Precise Timing for Electric Utility Operations

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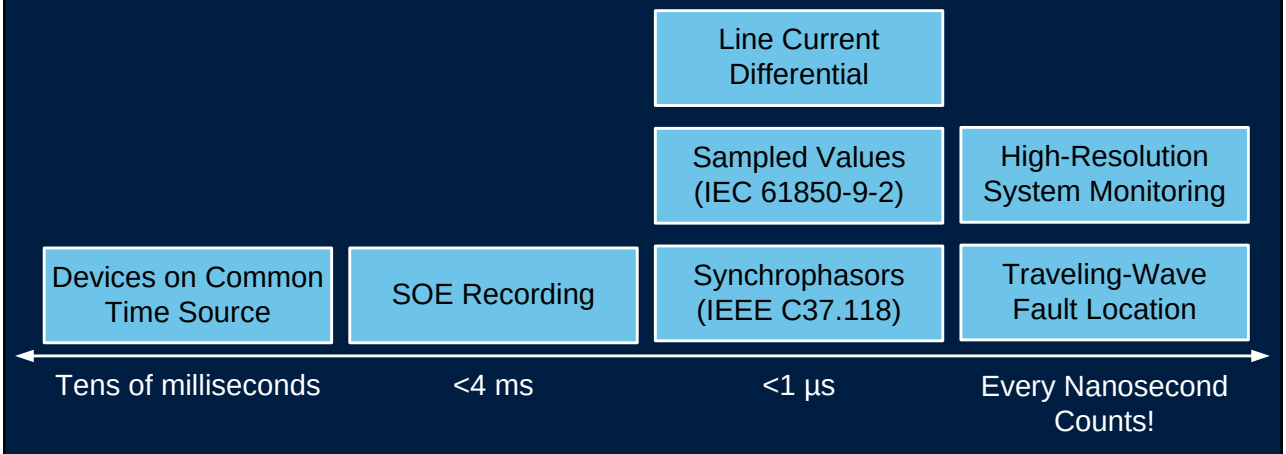
Precise Time Adds Value to Power System



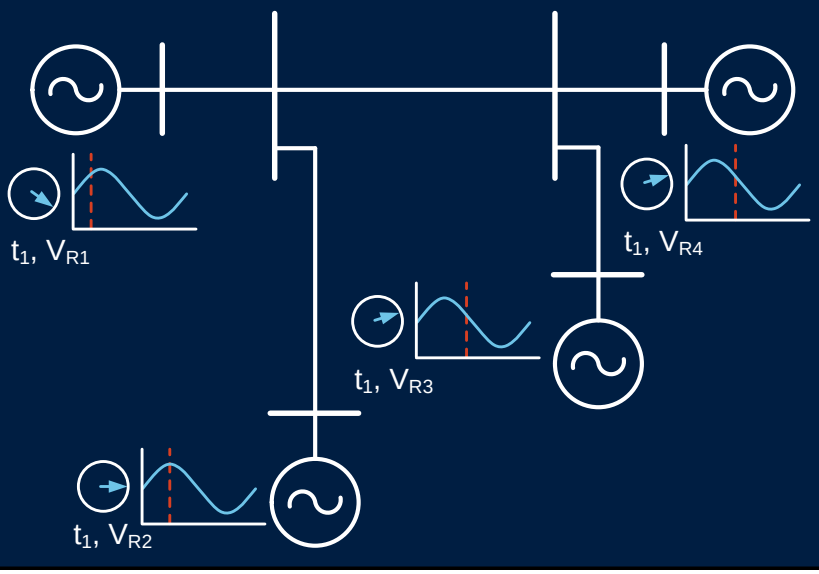
2003 Northeast Blackout
Lessons Learned

- Time synchronization for digital fault recorders (DFRs)
- Phasor measurement units (PMUs) for better system-level view
- Events time-tagged within 4 ms accuracy

Better SOE Reports Using Millisecond Accuracy

- Millisecond accuracy allows you to determine event sequence during cascading events
- NERC will require 2 ms accuracy for disturbance monitoring and reporting (PRC-002-2)

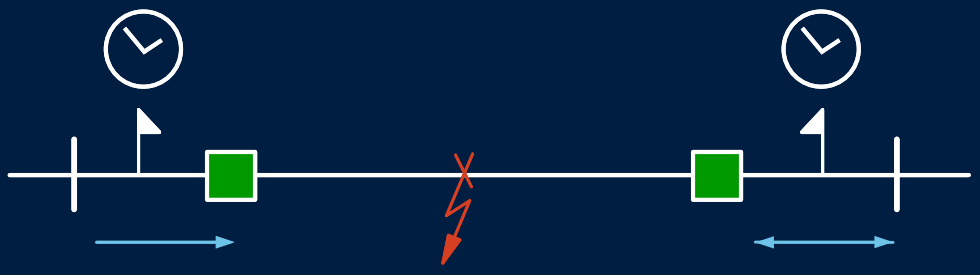
Synchrophasors Provide Snapshot of Power System



Timing Requirements for Synchrophasors
IEEE C37.118.2-2011

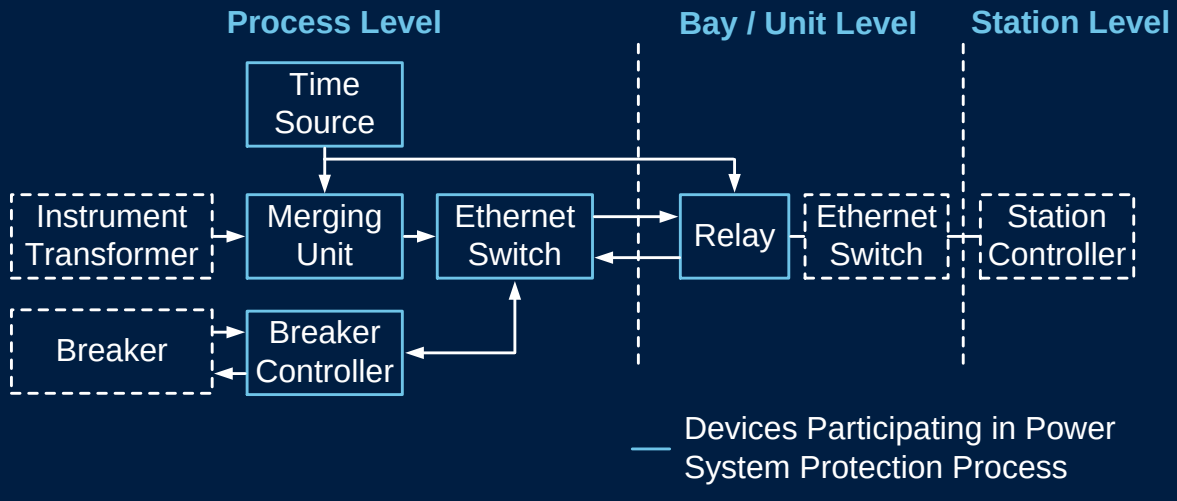
- Standard requires ≤1% total vector error for entire system
  - 0.01 radians (0.57 degrees)
  - ±26 µs in 60 Hz system
- Time source must be highly reliable
  - Standard assumes accurate time
  - PMUs require 1 µs accuracy

Line Current Differential Protection

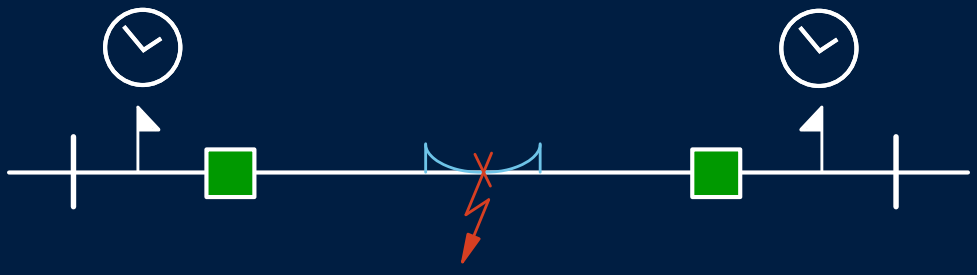


1 µs accuracy typically required to use time-aided line current differential scheme

Sampled Measured Values (IEC 61850-9-2)

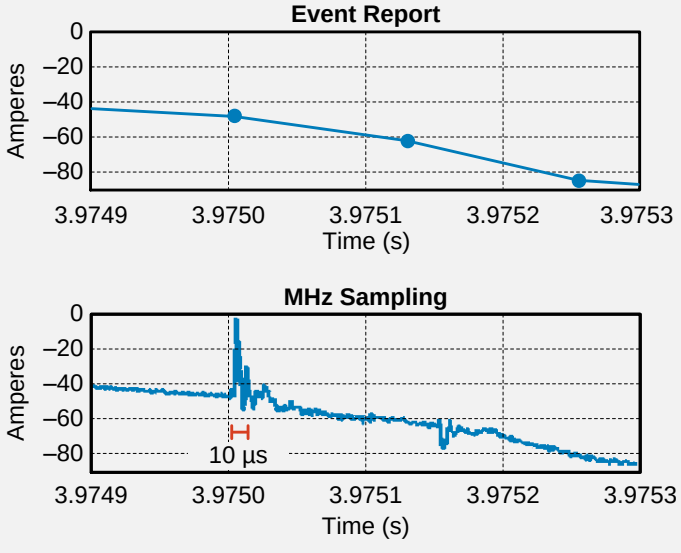


Traveling-Wave Fault Location



Every nanosecond of inaccuracy can result in 1 foot of fault location uncertainty

High-Resolution Event Reporting Removes Frequency Assumptions



Consider Potential Vulnerabilities

- Antenna failures
- Device failures
- Multipath errors
- Solar flares
- Jamming
- Spoofing

Mitigating GNSS Vulnerabilities

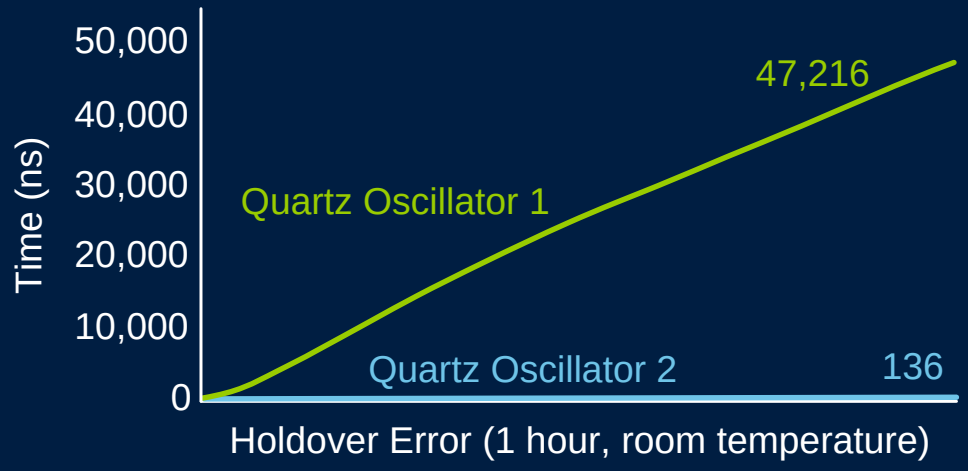
- Rugged equipment
- Stable holdover
- Multiple constellation comparison
- Wide-area time distribution with time source verification

Rugged Equipment

- Antennas are **most vulnerable** part of any GNSS timing system
- Substation clocks with Ethernet should carry IEEE 1613 certification

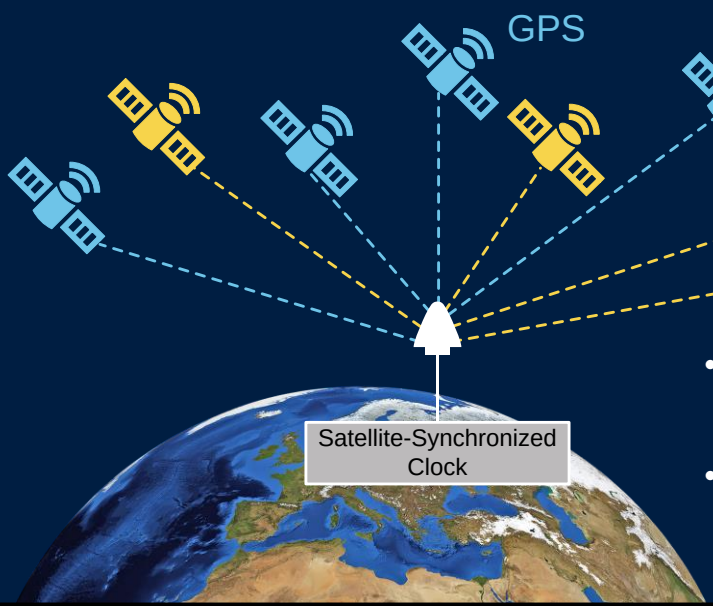
Holdover Is Significant for Synchrophasors

Oscillator Comparison



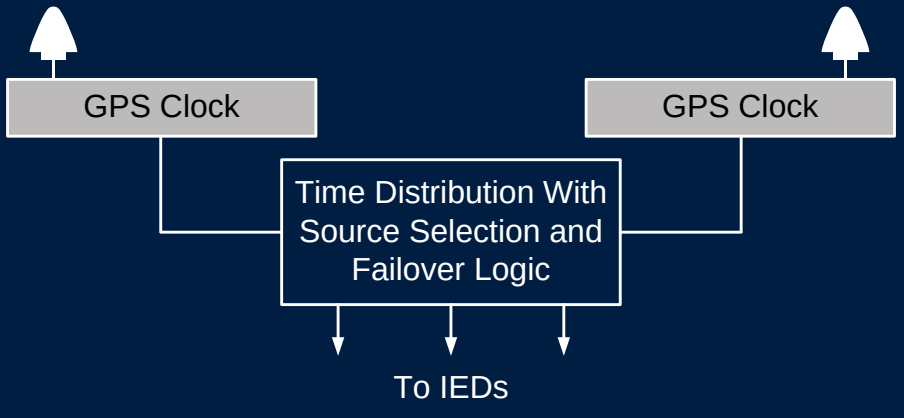
Cesium or rubidium oscillators can be even more accurate

Multiple Constellation Comparison



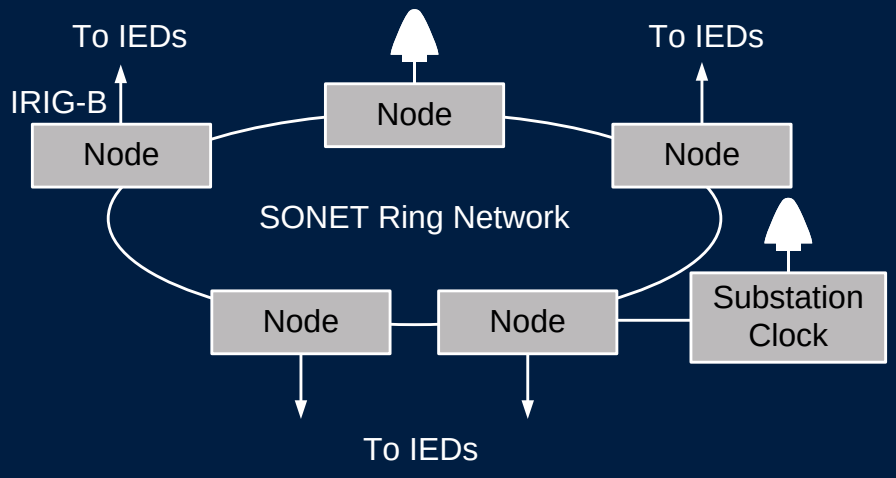
- Receive signals from two satellite constellations
- Verify pulses per second, date and time, and location

Redundant Clocks

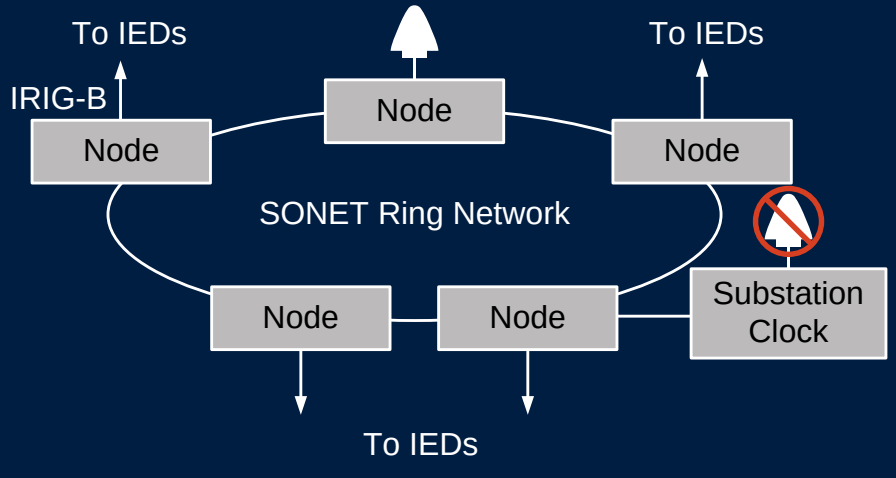


Signals are received by GPS clocks that are installed in different locations

Wide-Area Time Distribution
Using Synchronous Optical Networks (SONETs)



Wide-Area Time Distribution
Mitigates Local Vulnerabilities



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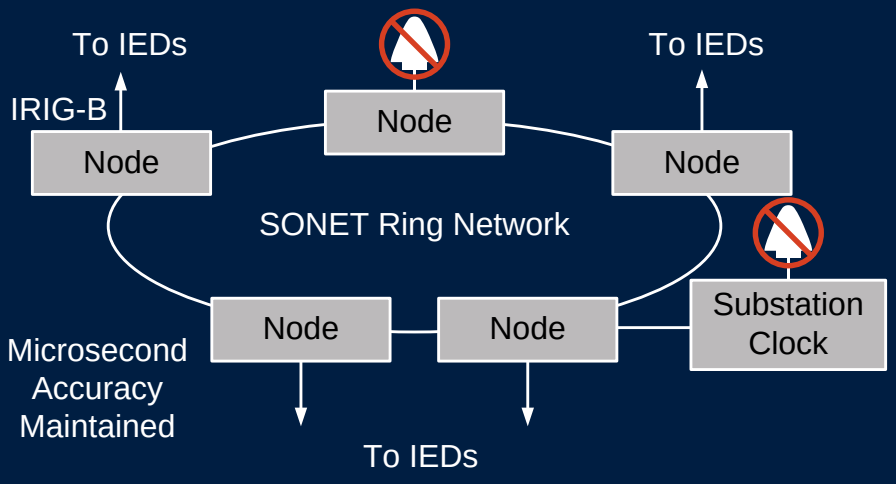
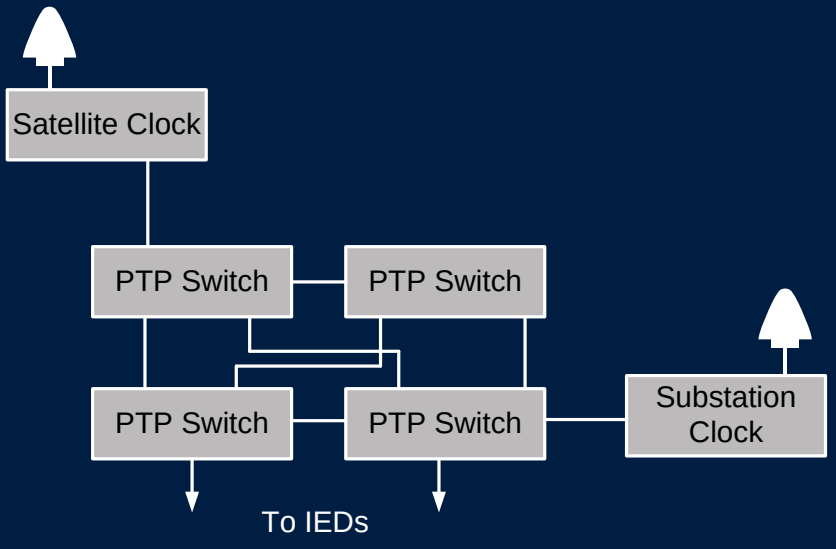
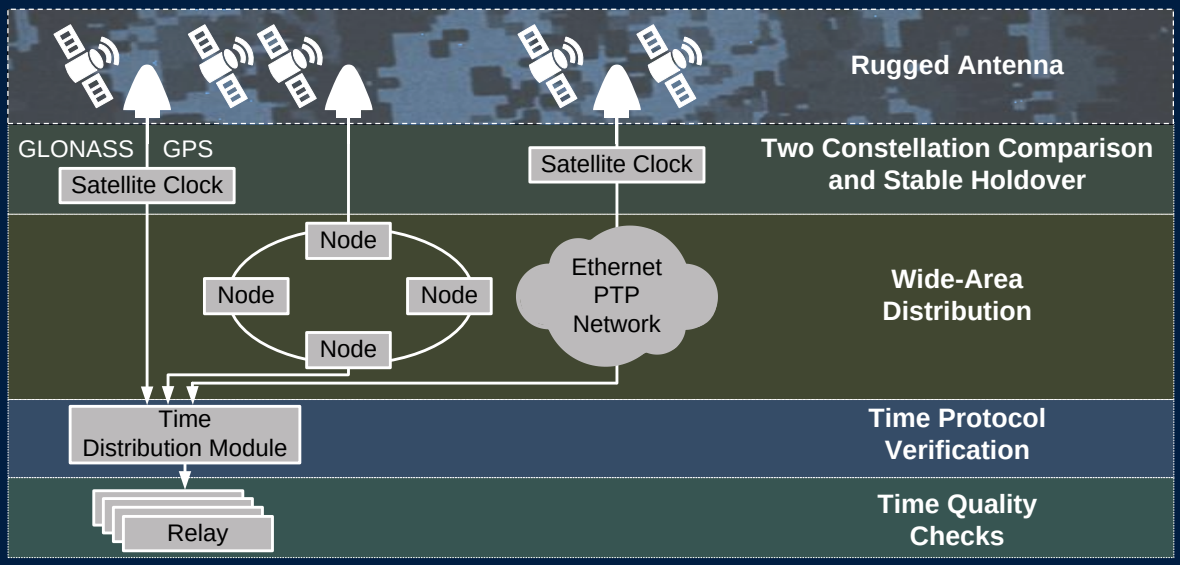


Wide-Area Time Distribution
Using IEEE 1588 Precision Time Protocol (PTP)



Layered Approach to Time Integrity



Questions?