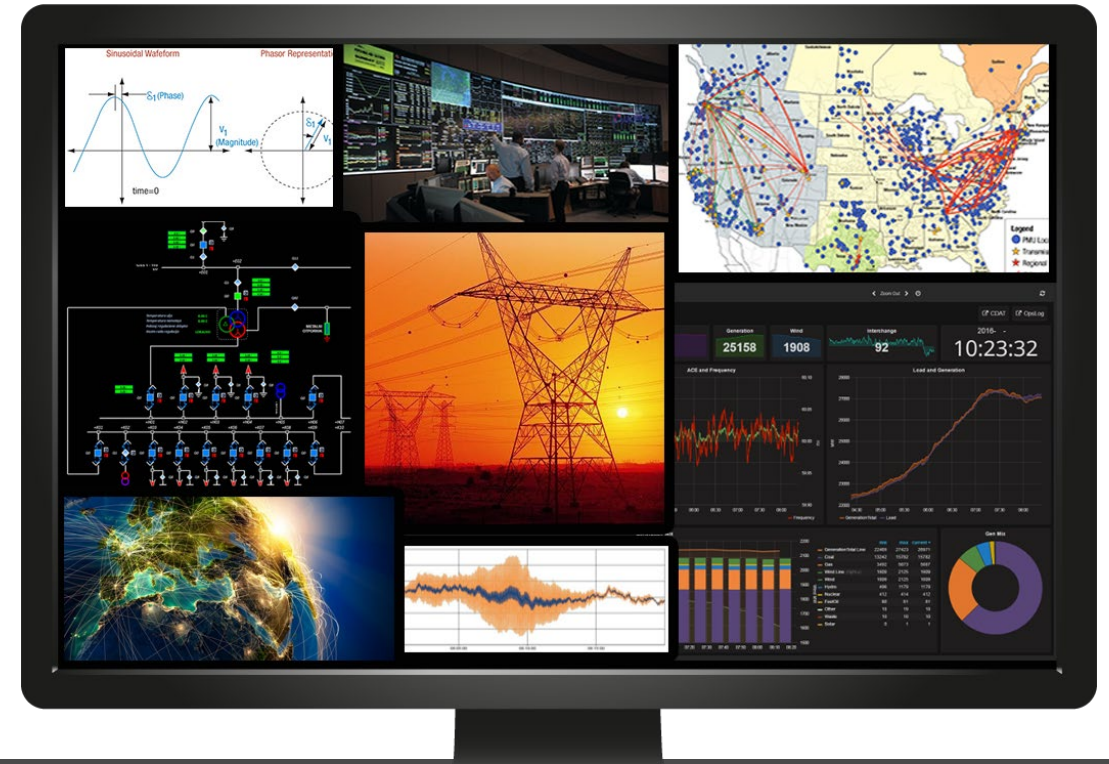


September 24/25 2025



Challenge in Synchronization

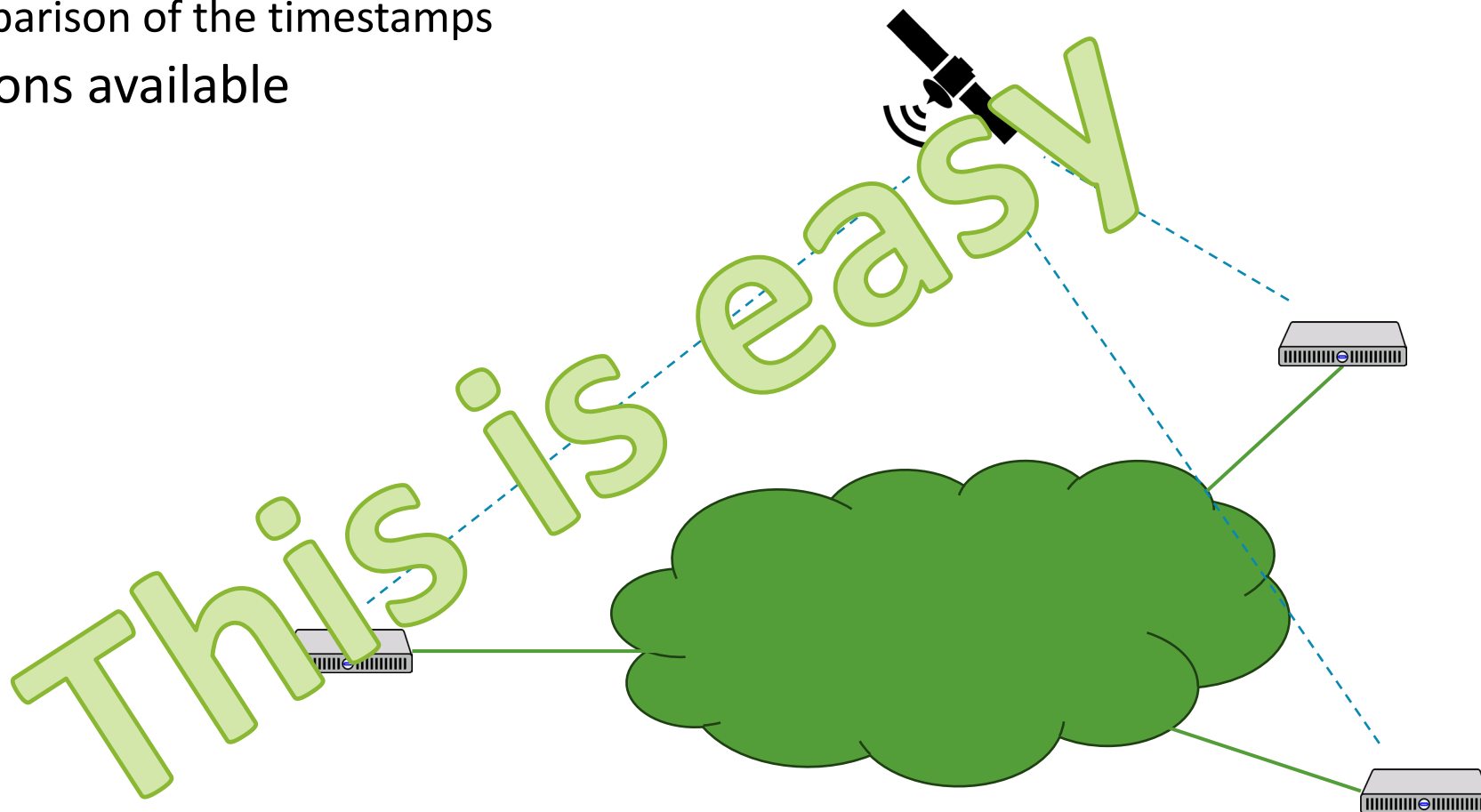
What is a Synchronized Waveform

Synchronized Waveform

- Accurately Timestamped
- Measures point on sinusoid
- Comparable across the system
- Sampling rates > 1 kHz
- Large range of values ($-V_{Base}$ to $+V_{Base}$)

Common Clock

- A single source of time keeping
 - Allows comparison of the timestamps
- Various options available
 - GPS
 - LEO
 - PTP
 -



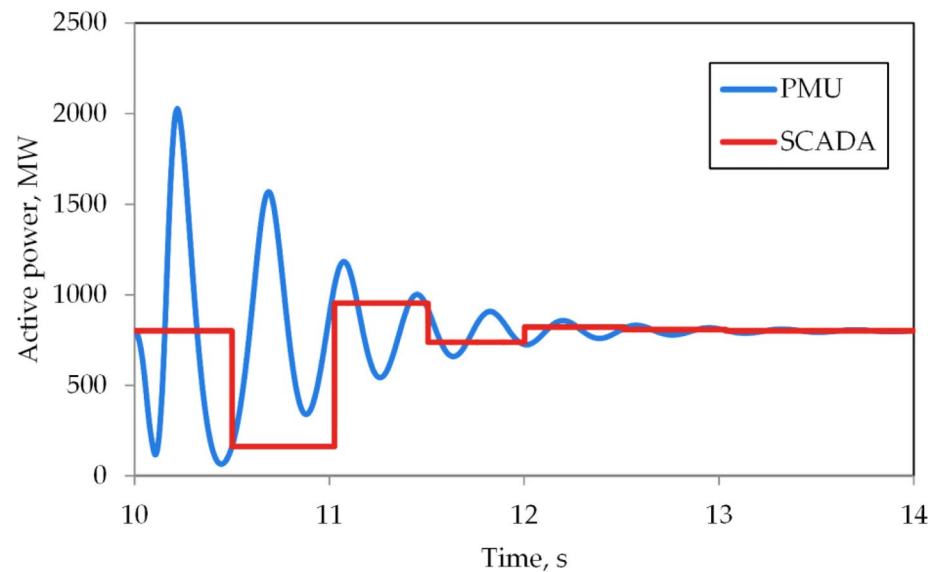
Transition to Higher Sampling Rates

■ We have done this before

- SCADA 0.001 Hz
- Synchrophasor: 30 Hz
- Synchronized Waveform: 4,200 Hz

X 3000

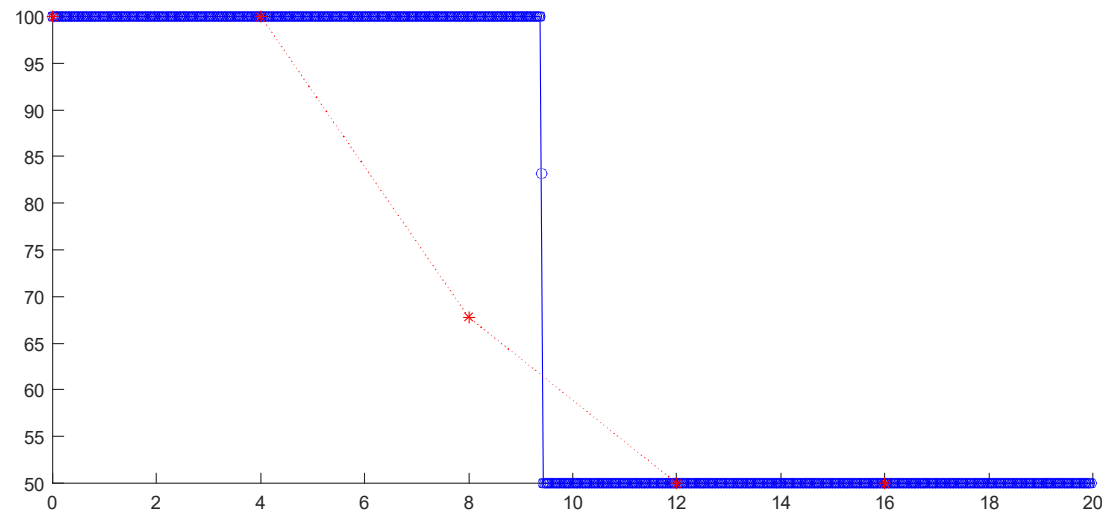
X 1400



What is going on - SCADA

■ SCADA Timestamps

- Not accurate
- SCADA measurement is not a single point in time
- Timestamp is applied anywhere in window



What is going on - PMU

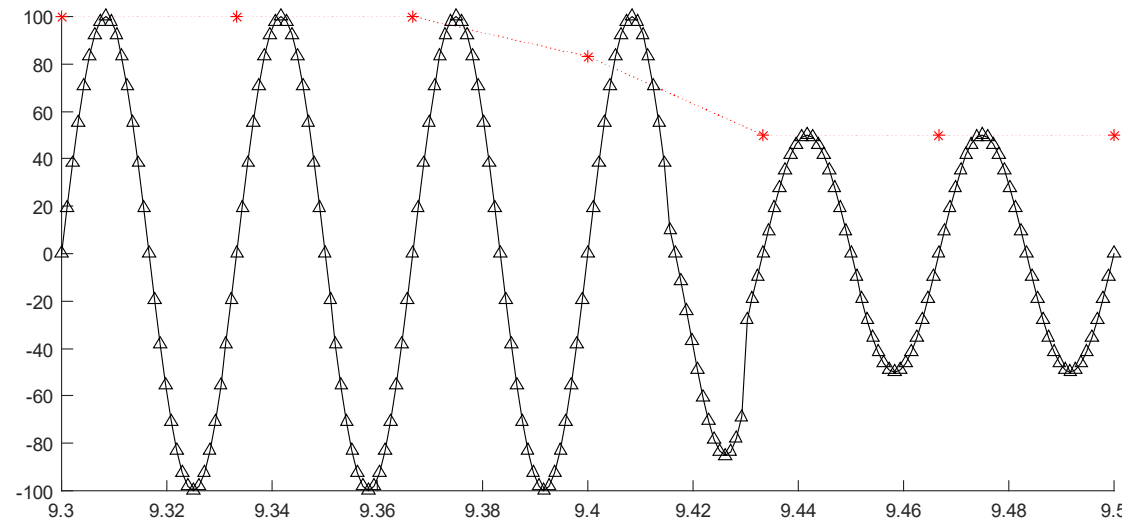
- PMU Timestamps
 - Very accurate
 - PMU is not a single point in time
 - Length depends on manufacturer – standard provides some information
 - Timestamp is applied at center of window (IEEE C37.118)

PMU Data is comparable(ish)

What is going on – Point On Wave

■ PMU Timestamps

- Can be very accurate
- Point On Wave is a single point
- Timestamp is applied when measurement is taken



Point on Wave SHOULD be comparable

Why is Point On Wave different

- Point on Wave measurement is old
 - DFRS existed in 1980s
 - Measure data in samples per CYCLE
- Synchronization is new
 - Frequency across the system differs
 - Sampling frequency is locked to system Frequency

Timestamp SyncWaveform – Issue 1

- Sampling frequency is not constant
 - Sampling frequency can differ across the system
 - Sampling frequency can differ across time
 - Sampling frequency can differ across phase
- This is an issue because:
 - Data formats are not designed for this
 - Manufacturer dependent implementations
 - People assume they can compare data when they shouldn't

Timestamp SyncWaveform – Issue 2

- Sampling Times are not consistent
 - Time between samples $\sim 1\text{ms}$
 - Maybe a sample at $t = 0$ or maybe not
- This is an issue because:
 - Comparing data becomes difficult
 - Manufacturer dependent implementations
 - Data would be ideal to compute propagation – off by 1 sample matters

SyncWaveform Solution

- We developed standards for PMUs
 - Thank you NASPI
- We have standards for Waveforms
 - The industry has had it for decades
- Some standards span PMU (Synchronization) and Waveforms
 - COMTRADE for data storage
 - IEEE 2664 for data transfer
 -

Let's standardize Measuring
Synchronized Waveforms

Thank you

