Benefits and Lessons - using synchrophasor measurements for Wide Area Situational Awareness (WASA)

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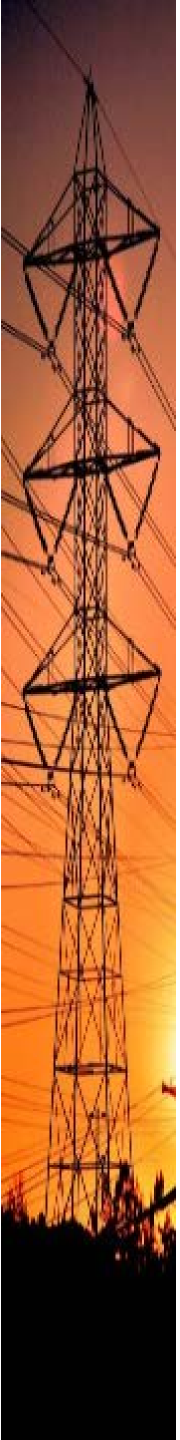
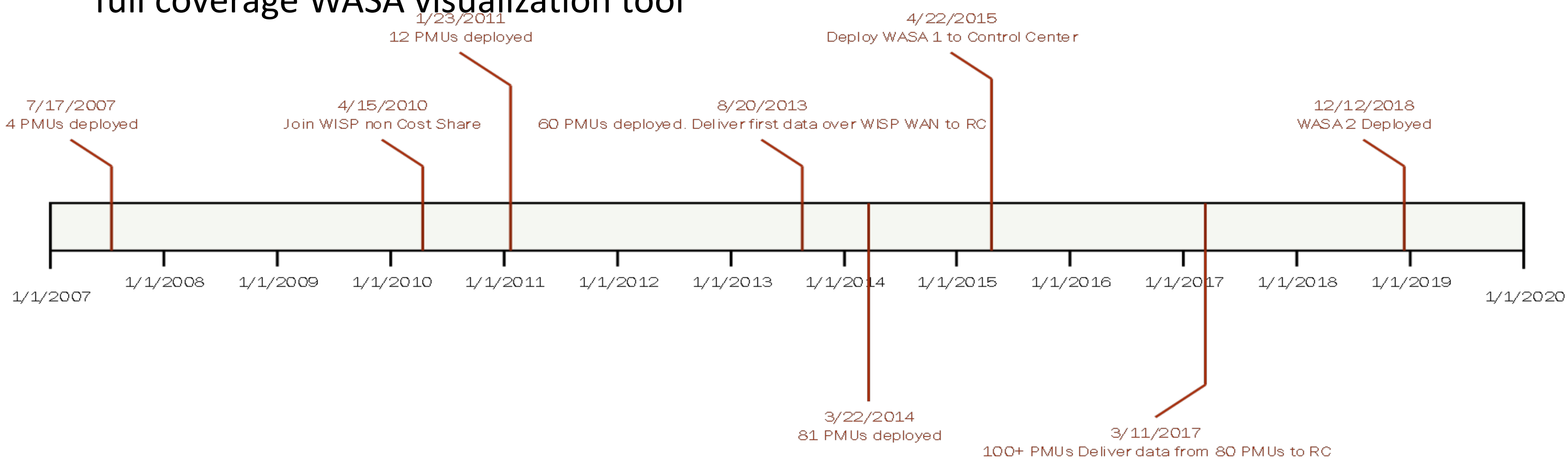


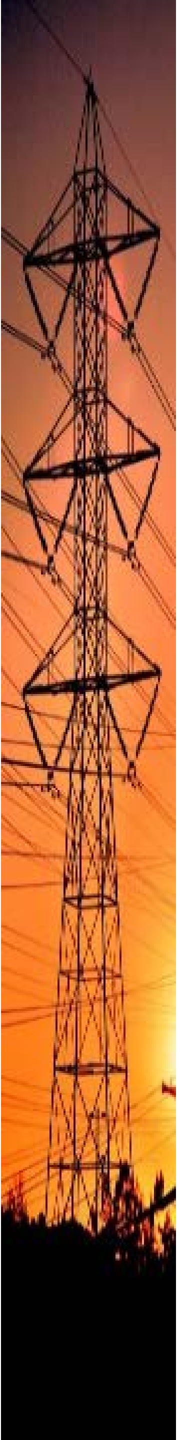
SDG&E System Overview

- Subsidiary of Sempra Energy ®
- Regulated public utility
- Safe and reliable energy service for 3.6 million consumers
  - 1.4 million electric meters
  - 873,000 natural gas meters
- 4,100 square-mile service territory in San Diego and southern Orange Counties (25 cities)
- 1,800 miles of electric transmission lines and 21,600 miles of electric distribution lines
- Two compressor stations, 160 miles of natural gas transmission pipelines, 8,100 miles of distribution pipelines and 6,200 miles of service lines
- 4,300 employees

Overview

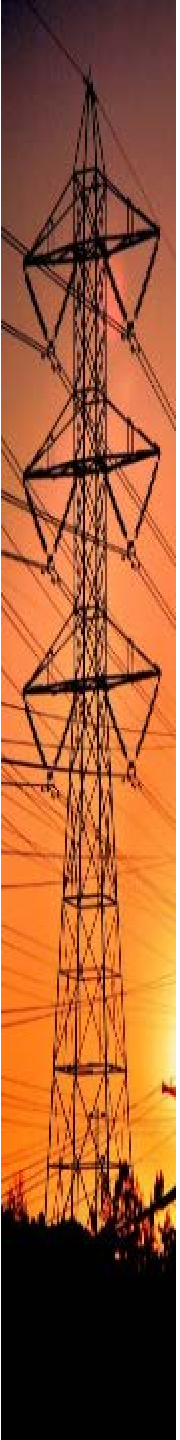
- Over the past 10 years SDG&E has significantly improved their reliability and response capabilities within their Transmission operations with the integration of synchrophasor data for improved wide area situational awareness. (WASA)
- SDG&E was a non cost share participant in the Western Interconnect Synchrophasor Program (WISP)
- Additional PMU's have been deployed since the completion of the first phase in 2013, the additional coverage necessitated improvements in communication and data archiving infrastructure.
- The additional coverage, as well as sharing of synchrophasor data with neighbors using the WISP WAN, has and will continue to unlock additional benefits, ultimately enabling a full coverage WASA visualization tool





WASA Applications Benefits

- Real-Time Operations
  - Ensure Reliability and Safety of Electric Grid
- Digital Information System (Video Wall) Technology
  - System-wide information, refreshed at a high report rate
- Key Steps:
  - Consider value synchrophasor technology provides in the Operations Horizon
  - Develop operational use cases to define how PMU data and synchrophasor application outputs can be used in the control room
  - Use available resources e.g. NASPI CRSTT and D&NMTT

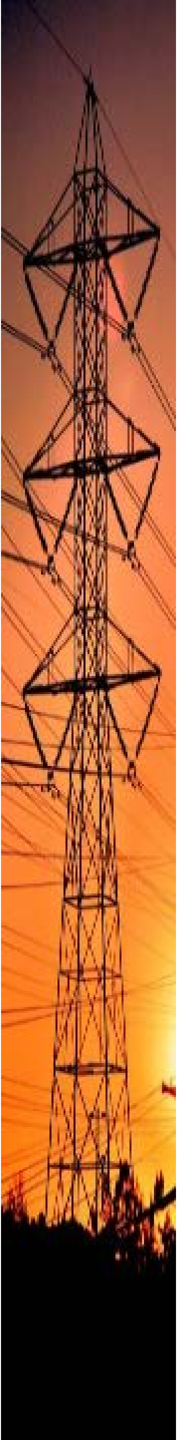


PMU Current, Voltage and Frequency Measurements

- Potential Use:
  - Supplement SCADA data used by System Ops staff to monitor Real and Reactive Power.
- Value Add:
  - Displaying down-sampled or full stream PMU data (e.g., 30 samples per second) will allow staff to detect abnormalities that may go unobserved with SCADA data. Being able to identify and address such conditions in Real-time may greatly reduce their impact.

SCADA vs. PMU Voltage and Current

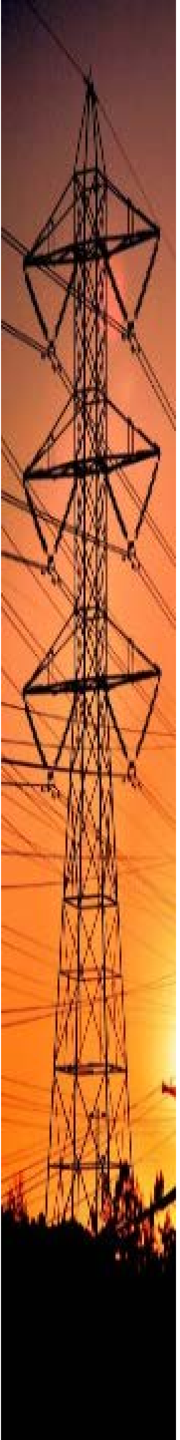
Comparing full stream sub-second PMU measurements with SCADA data. This data was captured during the testing of new generator control settings that caused unit output to swing rapidly for approx. 30 seconds and resulted in small scale voltage oscillations on the 138 kV system.



PMU-Based Phase Angle Delta Measurements

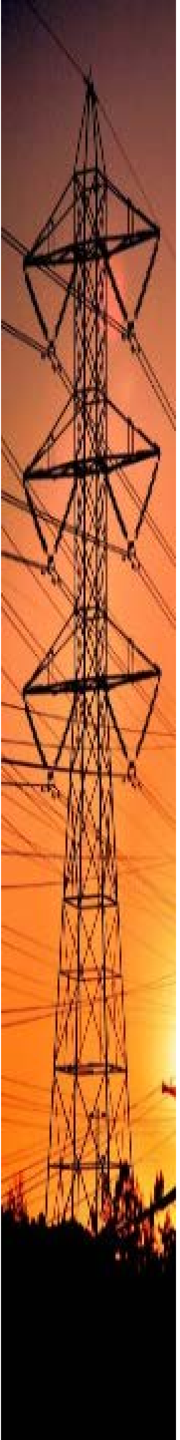
- Potential Use:
  - Local Area - Monitor bus voltage angle difference between line terminals to determine if line will be within maximum allowable closing limits prior to test.
  - Wide Area - Monitor phase angles across Wide-Area to identify significant divergences that indicate increased static stress.
- Value Add:
  - Increase amount of time staff has to take corrective action and reduce phase angle to within acceptable limits if needed; allow staff to identify increases in static stress that may be precursors to a disturbance event.
- In Progress
  - Working with Southern California Edison and Arizona Public Service to share key interconnect phasor measurements

Monitoring Local Phase Angle Deltas



Oscillation Detection & Mode Meter

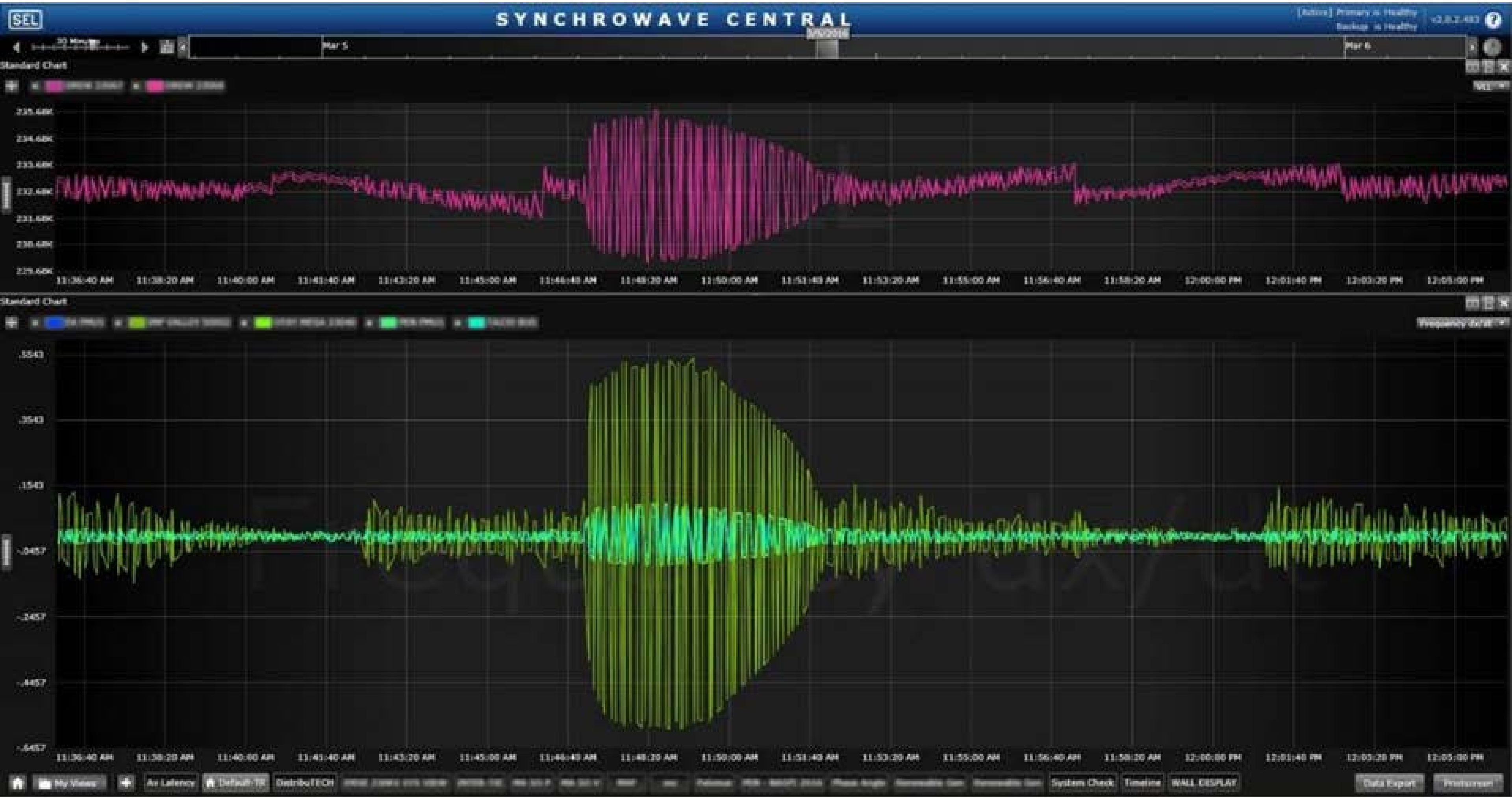
- **Oscillation Detection:**
  - Tools that calculate damping after a disturbance occurred or detect forced oscillations. This is done in several seconds when oscillations are large in magnitude.
- **Mode Meter:**
  - Tools that estimate damping from ambient noise data. These tools extract information from small-signal oscillations from minutes of ambient noise. Mode meter is a useful tool for operations, since it can provide early detection of damping issues in the system.
- **Potential Use:**
  - Detect oscillations and low damping conditions that indicate abnormal or unacceptable system behavior. ***System has already experienced oscillations that were not visible to operations, oscillation detection now partially automated***
- **Value Add:**
  - Identify excessive or persistent oscillations or low damping levels that could adversely impact system reliability or result in unacceptable system performance.

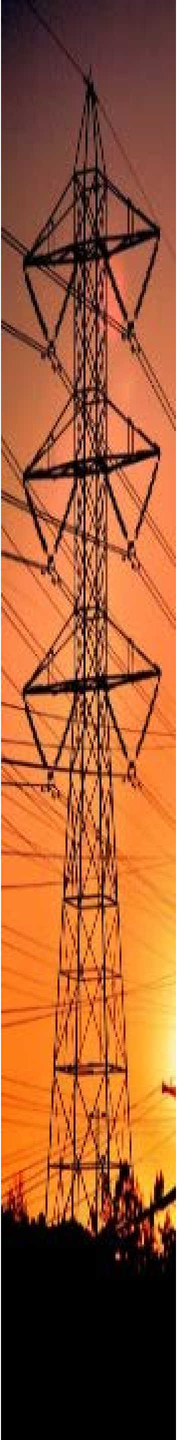


Detailed Operational Use Case Example

- **Title**: Local Area Oscillations from AVR Malfunction
- **Category**: Bus Voltage Monitoring
- **Reliability Goals**:
  - Know status of generation and transmission resources available to address undesirable voltage conditions.
  - Know the status of any SPS, or any other protection schemes, which may operate to alleviate unacceptable voltage conditions within the TOP Area.
  - Operate voltage control devices, or reactive resources, as necessary to maintain optimal voltage levels across the TOP Area.
  - Identify voltage limit exceedances within the TOP Area.
  - Take the actions necessary to return equipment voltage within limits within an acceptable amount of time.
- **Use of Operational Tools**:
  - EMS (Primary) – System Ops staff to rely on EMS displays to monitor pre- and post-Contingency voltage conditions and identify unacceptable system performance.
  - WASA App. (Support) – System Ops staff to monitor application and identify voltage signatures that identify abnormal conditions or system performance.
- **Related Documentation**:
  - Transmission System Voltage and VAR Control, Monitoring of Real-Time SOL and IROL Exceedances Procedure, etc.

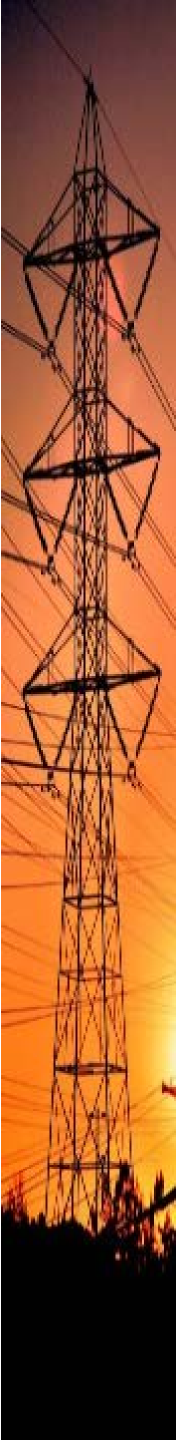
Local Area Oscillations from Inverter @ Solar Gen





Security

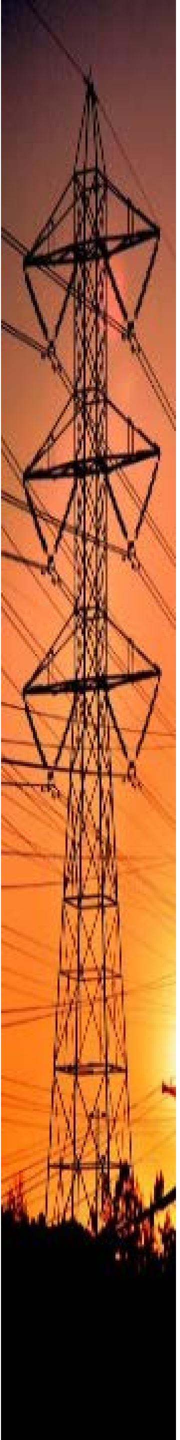
- Installing PMUs in a substation does not by default create NERC CIP compliance issues
- Standard critical infrastructure review by the utility determines CIP requirements
  - Separate PMUs vs. Enabling PMU functions in a relay
- Opting for serial communications vs. IP communication to stream synchrophasor data is no longer a method to avoid CIP compliance
- All this said it is still advisable to build the synchrophasor data delivery architecture to be CIP compliant
- Get advice form domain Subject Matter Experts, others have deployed synchrophasor architectures that are CIP compliant



Redundancy

- Build for the future
- Whether installing stand-alone PMUs or enabling PMU functionality in a relay or other IED build in redundancy down to the CT/PT level
- Install PDCs with local storage in the substation
- Use redundant communication from the substation to your control / data centers

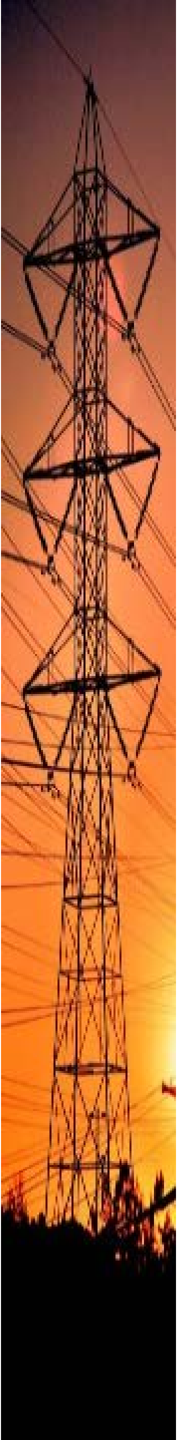
NASPI



Communications

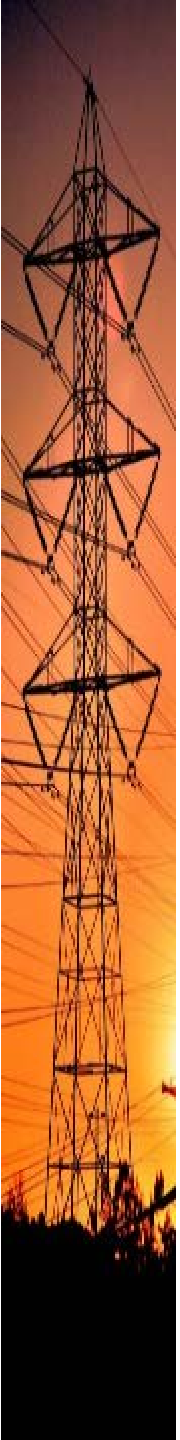
- Bandwidth requirements are higher than what is needed for SCADA
- Set specific SLAs with vendors and your own IT departments
  - Latency
  - Availability
- Install tools to automatically monitor communications and send notifications when issues arise
- New communication protocols for synchrophasor data coming soon

NASPI



Archive synchrophasor data

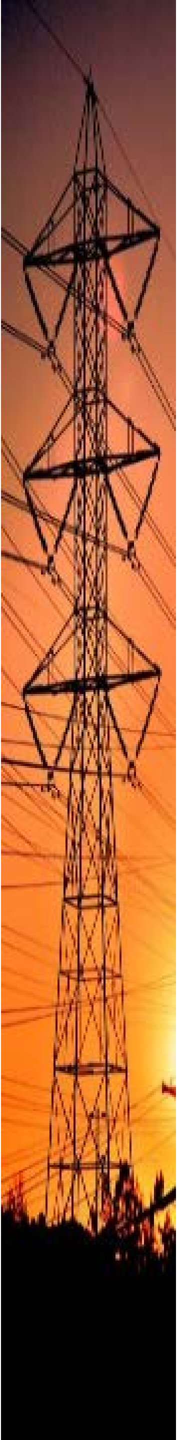
- Synchrophasor data can be used for meeting MOD 26 and MOD 27
- Synchrophasor data can be used to comply with PRC 002-2
- Build a reliable archive system
- Determine how long archives are to be maintained
  - Steady state vs Event
- Investigate multiple archive technologies, find best fit for use case
  - OSISoft PI
  - SEL SynchroWAVe
  - openHistorian
  - BPA DST files
  - PhasorPoint
  - AWS, etc.

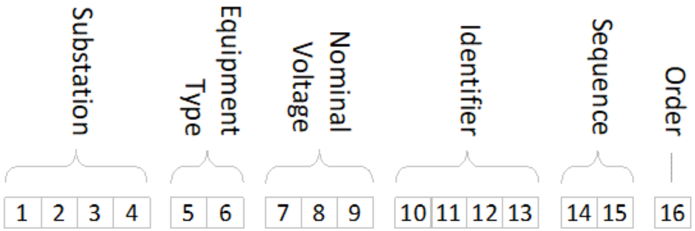


Develop and follow a naming convention

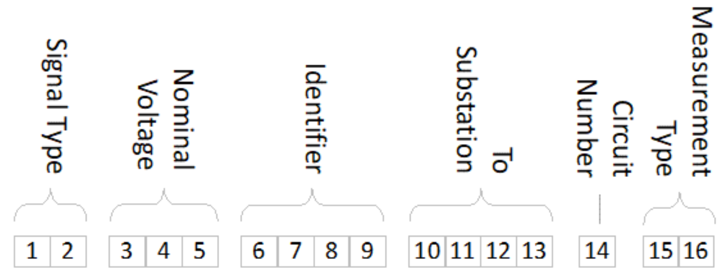
- As early as possible in the process it is important to develop and follow a naming convention for PMU naming and Signal naming
- Once applications and archives are configured poor naming syntax is difficult to correct

SDG&E naming convention





SDG&E Naming Convention Internal PMU Name



SDG&E Naming Convention Internal Signal Name

Document contains detailed descriptions, parameter definitions, and examples for every section of name sub fields

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