Micro-synchrophasors (µPMUs) in Electric Power Distribution Systems

5/29/15 SF PES Chapter Workshop

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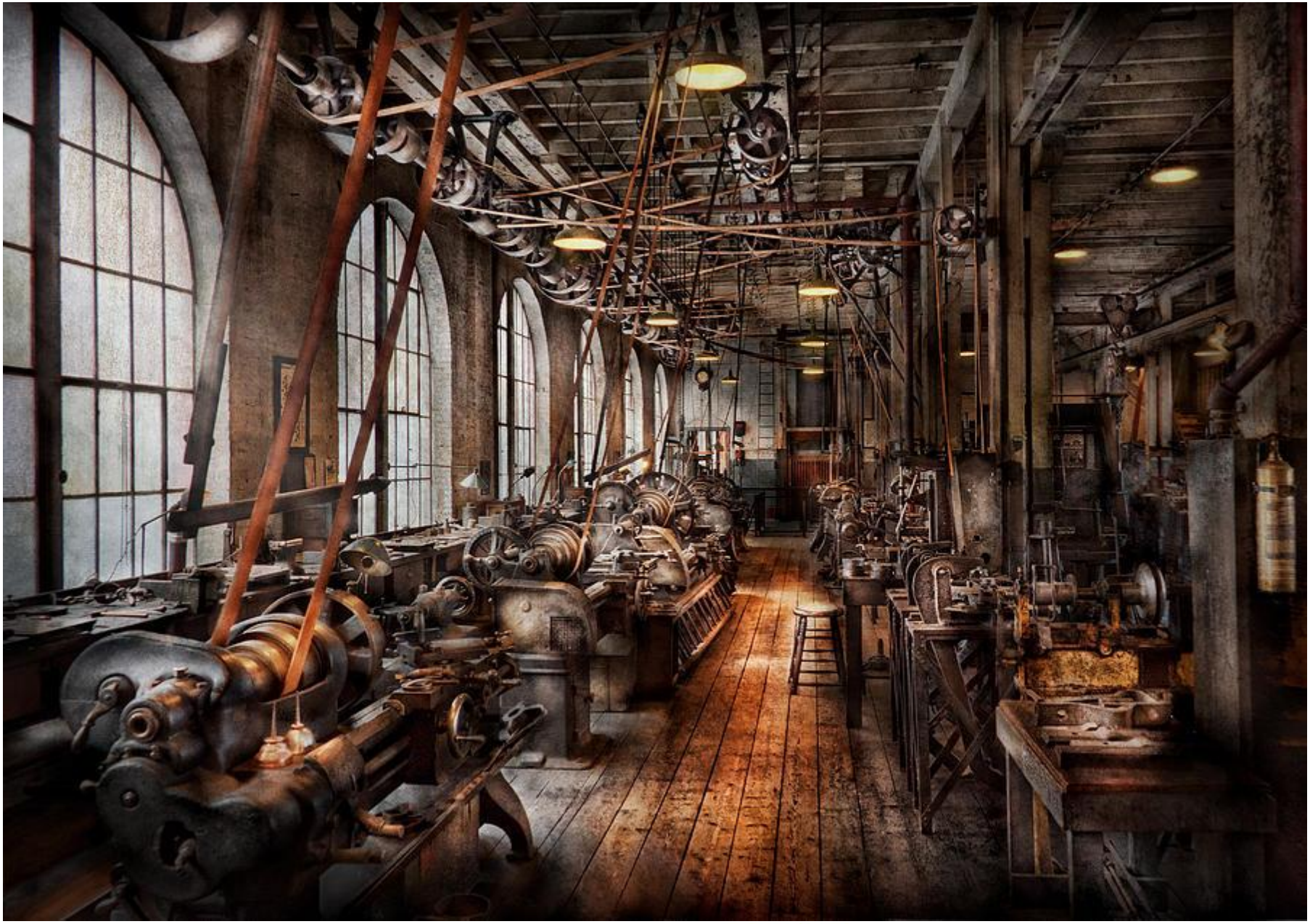

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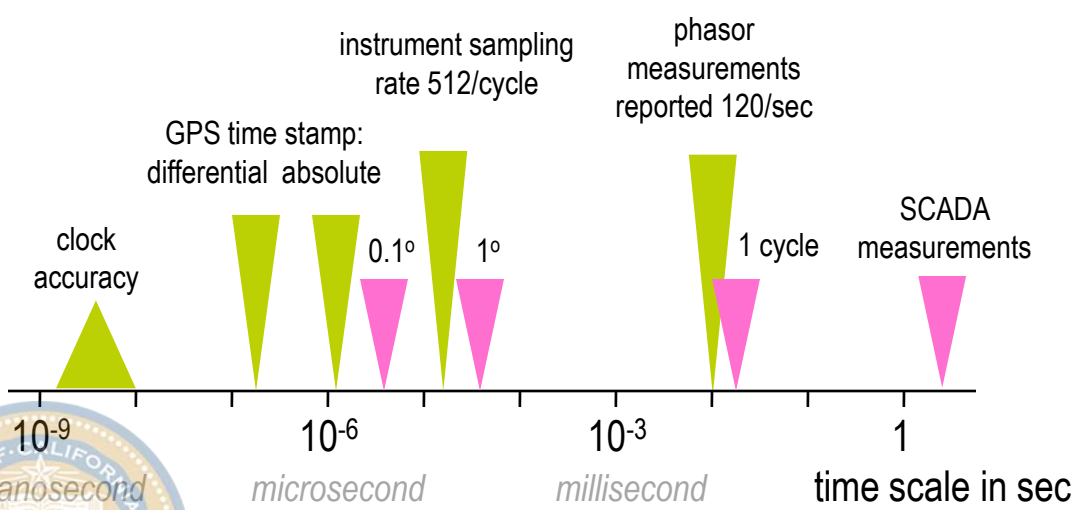
Micro-synchrophasors (µPMUs) for Distribution Systems

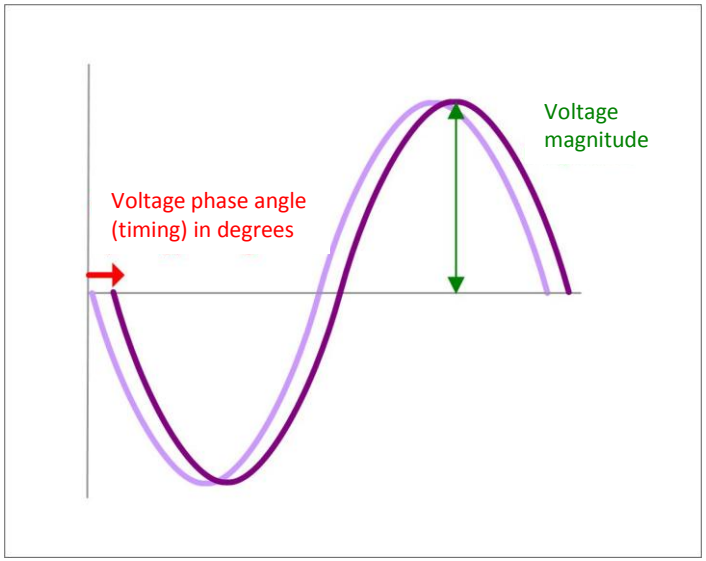
Three-year, $4.4 M ARPA-e project started April, 2013

Research partners CIEE, UC Berkeley, Lawrence Berkeley National Lab, Power Standards Lab

Objective: Explore the value and applications for high-resolution measurements of voltage phasors across distribution systems

Key: cross-referencing *simultaneous, high-precision* measurements at separate locations, using GPS time stamps





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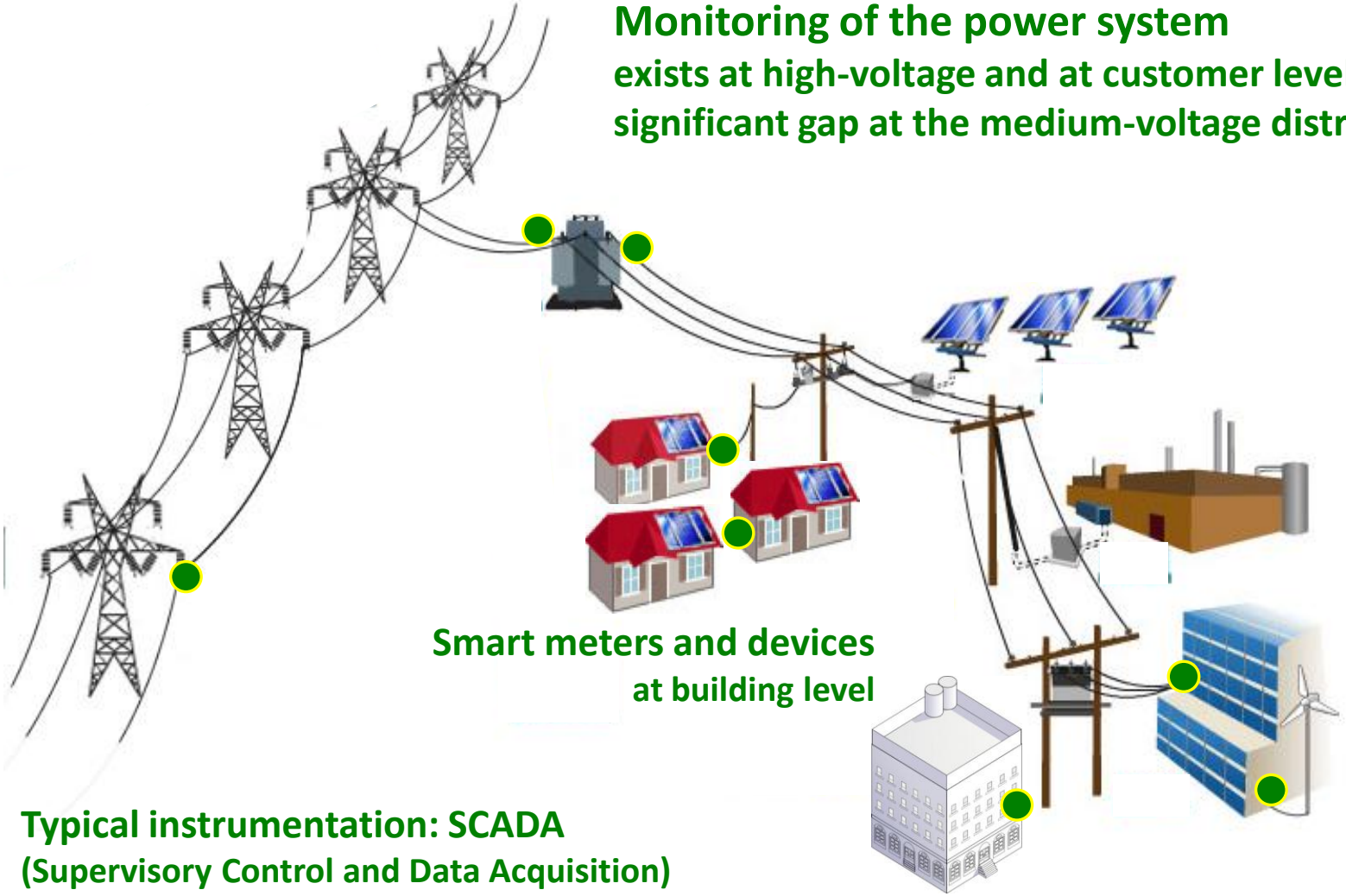
Monitoring of the power system

exists at high-voltage and at customer level, with a significant gap at the medium-voltage distribution level



Smart meters and devices

at building level

Typical instrumentation: SCADA

(Supervisory Control and Data Acquisition)

at the transmission level, down to substation

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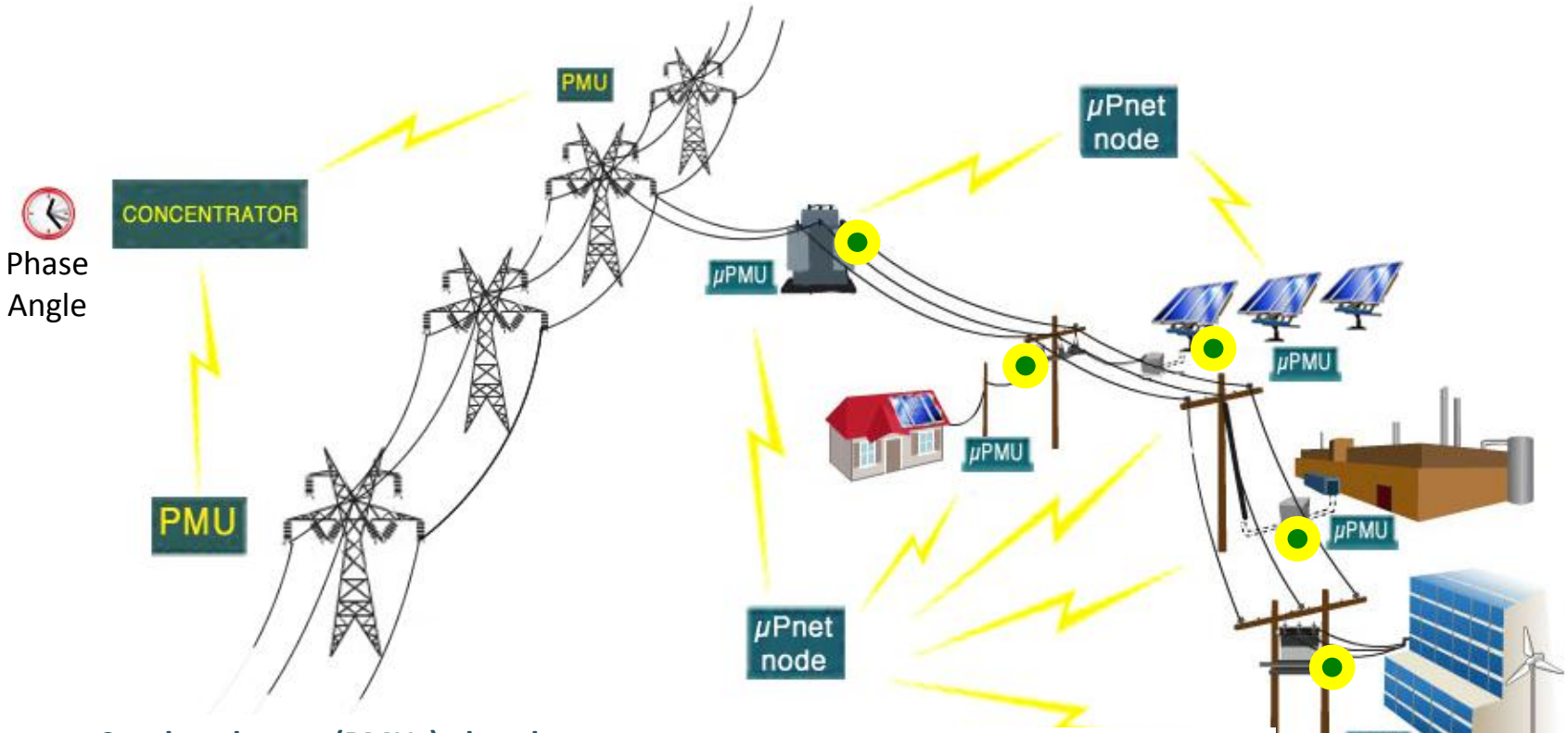
Distribution Synchrophasor network concept:

Create observability and transparency for medium-voltage circuits to support integration of distributed resources



Synchrophasors (PMUs) already increasingly being deployed on transmission systems

Micro-synchrophasor (μPMU) network for distribution

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General Project Objectives

- develop a network of high-precision phasor measurement units (µPMUs) to measure voltage phase angle to within 0.01°
- understand the value of voltage phase angle as a state variable on power distribution systems
- explore applications of µPMU data for distribution systems to improve operations, increase reliability, and enable integration of renewables and other distributed resources
- evaluate the requirements for µPMU data to support specific diagnostic and control applications:
  - topology detection
  - state estimation
  - fault location
  - dynamic characterization (load, DG, oscillations)
  - volt-VAR optimization
  - real power / load balancing with DER
  - microgrid islanding control
  - transient mitigation with DER
- advance the adoption of this technology and its successful applications through technology transfer and outreach

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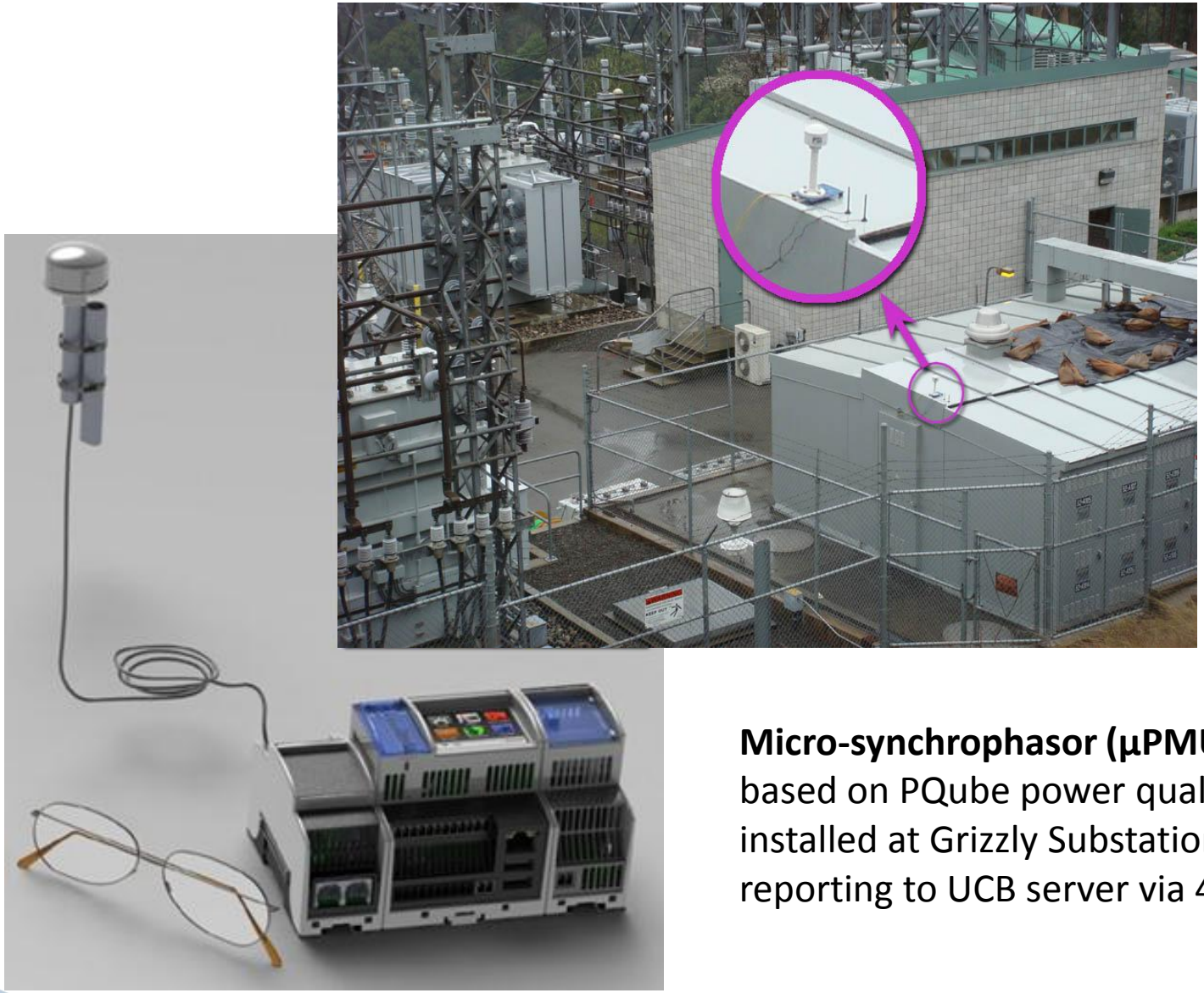

Micro-synchrophasor (µPMU)
based on PQube power quality recorder installed at Grizzly Substation reporting to UCB server via 4G wireless

Power Standards Lab
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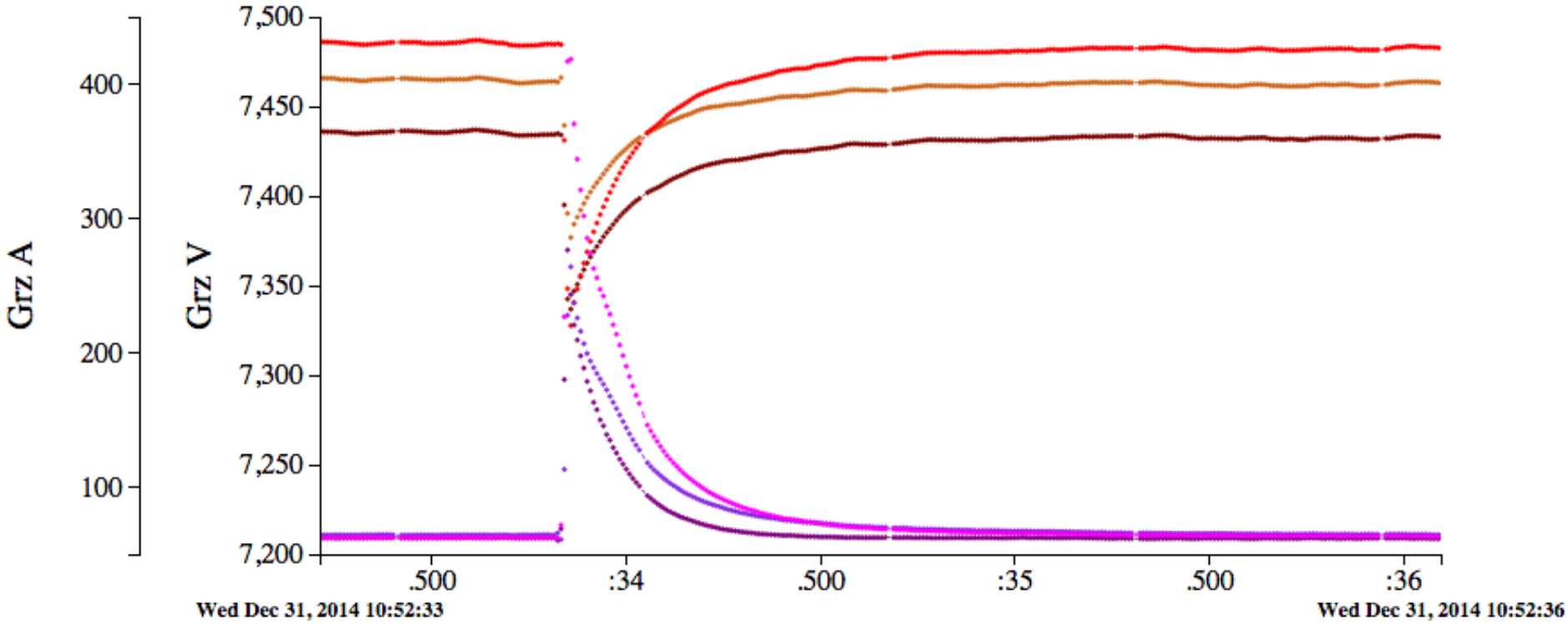

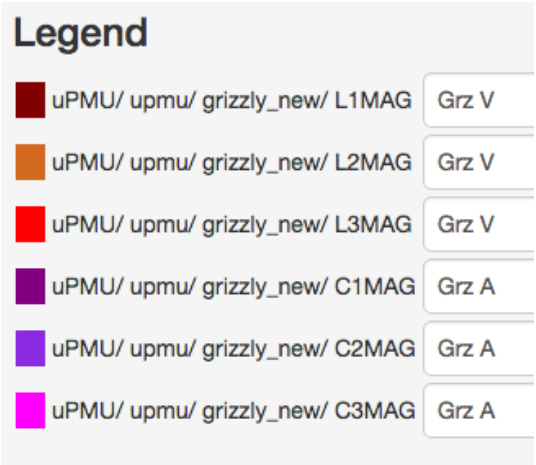

Sample µPMU Data from UCB Quasar Server:
Local Arc Flash (Fault) Incident

Current during arc flash momentarily increases six-fold on phase 3, voltage sags by 0.02 p.u.

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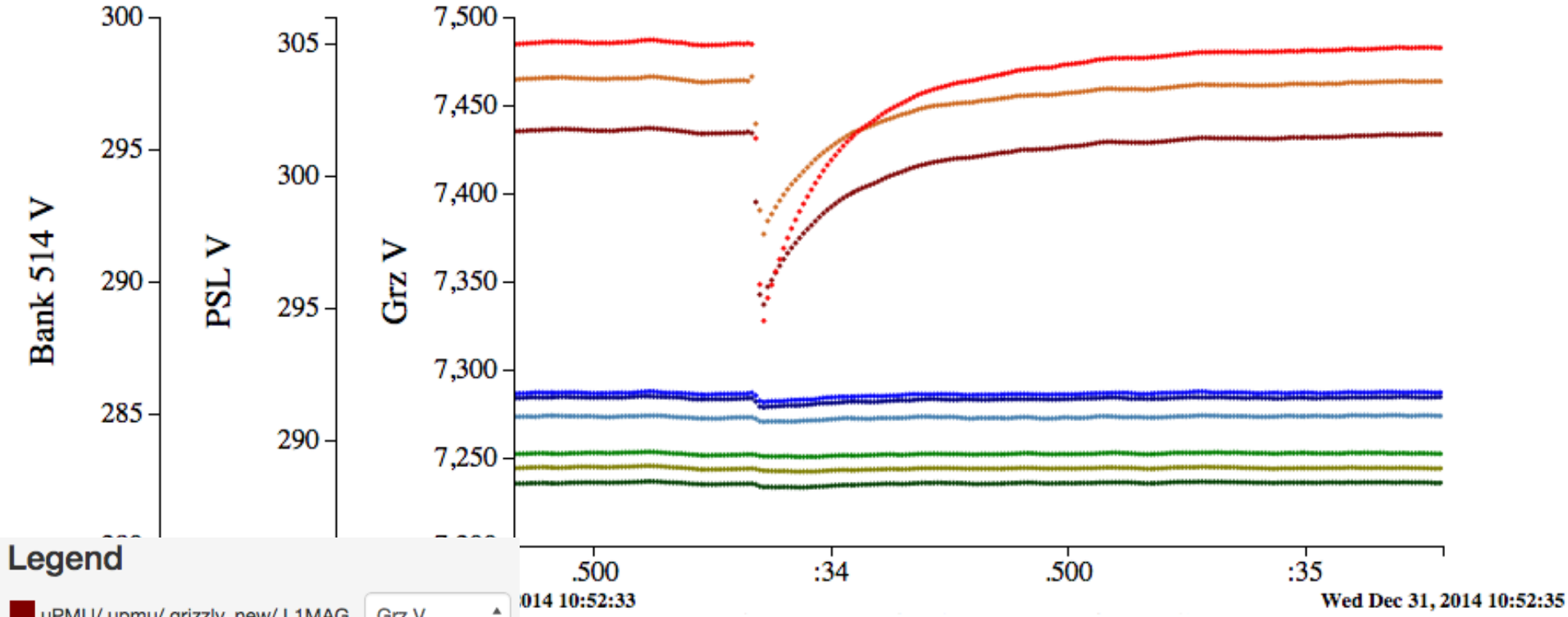

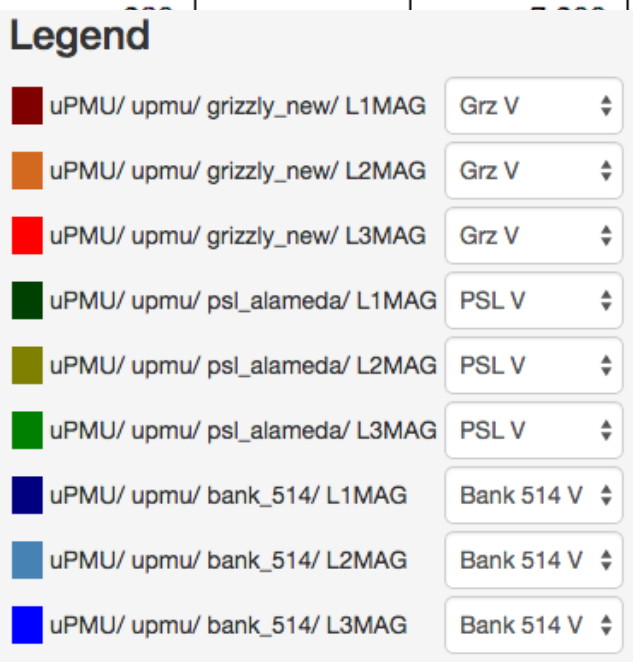

The arc flash caused a voltage sag of about 0.02 p.u. at Grizzly, propagating through the transmission network and visible at PSL in Alameda.

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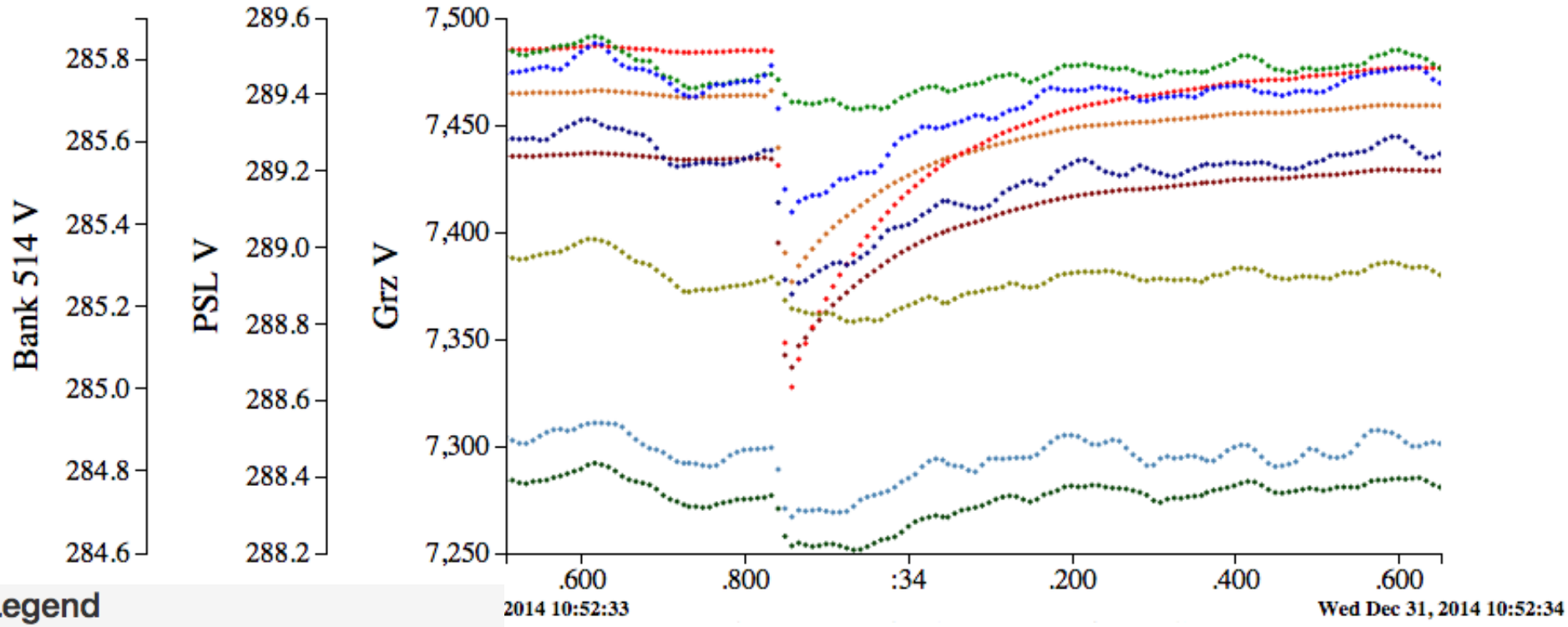

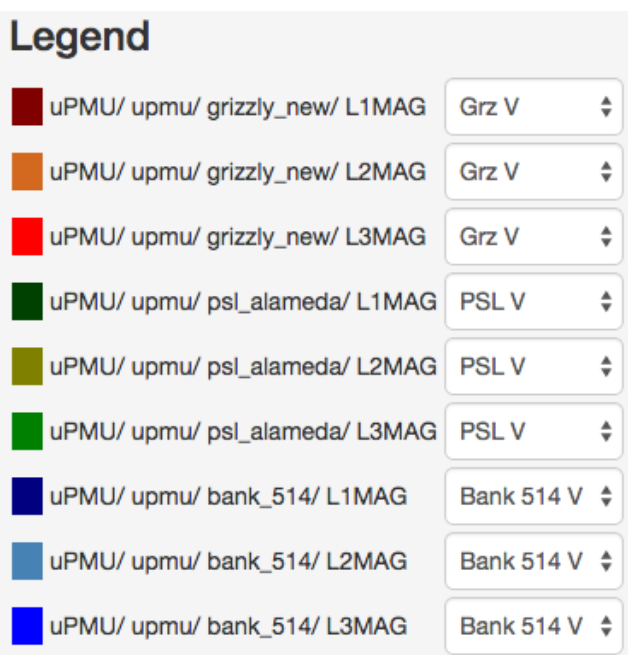

Voltage disturbance propagation due to arc flash: about 0.0015 p.u. at neighboring transformer Bank 514 and 0.0003 p.u. at PSL

Relevant applications: Fault location; equipment health diagnostics

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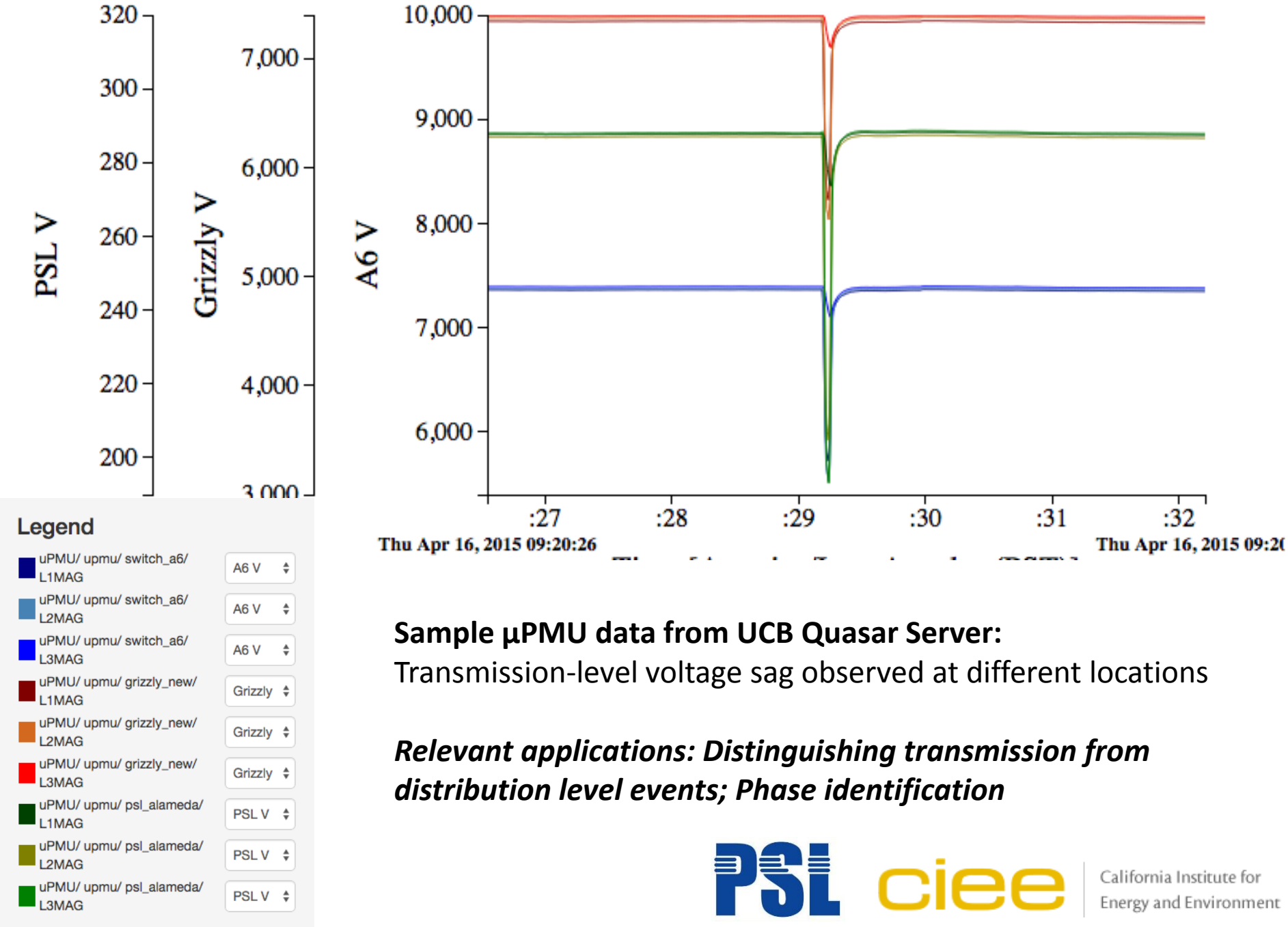

Sample µPMU data from UCB Quasar Server:
Transmission-level voltage sag observed at different locations

Relevant applications: Distinguishing transmission from distribution level events; Phase identification

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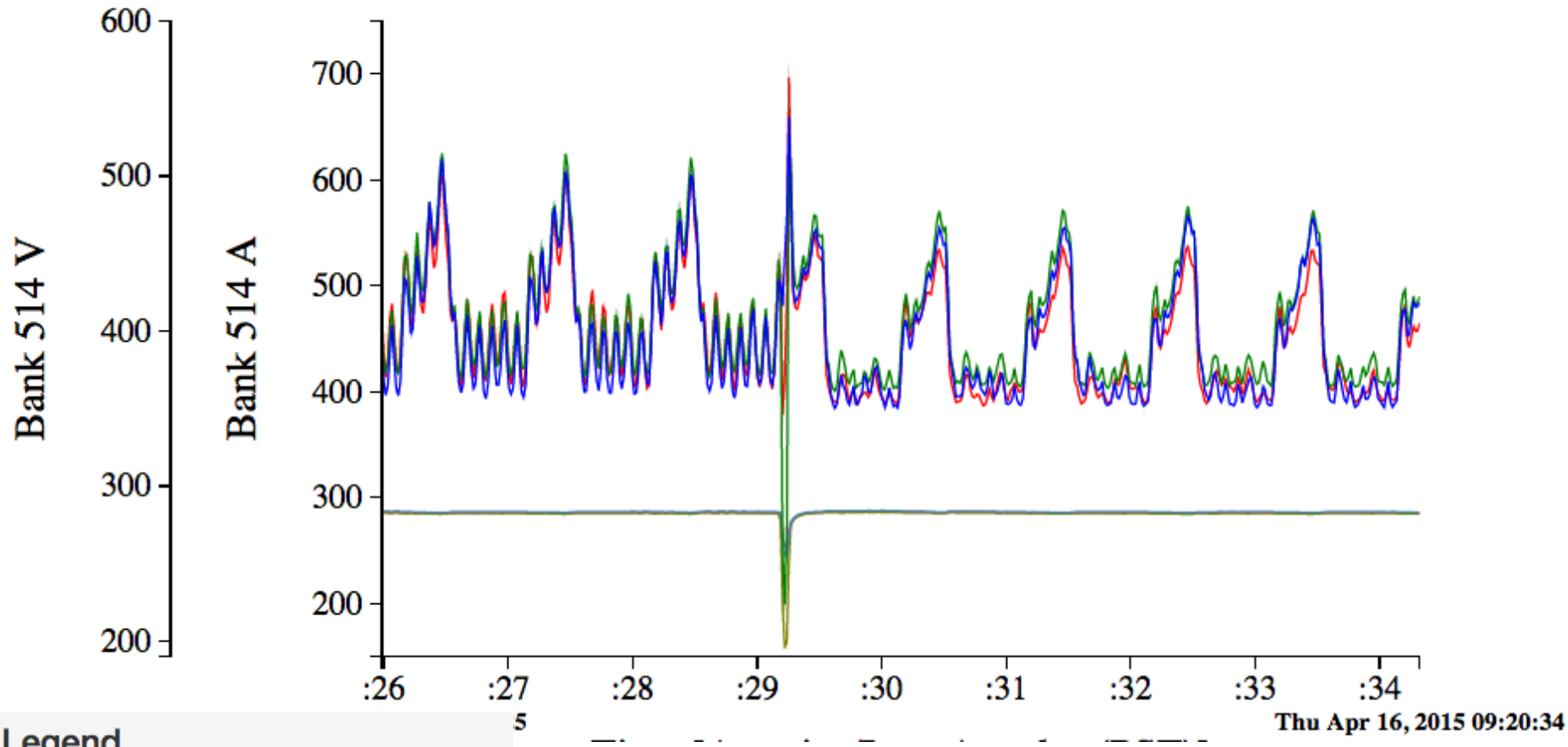

Legend

uPMU/ upmu/ bank_514/ L1MAG	Bank 514 V
uPMU/ upmu/ bank_514/ L2MAG	Bank 514 V
uPMU/ upmu/ bank_514/ L3MAG	Bank 514 V
uPMU/ upmu/ bank_514/ C1MAG	Bank 514 A
uPMU/ upmu/ bank_514/ C2MAG	Bank 514 A
uPMU/ upmu/ bank_514/ C3MAG	Bank 514 A

Loss of load due to voltage sag

Relevant applications: Identifying causes of downtime

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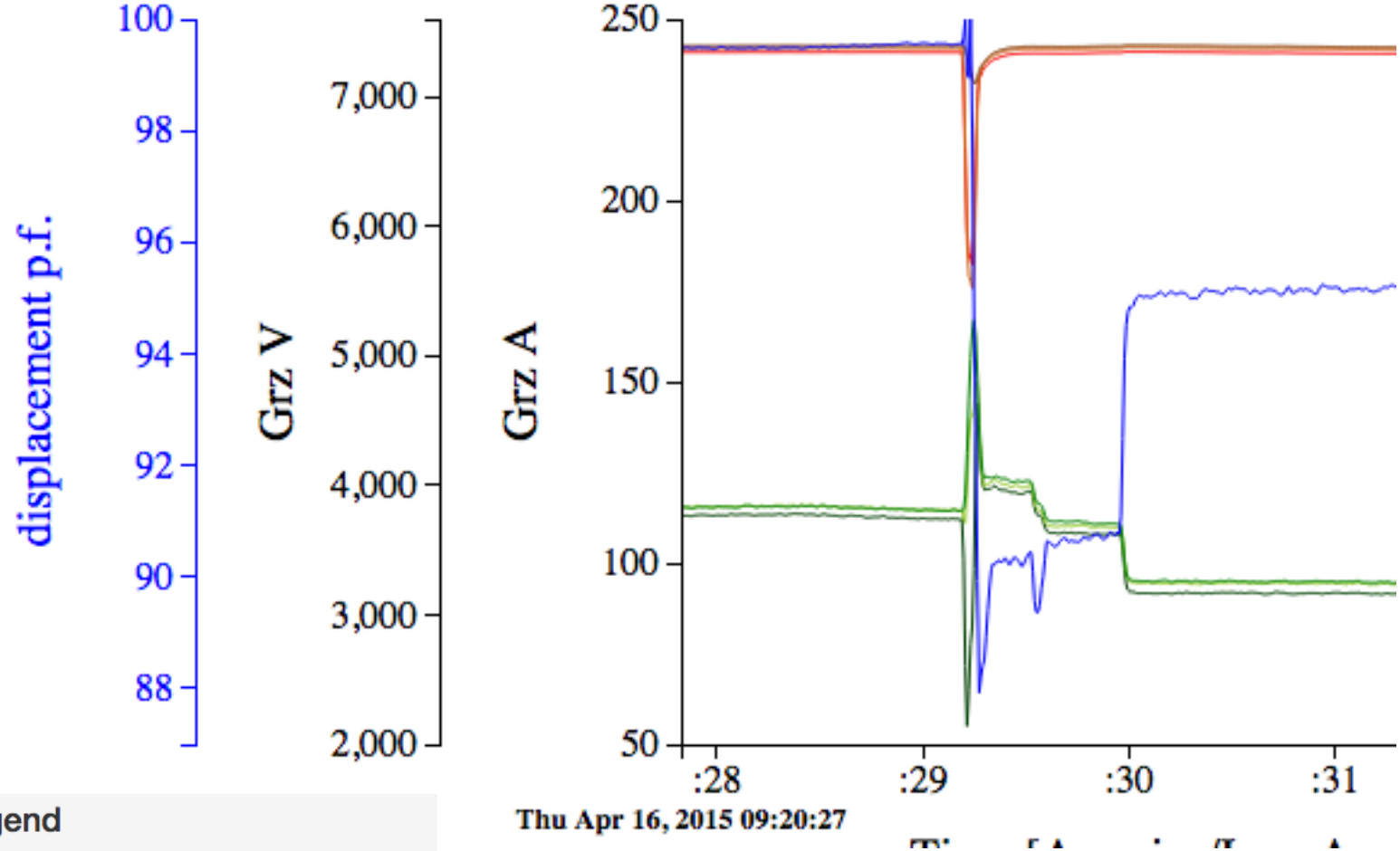

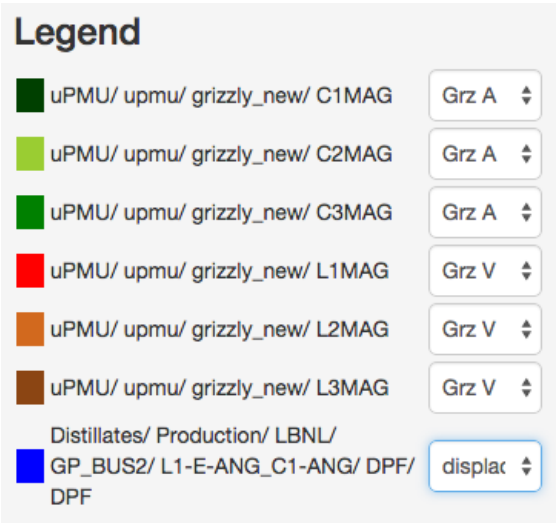

The power factor drops in response to the voltage sag…

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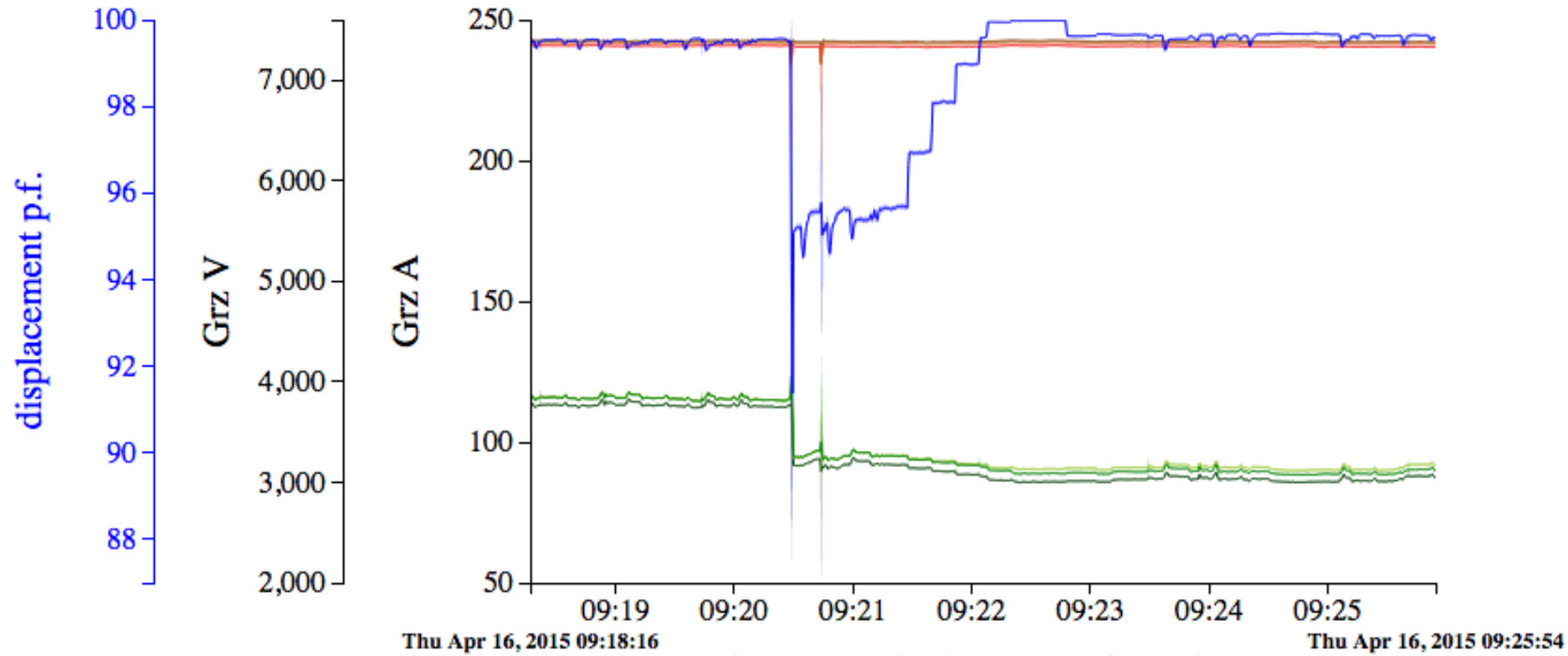

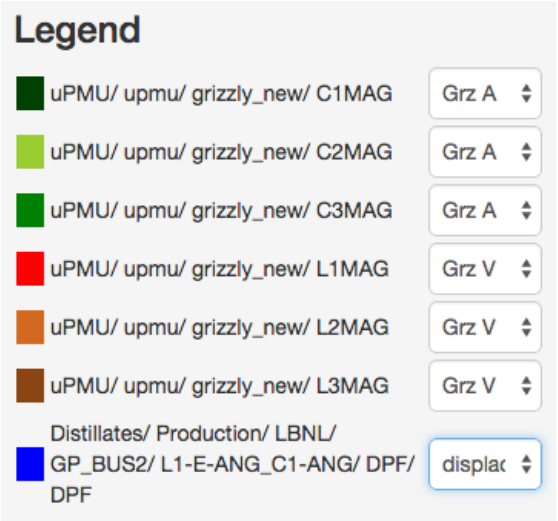

…and recovers.

Relevant applications: Load diagnostics, Volt-VAR optimization

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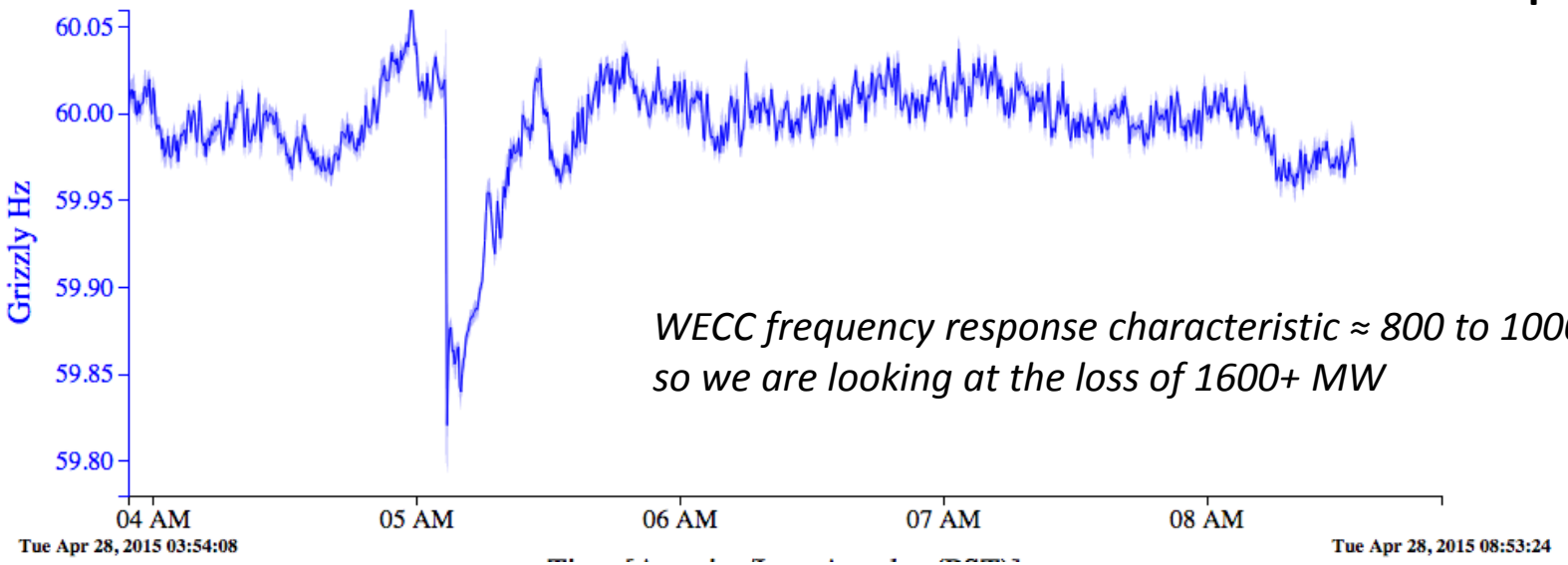
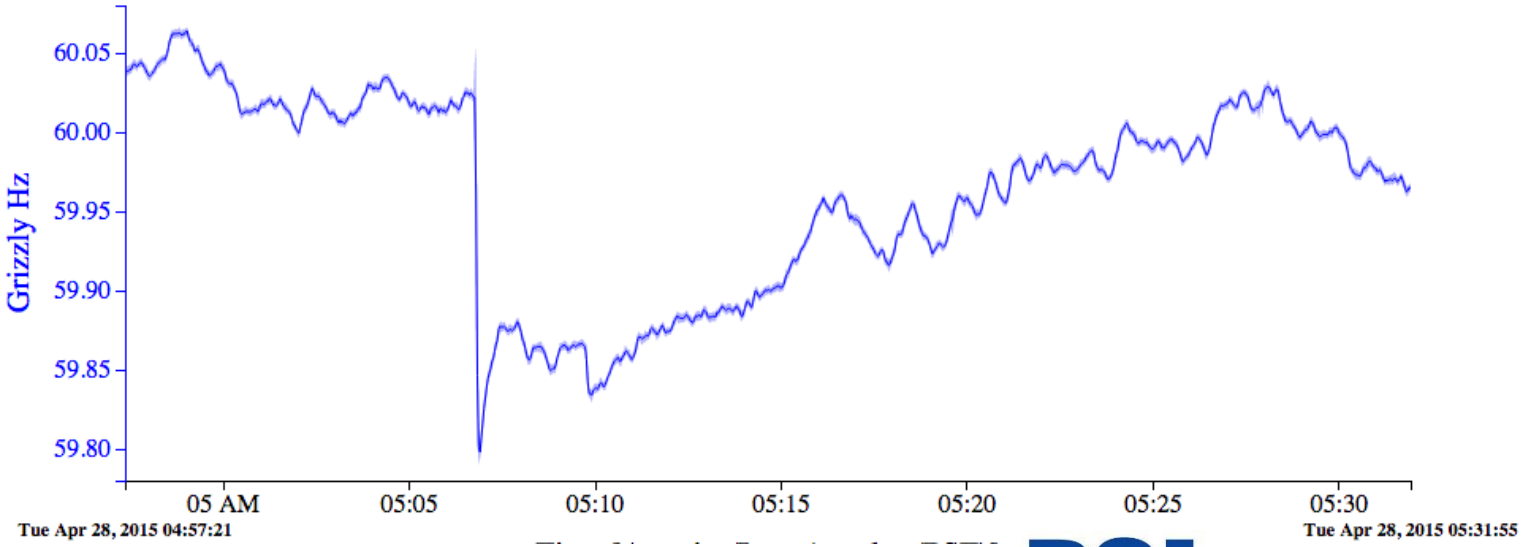


WECC frequency response characteristic ≈ 800 to 1000 MW/0.1 Hz so we are looking at the loss of 1600+ MW



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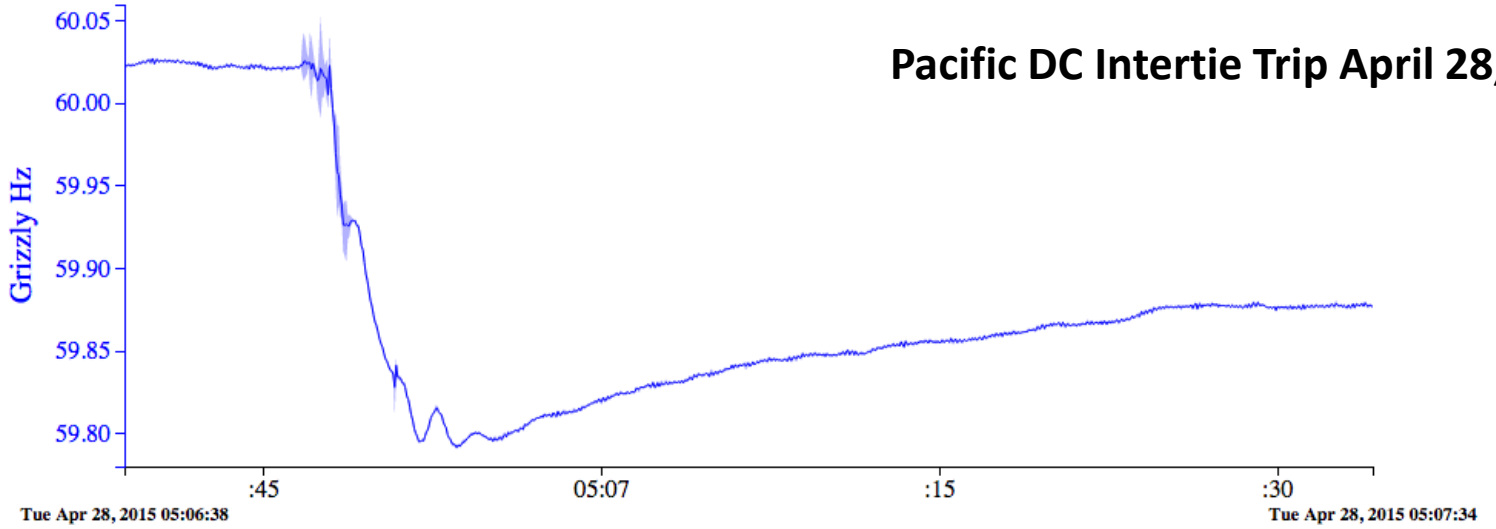

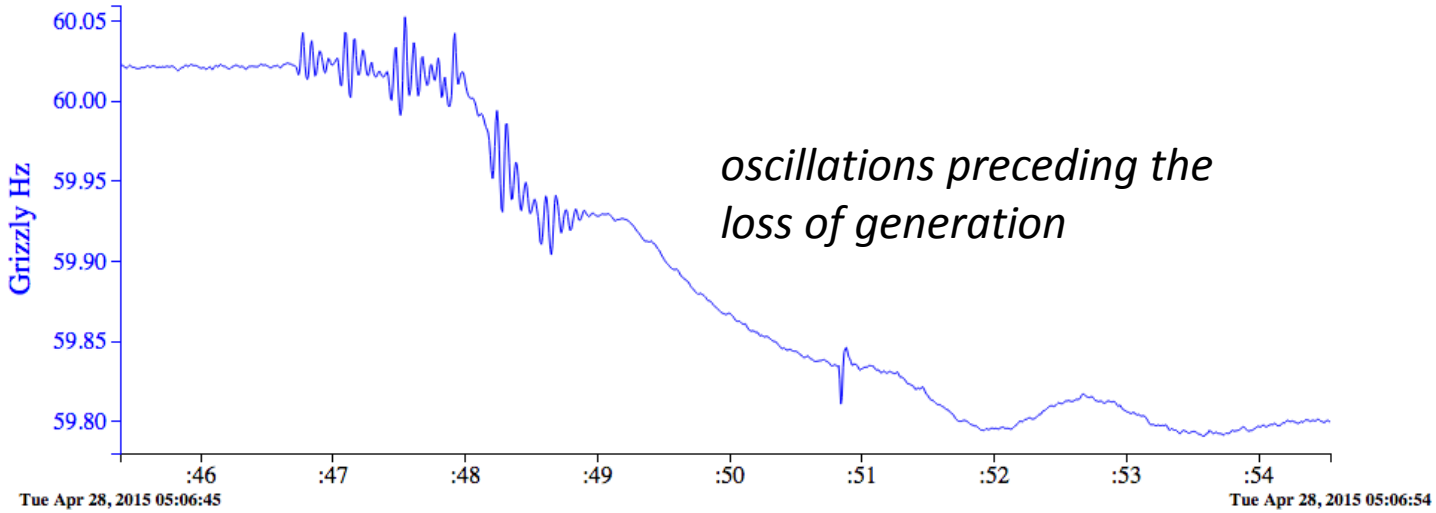

oscillations preceding the loss of generation

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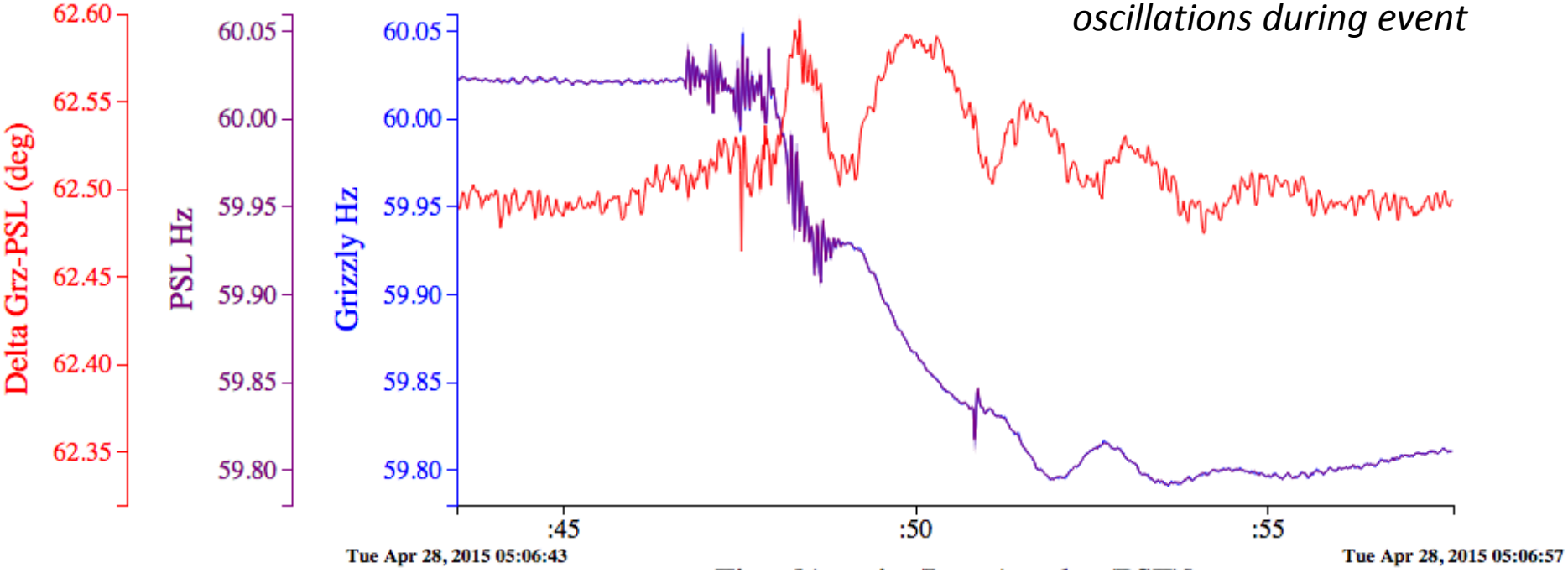
local voltage phase angle oscillations during event



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