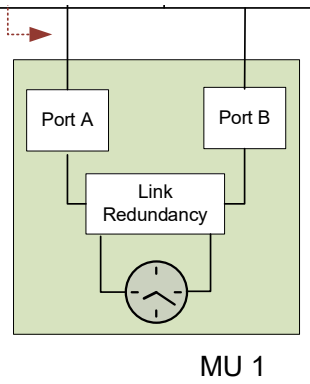
Presence of multiple master clocks



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

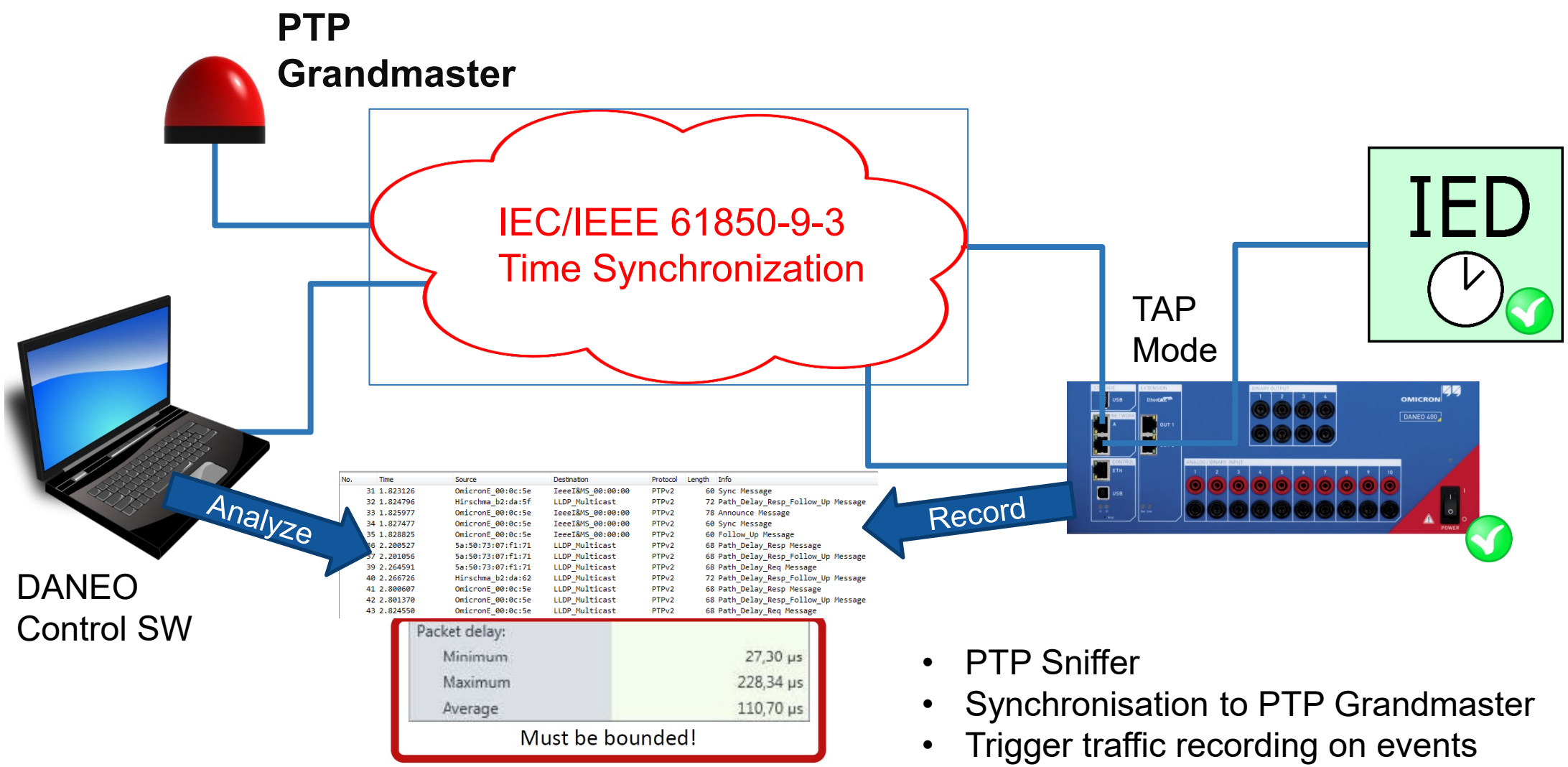
IED 2 sees 4 different clocks, 2 at each port and could also be synchronised by IED 1.

- 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 failures through testing



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

Summary[1]

Precise time synchronisation is crucial to digitalisation of power systems.

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

Utilities should follow best practices, such as:

- Use combined GPS & GLONASS receivers, as they are more difficult to “spoof”
- Use high stable oscillators (OCXO, atomic clocks), to help bridge temporary signal loss due to jamming or space weather
- Use atomic clocks as back up time source over wide area network

1 Special thanks to Rodney Hughes (RodHughesConsulting), Birkir Heimisson (LANDNSET) and Fred Steinhauser (OMICRON) for their input and help with the presentation.

THANK YOU