# COSECTIME:
# Coordinated secure timing for digital power transmission systems

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# Abstract

The power transmission system is increasingly dependent on accurate timing for reliable operation and control. In particular, real-time streaming of data from networked Phasor Measurement Units (PMUs) for wide-area monitoring and automated control implies increasing dependence on accurate, available, and reliable microsecond-level timing.

The overall goal of the COSECTIME project is to demonstrate the applicability of state-of-the art fibre-optic time transfer techniques for traceable and secure synchronization of digital power transmission network measurement and control systems.

We will present results from a pilot demonstration in which the transmission system operator (TSO) generates its own autonomous UTC traceable atomic time scale(s) and distributes timing to a IEC 61850 digital substation through a IEEE1588PTP-WR fibre optic network.

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# Power sector timing requirements

**Table 2. Power system uses of time-dependent data**

| Grid application | Timing requirements (minimum reporting resolution and accuracy relative to UTC) |
|---|---|
| Advanced time-of-use meters | 15, 30, and 60 minute intervals are commonly specified (ANSI C12.1) |
| Non-TOU meters | Ongoing, with monthly reads or estimates |
| SCADA | Every 4-6 seconds reporting rate |
| Sequence of events recorder | 50 µs to 2 ms |
| Digital fault recorder | 50 µs to 1 ms |
| Protective relays | 1 ms or better |
| Synchrophasor/phasor measurement unit (30 - 120 samples/second) | Better than 1 µs<br>30 to 120 Hz |
| Traveling wave fault location | 100 ns |
| Micro-PMUs (sample at 512 samples/cycle) | Better than 1 µs |
| **Communications protocols** | |
| Substation local area network communication protocols<br>(IEC 61850 GOOSE) | 100 µs to 1 ms synchronization |
| Substation LANs (IEC 61850 Sample Values) | 1 µs |

North American Synchrophasor Initiative | March 2017
NASPI-2017-TR-001
PNNL-26331

**Time Synchronization in the Electric Power System**

**NASPI Technical Report**

**NASPI Time Synchronization Task Force**

**March 2017**

NASPI North American SynchroPhasor Initiative

https://www.naspi.org/node/608

# Norwegian power sector regulatory requirement on 'secure timing sources'

The Norwegian energy preparedness act requires 'secure timing sources' for control systems:

§ 7-14 **j) Sikker tidsreferanse**
*Driftskontrollsystem som er avhengig av eksakt tidsreferanse,*
*skal ha **sikre kilder** for tidsangivelse.*

https://lovdata.no/dokument/SF/forskrift/2012-12-07-1157/KAPITTEL_7#§7-14

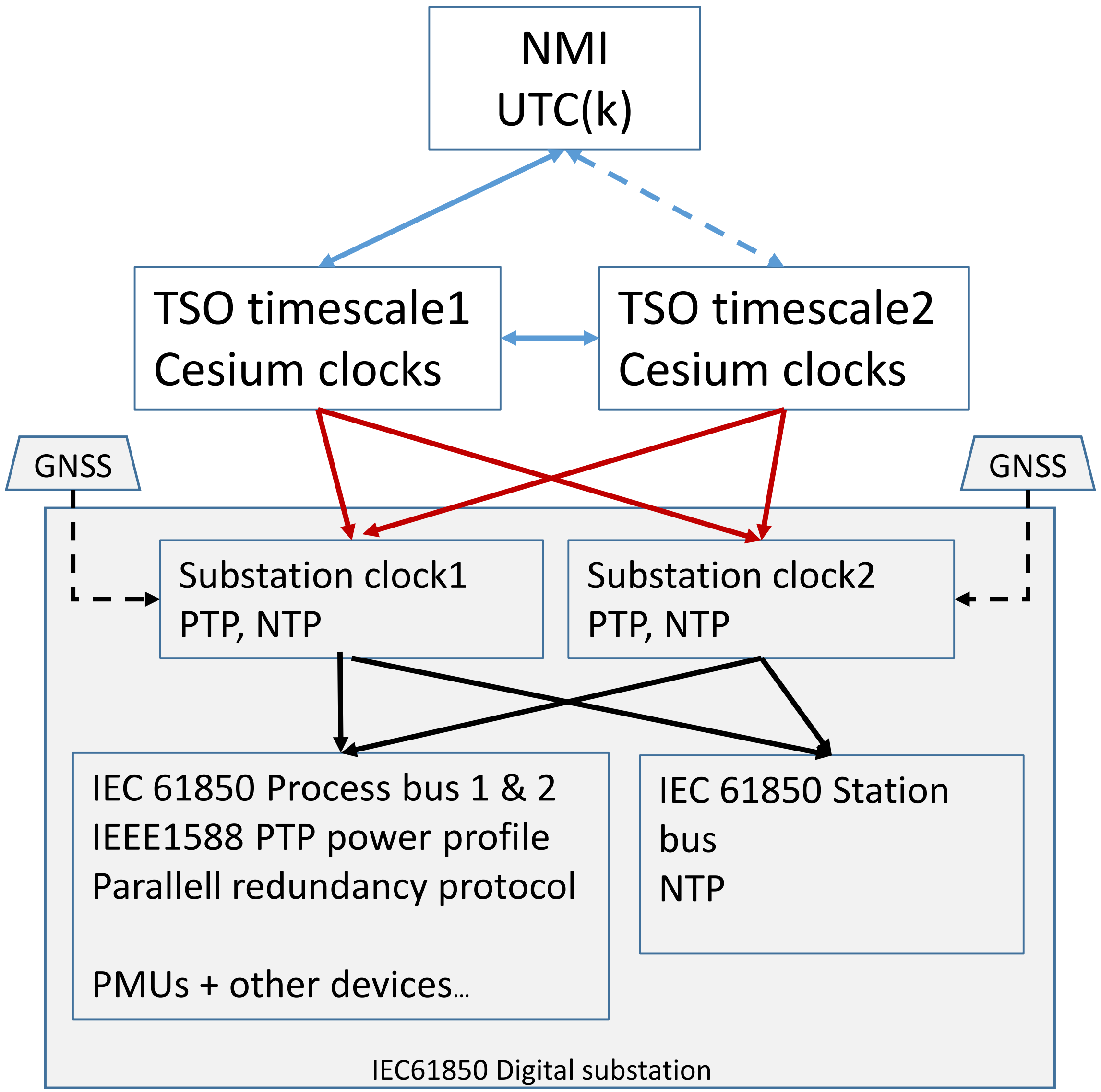
Reasons for the requirement :

- GNSS timing vulnerabilities (jamming, spoofing)
- Avoiding single points of failure (i.e. relying on a single source of timing)

Methods to comply with the requirement not specified in detail

- Operating and controlling highly accurate clocks indicated as an option

# COSECTIME demonstration of secure timing sources




UTC(k) offset: < 10s ns from UTC (goal)
UTC(k) –TSO link uncertainty: < 10 ns
Link technologies: Transportable Cs clock
IEEE1588 White Rabbit (fiber)

TSO timescales: < 100 ns from UTC (goal)
Microsemi 5071A Cs clocks give extended autonomous operation
Timescale steering every few months

TSO master clock to substation distribution link
Calibration requirement: 10 – 100 ns* uncertainty
Link technology: IEEE1588 PTP (White Rabbit) over DWDM
Link asymmetry calibration using mobile Cs clock

Station clocks < few 100 ns* from UTC
Meinberg M3000 with multi reference input card
Rb oscillator for holdover capability

Station timing distribution:
IEEE1588 power profile to PMUs/IEDs , NTP to station bus

Requirement for PMU/IED timestamps < 1 µs from UTC

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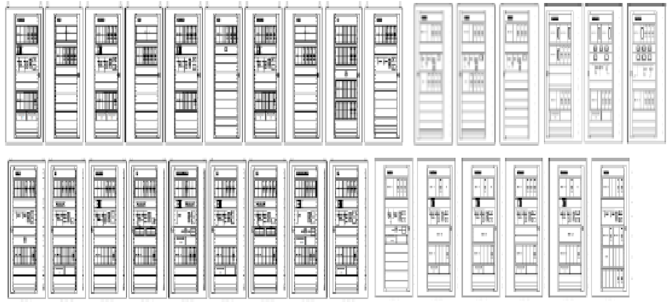
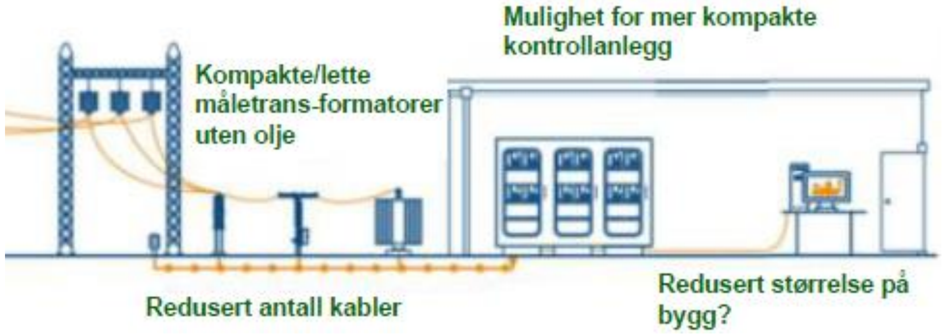
# Statnett R&D IEC61850 Digital station pilot project



**Conventional substation control room:**

- Up to 30 instrument racks
- 800 power and signal cables from analogue measurement devices
- Cumbersome calibration of signal delays




**Digital pilot substation control room:**

- 4 instrument racks
- 7 power cables / optical fibers
- Timestamped digitized sampled values over IEC61850-9-2 process bus
- IEEE 1588 PTP power profile on process bus
- Station clocks using timing from Statnett master clocks + GNSS

**Digital substation pilot redundancy:**

- Duplicated process bus using PRP (parallell redundancy protocol)
- Redundant Meinberg station clocks with Rb-oscillators for holdover
- Statnett master timescale(s) to Seven Solutions WR Switch via DWDM network to WR Zen 1588 PTP/WR slaves as timing sources

# COSECTIME pilot demonstration lessons I

White Rabbit in DWDM network

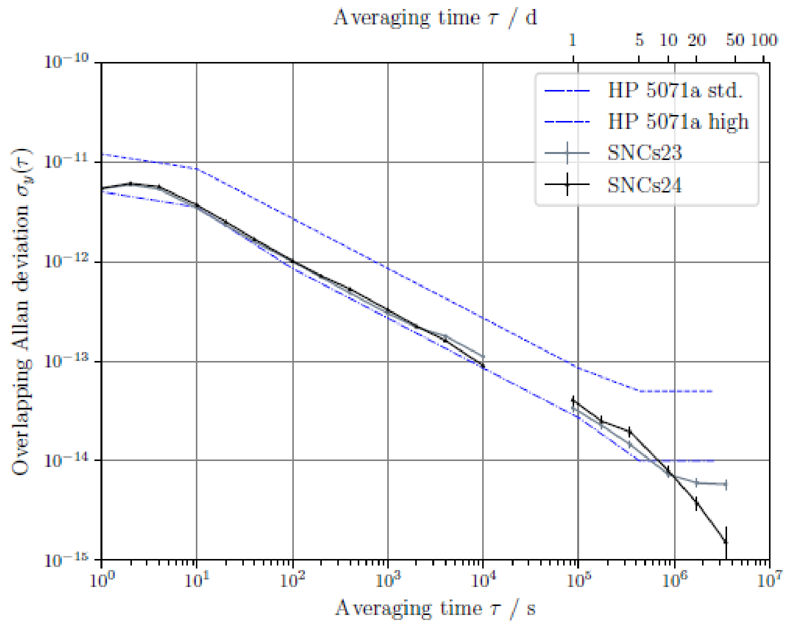
- Unable (yet) to make WR slave phase lock to master using 1310 nm to DWDM managed wavelength SyncE compatible transponder cards
- Standard IEE1588 PTP works over the same transponders
- Work underway to test PTP-WR over alien wavelength

PTP distribution of Statnett atomic timescale to digital station pilot

- Link asymmetry + station clock GNSS timing calibrated with mobile cesium clock
- Measurement of PTP link stability to be carried out in October against mobile cesium clock

Industrial 5071A cesium clocks for timescale generation

- Standard performance Microsemi 5071A – close to stability spec for high perf.
- Temperature coefficient of relative frequency offset
  -5 x $10^{-15}$ / K over 22 +/- 10 degrees C
- Cesium clock in data center rack with forced convection cooling:
  + 4 ns/d fast compared to lab calibration at 22 C natural convection

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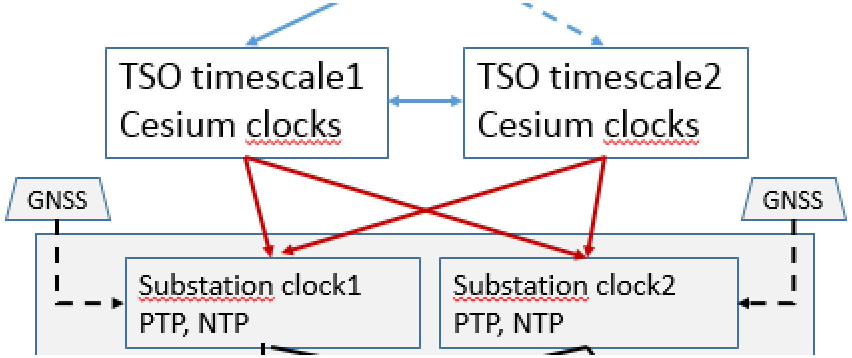
# COSECTIME pilot demonstration lessons II: Calibration

Calibration issues:

- Calibration using a mobile cesium clock is accurate (few 10s of ns) and easy during short calibration hauls (< 1 d)
- Calibration  using a reference calibrated GNSS timing receiver is time consuming and not practical to install in secure data center / sub station locations
- Calibration of PTP delay asymmetries at user sites (digital stations) is a practical challenge using a mobile clock (Statnett 150 locations in Norway).
- Calibration of PTP delay asymmetries at user sites could potentially use local GNSS timing as a reference ***IF*** vendors install calibrated  GNSS timing receivers using correct values for antenna locations.  The current pilot installation was uncalibrated and showed + 200 ns timing offset wrt UTC.

# COSECTIME pilot demonstration lessons III: Redundancy




Multiple reference sources at the digital substation pilot

Fully implemented each station clock will see four sources of timing:

- Statnett atomic timescale 1 and 2 (over PTP)
- GNSS timing
- Local Rb holdover oscillator (disciplined)

| Priority | Source | Status | Offset |
|---|---|---|---|
| 01 | PTP (IEEE1588) | Signal available, Is master | +0.0ns |
| 02 | GLONASS/GPS Receiver | Signal available | -14.0ns |
| 03 | ext. Osc. | Signal available | -16.0ns [ +19.0ns] |
| - | PPS in | Not prioritized | N/A |
| - | IRIG | Not prioritized | N/A |

In princple on could use multi source clock offsets select sync source based on correctness (clustering as in NTP)

- Detect timing jumps due to e.g.
    - Reference timescale errors
    - Changes in PTP delay asymmetry
    - Errors in GNSS timing

# COSECTIME outlook

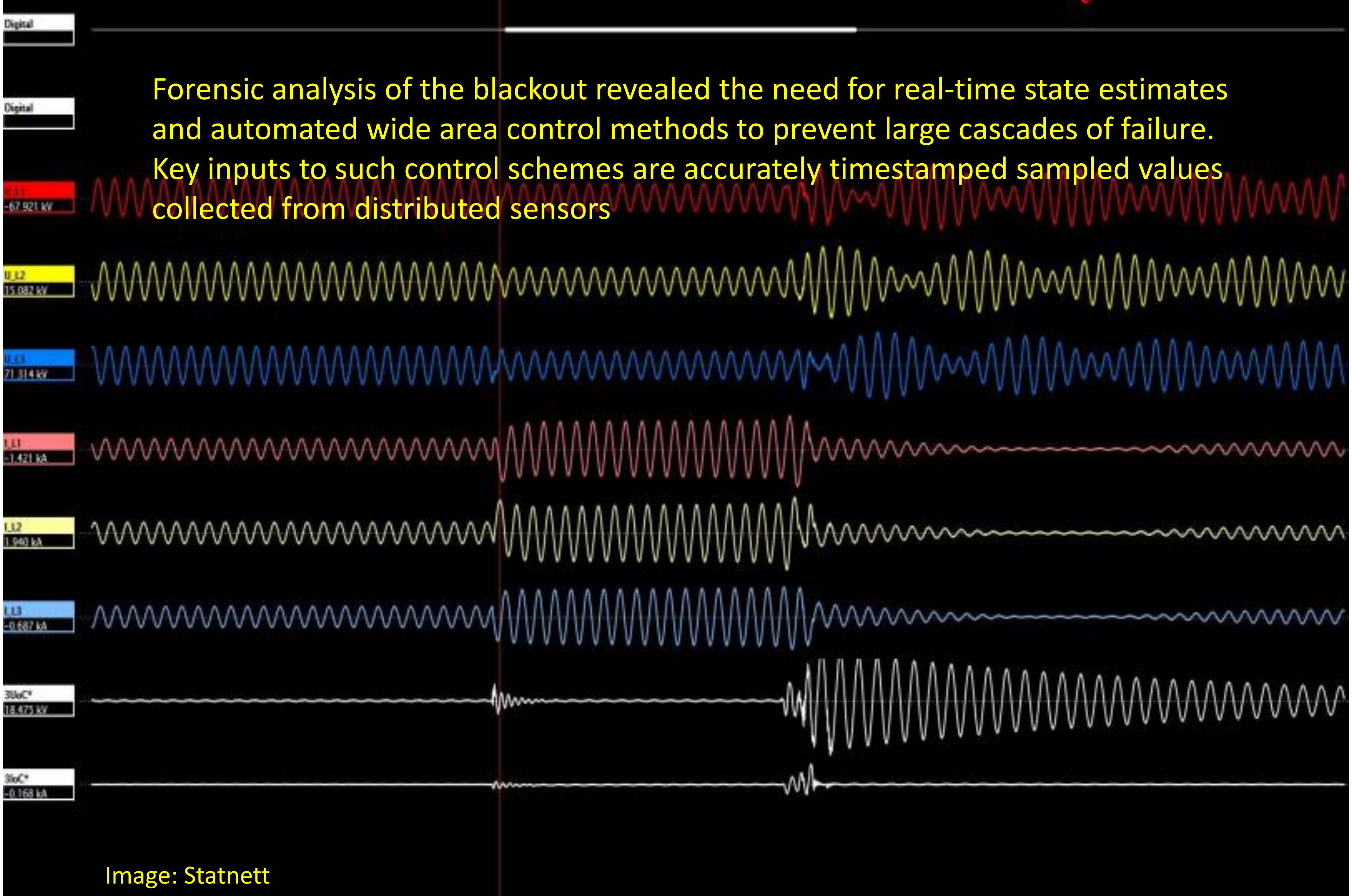
Ongoing work in COSECTIME pilot demonstration

- Testing IEEE1588 PTP-WR over alien wavelength in DWDM system
- Establishing a PTP (PTP-WR) link between Statnett timescale(s) and UTC(JV)
- Real time monitoring of cesium clock stability in data center environment
- Sorting out inconsitencies in leap-second implementation in PTP/PTP-WR devices
- Systematic archiving of station clock multi reference time offset data to central log/analysis databases
- Testing of redundancy switching at digital substation pilot

Questions?

Traditionally  electric power transmission systems have been designed and operated with very large safety margins
Actions to stabilize the transmission system could be applied after careful consideration…

The northeast US blackout in 2003 was an expensive (USD 6 billion) wake-up call….




Forensic analysis of the blackout revealed the need for real-time state estimates and automated wide area control methods to prevent large cascades of failure. Key inputs to such control schemes are accurately timestamped sampled values collected from distributed sensors

Image: Statnett

Timestamping with microsecond accuracy is needed for truthful real time state estimates
IEC61850 was born out of the need to standardize handling of digitally sampled values.


Image: ABB