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SYNCHROPHASORS & THE GRID

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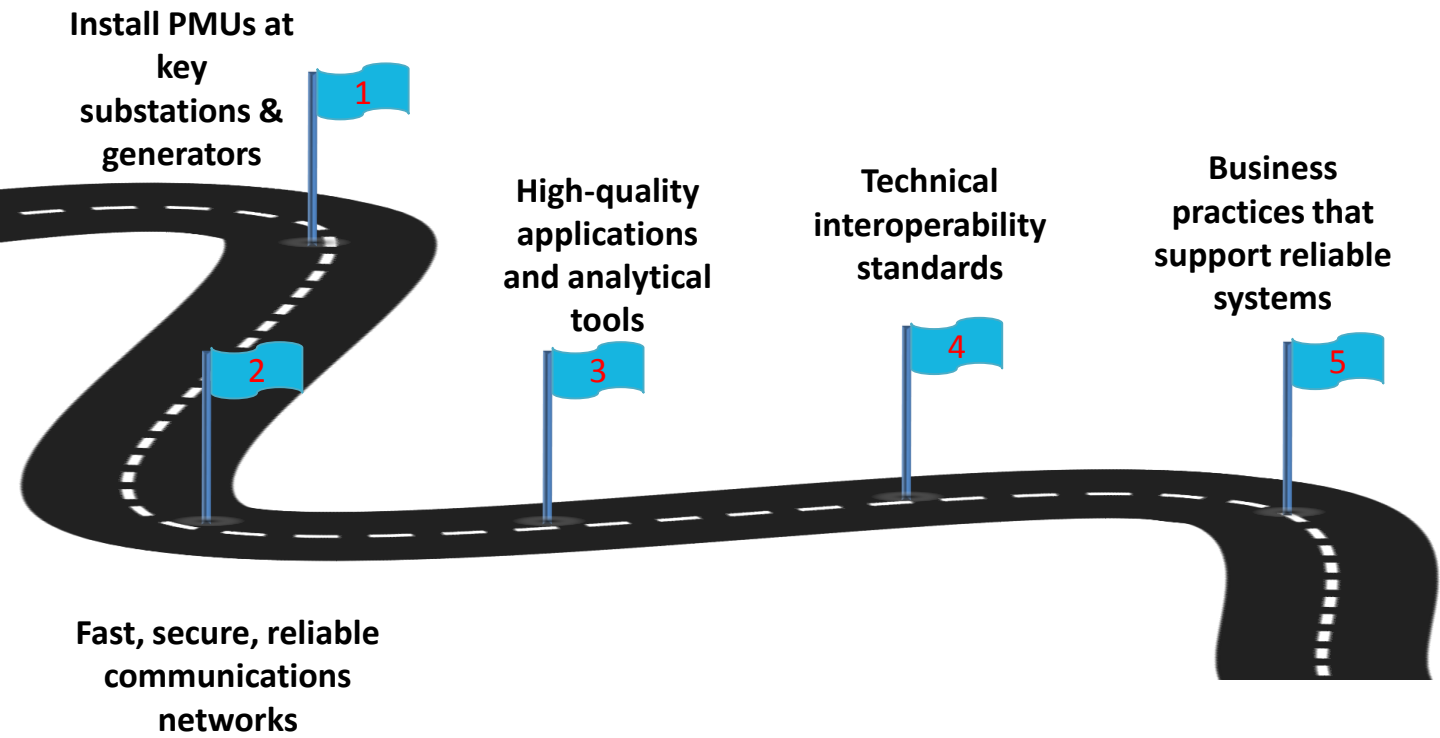
Synchrophasor technology improves grid reliability

- 30-60 samples/second (100 times faster than SCADA) & time-synced, provides real-time situational awareness
- High volumes of highly granular data enable insight into grid conditions
  - Early warning of grid events & dynamic behavior
  - Fast identification of failing equipment and asset problems
  - Better models of equipment, generators and power system
- Redundant, secure operator tools and automated system protection

Grid visibility -- PMUs v. SCADA

Synchrophasor technology elements



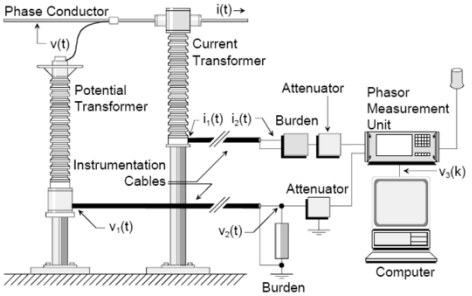
Phasor measurement units

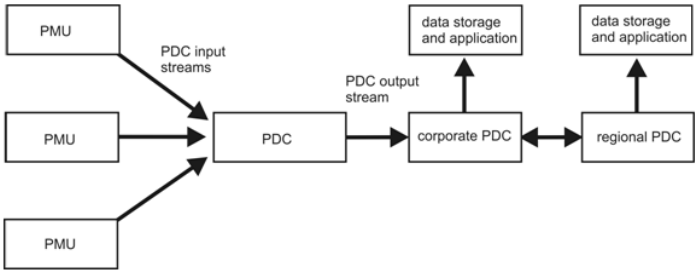
Phasor = complex mathematical value representing magnitude and phase angle of an AC waveform

Synchrophasor = phasors calculated for a common point in time

PMU

PMU installation in substation

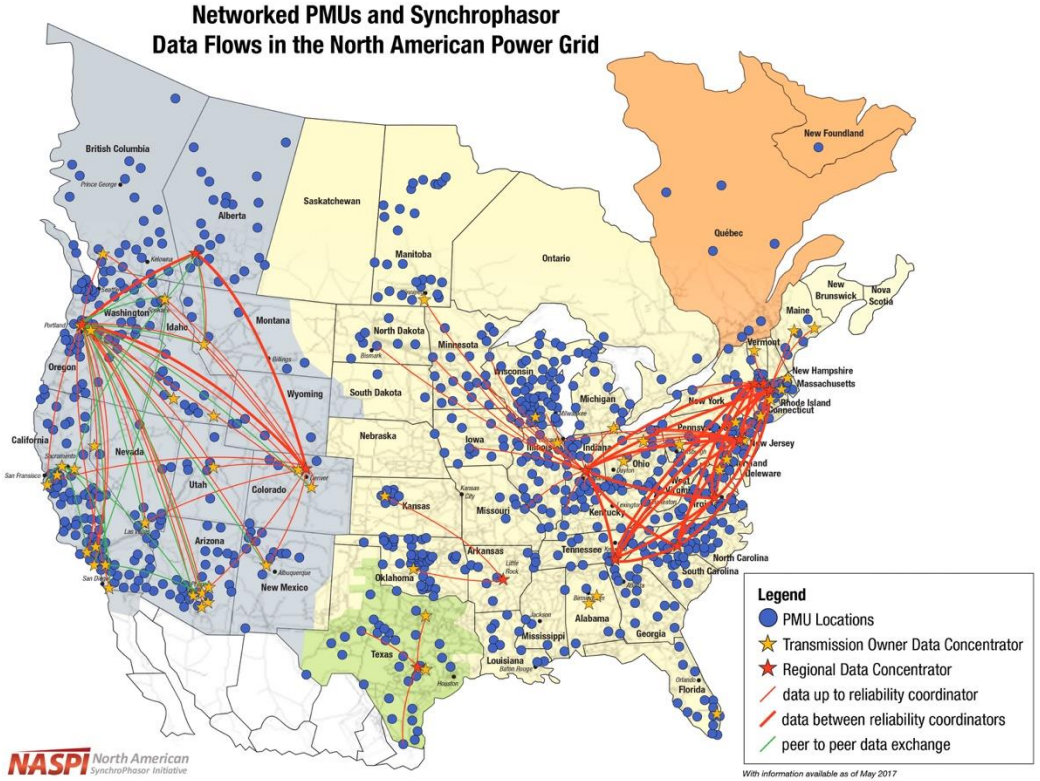




Networked PMUs across North America

2017 North America Synchrophasor networks

- Over 2,500 networked PMUS
- Most RCs are receiving and sharing PMU data for real-time wide-area situational awareness



Current uses for synchrophasor technology

Situational awareness

- Wide-area visualization
- Oscillation detection
- Phase angle monitoring
- Voltage stability monitoring
- Trending
- Event replay
- Alarms and alerts
- Linear state estimation
- Fault location

Off-line analysis

- NERC standard compliance
- Forensic event analysis
- Model validation (equipment, generation, power system)
- Identify equipment problems & mis-operation
- Field equipment commissioning

A bad day in the Western Interconnection

Event Replay of 9/8/2011 Southwest Blackout

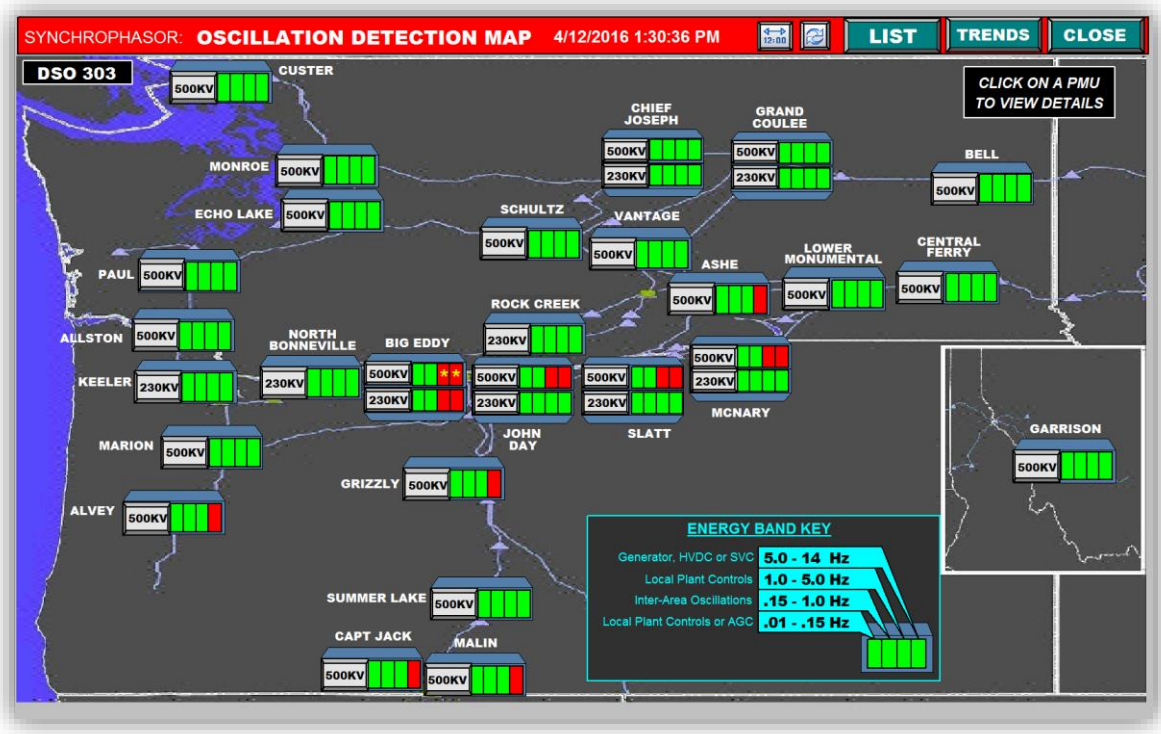
★ **Data Source:**

Power grid frequency data collected by FDRs(Frequency Disturbance Recorder)

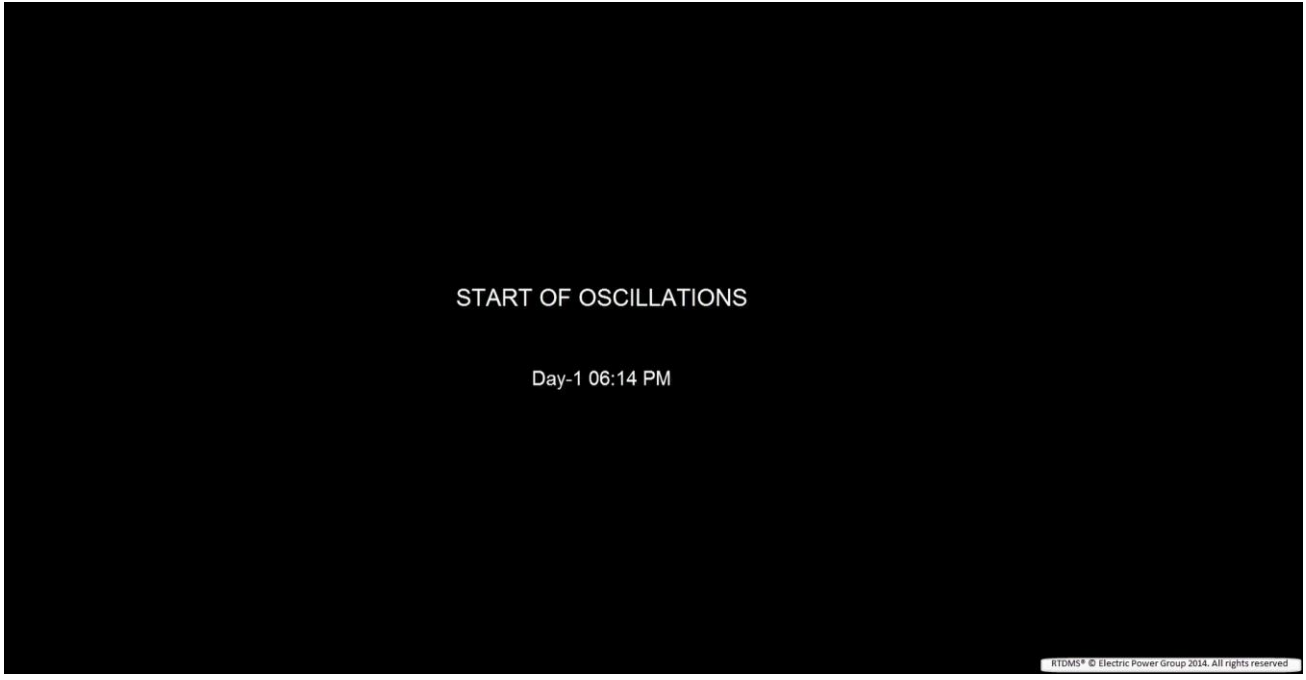
★ **Event Description:**

On 9/8/2011, the Southwest Blackout occurred when a 500-kV line connecting Arizona with San Diego tripped following a capacitor switchout. This widespread power outage affected large areas of Southern California as well as western Arizona, northern Baja California, and Sonora. This event left nearly 7 million people without power.

BPA oscillation detection tool



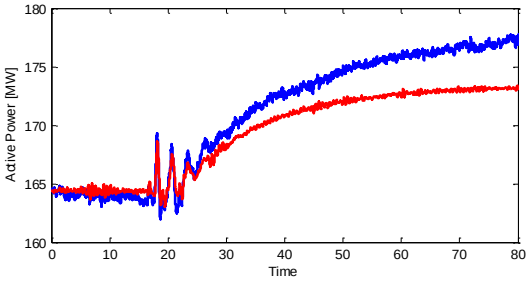
Wind farm oscillations discovered with PMU data

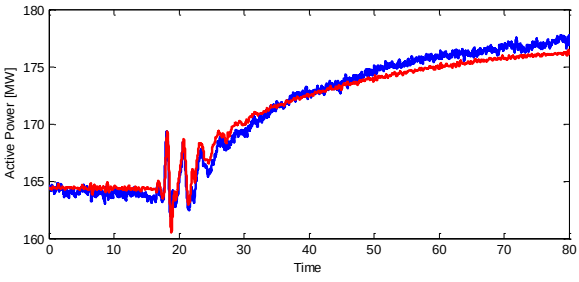


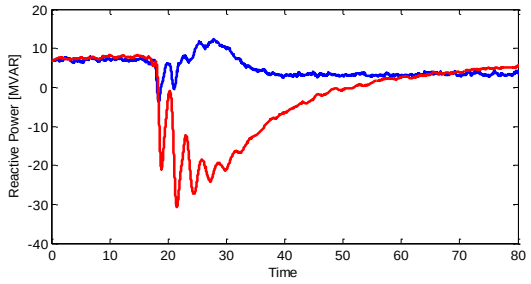
Better data yields better generator models

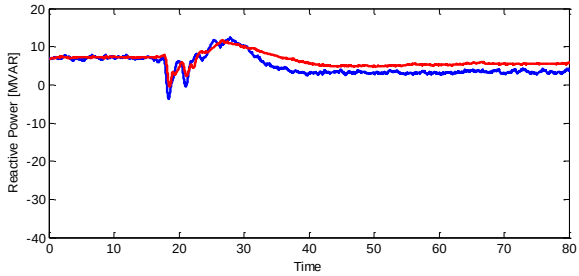
BPA generator model - before **(2014) and after (2015) PMU data validation**

Blue – actual event recording, red = model





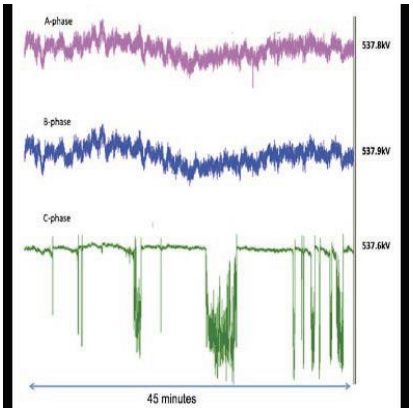




Monitoring substation equipment

Use PMUs, observations, and anomaly detection to spot failing equipment; proactively isolate and replace failing equipment before it does damage (to staff or equipment), causes unscheduled outages and raises costs.

PMU trace of Dominion CCVT voltage before it failed



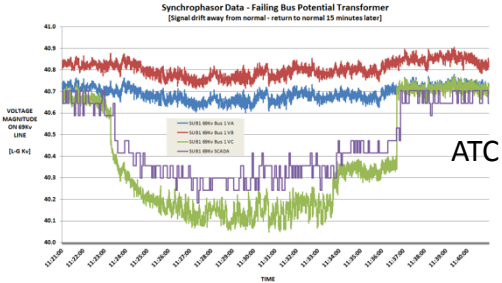
PMU trace – Dominion Virginia Power

What happens when a CCVT fails and blows up

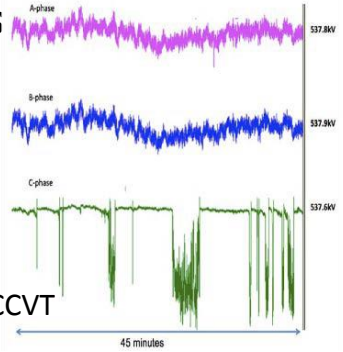
Photos -- EPG

Other problems detected with PMUs

- Generator settings and equipment failures, including governor & stabilizer malfunctions and control errors
- Identify transmission conditions such as local phase unbalance or negative sequence current that could harm a generator
- Transmission equipment problems including failing transformers, loose connections, fault analysis, cap bank switching problems, & monitoring PQ, harmonics & noise that can affect customers
- Verify operation of system protection devices



ATC failing bus PT



Dominion failing 500 kV CCVT

Use PMUs to meet NERC reliability standards

Standard Number	Title
BAL-003-1	Frequency Response and Frequency Bias Setting
FAC-001-2	Facility Interconnection Requirements
IRO-003-2	Reliability Coordination – Wide-Area View
MOD-026-1	Verification of Models and Data for Generator Excitation Control System or Plant Volt/Var Control Functions
MOD-027-1	Verification of Models and Data for Turbine/Governor and Load Control or Active Power/Frequency Control Functions
MOD-033-1	Steady-State and Dynamic System Model Validation
PRC-002-2	Disturbance Monitoring and Reporting Requirements

More synchrophasor uses

- Renewables integration – modeling, oscillation mitigation, transmission management
- Dynamic line loading for greater throughput w/o more capital investment
- Baselining – understanding "normal" and discovering new potential problems
- Electrical island detection and blackout restoration
- System protection operations monitoring
- Automated system protection operation
- Monitor ground-induced currents (from GMDs) and seismic event impacts
- Backup & correction for EMS data system

What's next for synchrophasor technology

- Advanced machine learning using PMU data to identify anomalous events and develop operator decision support tools
- Automated, autonomous system protection schemes, including wide-area damping
- Distribution-level uses for synchronized grid-level measurements (e.g., for two-way grid monitoring and analysis)
- Advance PMU deployment and applications use and data-sharing across TOs and RCs

Challenges for synchrophasor technology development

- Building and maintaining cyber-secure synchrophasor networks and applications for field assets with high volumes of high-speed data
- Need multiple, redundant high-reliability timing sources to support time synchronization
- Data-sharing for real-time situational awareness and with researchers and transmission operators to do big data analysis for baselining, anomaly detection, mis-operations diagnosis and operator decision support tools

North American Synchrophasor Initiative

- A voluntary collaborative of industry, government, academia, and more working to advance and accelerate the value and use of synchrophasor technology
- Developing standards, guiding R&D, joint learning and problem-solving to improve applications and business processes, building consensus strategies
- Established in 2007
- Funded by DOE with support from EPRI

Video credits

- PMUs v. SCADA – Electric Power Group
- Southwest blackout – FNET -- Dr. Yilu Liu, CURENT-University of Tennessee Knoxville
- Windfarm oscillations – Electric Power Group RTDMS

Other credits

- Map – North American Synchrophasor Initiative
- BPA application screen captures – BPA
- PMU data traces from Dominion Virginia Power & American Transmission Company

More information – www.naspi.org

THANK YOU!

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