Open Micro-PMU: A real world reference distribution micro-phasor measurement unit data set for research and application development

Emma M. Stewart – Lawrence Livermore National Laboratory

July 18th 2017

IEEE PES GM: Big Data Access and Big Data Research Integration in Power Systems

Overview

- microPMUs – how we got here, where we are going
- Powerdata.lbl.gov
- BTrDB
- Use Cases for microPMU data
- Contact information

Background to Micro-synchrophasors (µPMUs) for Distribution Systems

ARPA- funded project which developed a network of high-precision phasor measurement units (µPMUs) to measure voltage phase angle to within 0.01°

Built Berkeley Tree Database (BTrDB) for collecting raw data at 120 Hz, processing 'distillate' streams online, visualizing and archiving data

Getting µPMU data into distribution systems:

- Transitioning to commercial systems
- Sold as a quick start kit from PSL with a server and BTrDB
- 40+ are installed in the field (through this research, 100's more now)
- Utilize combination of 4G LTE,
- Possible Locations: Piggy backed onto revenue metering, where exiting PT and CT locations or at simple plug in customer locations for single phase information

BERKELEY LAB
Lawrence Berkeley National Laboratory

PSL

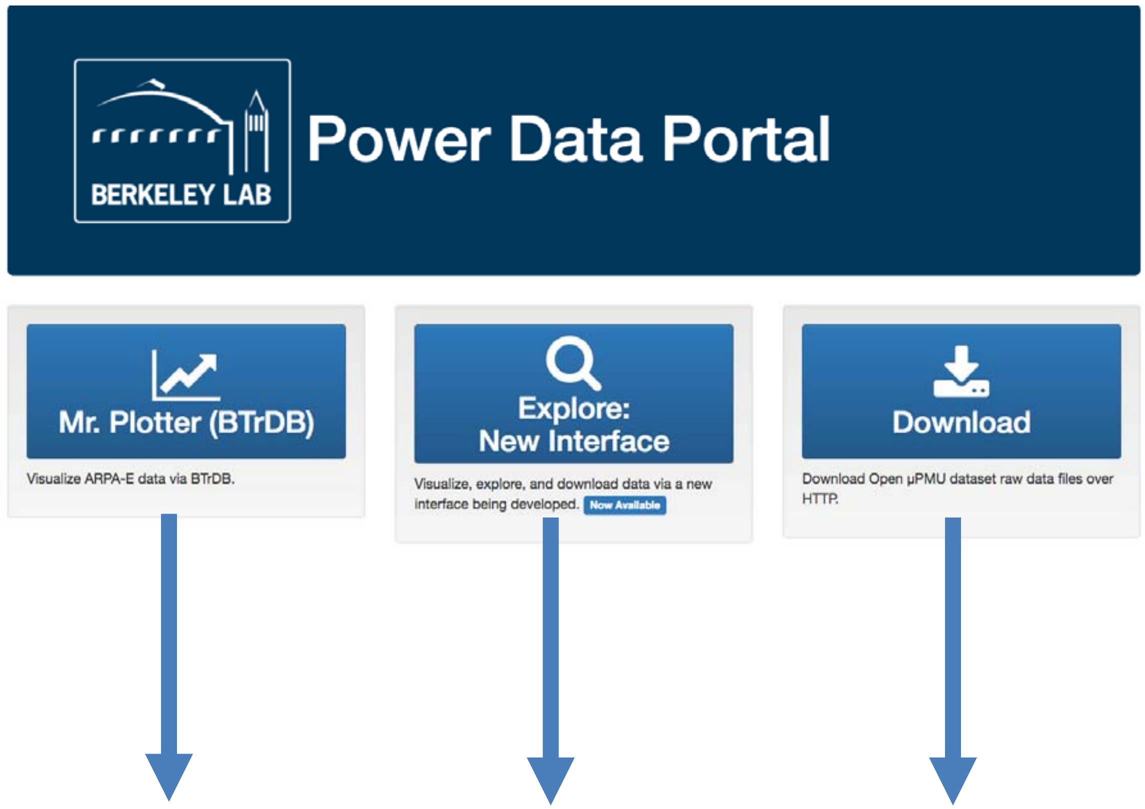
ciee California Institute for Energy and Environment

Powerdata.lbl.gov a reference microPMU dataset

Reference Dataset

LBNL is making a 3-month reference dataset from three micro-PMUs on a 12-kV system available for researchers
Available through 3 mediums…
BTrDB (RHS)
Or a bulk download

see powerdata.lbl.gov



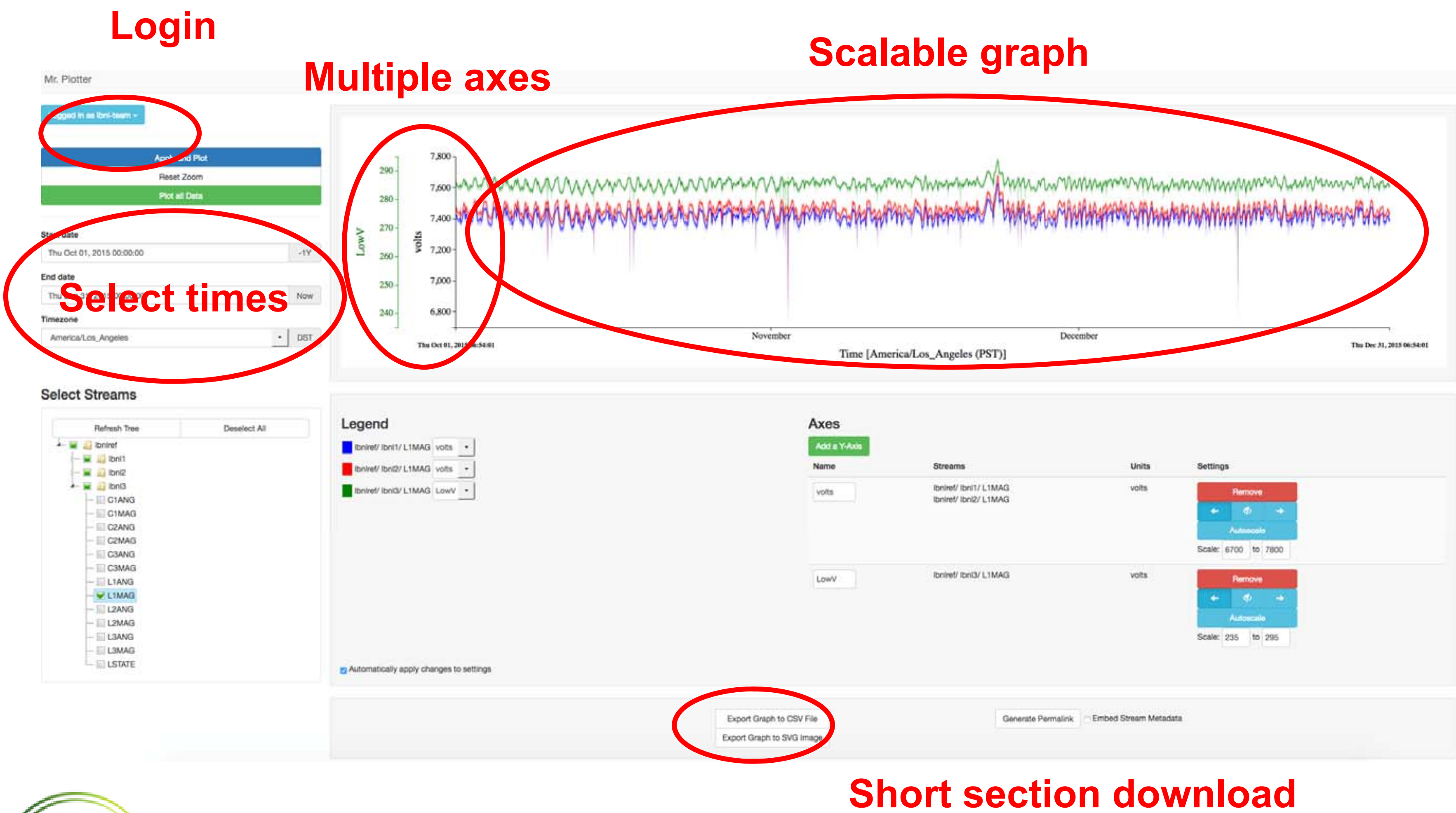
Download or visualize in BTrDB

Real time data from an LBNL building

Bulk download

IEEE PES Power & Energy Society® IEEE

BTrDB Interface for PowerData Set



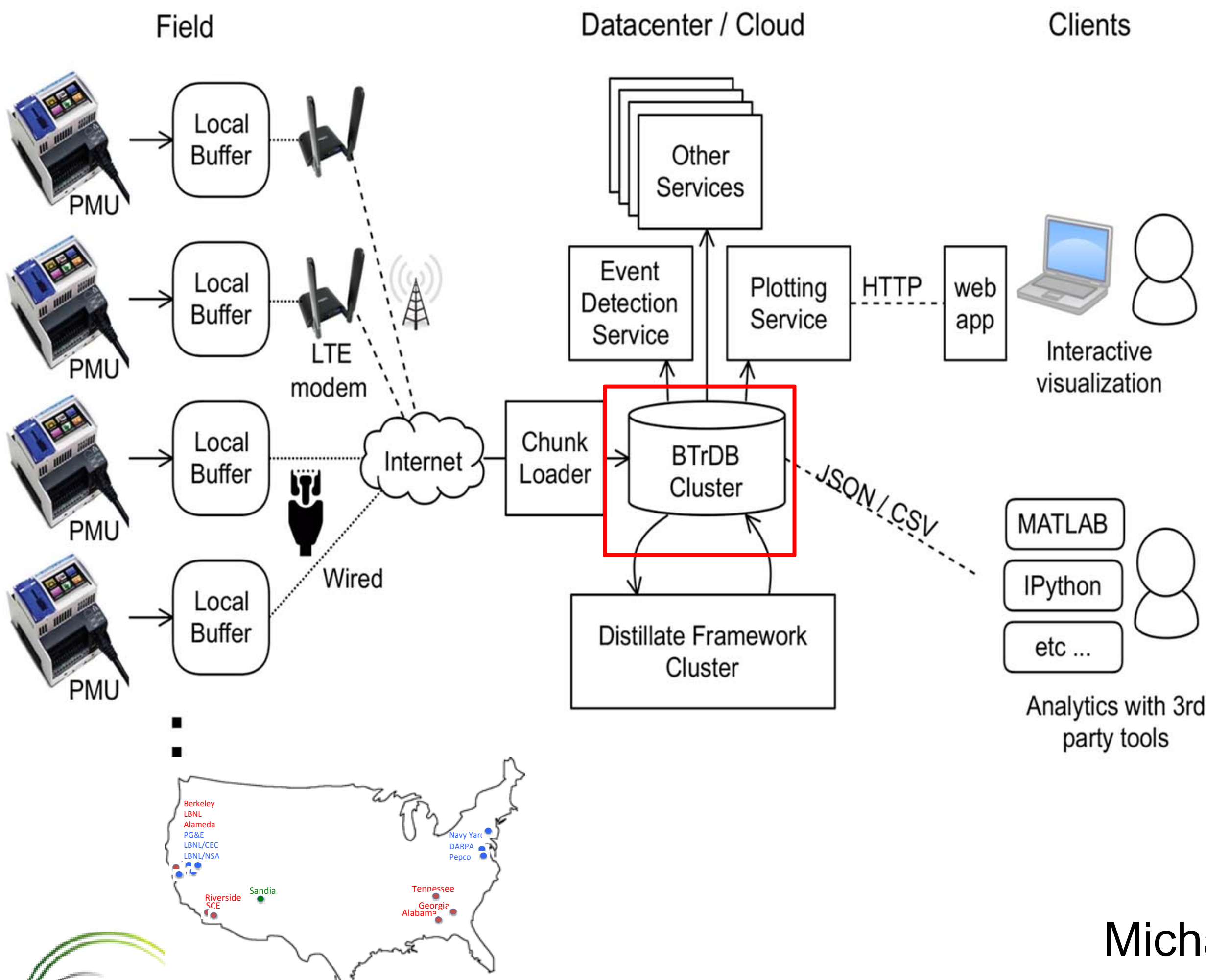
LBNL Installation (1)

- 3 uPMUs in 1 electrical path
- Oct 1 2015 to Dec 31 2015
  - Normal load at the lab and shutdown period from Dec 24 – 31
- All locations for the data these measurements have been scaled to the primary voltage with the applied PT and CT ratios.
- LBNL 1 (Grizzly bus1 2):
  - 7.2kV-120V x 3 0.3 Class PTs
  - 1.2 Class CT 1200:5A, PSL precision CT 5A:
  - 0.333mV
- There are two copper busbars of negligible impedance between LBNL 1 and 2 and the following underground cable.
- 6-750 KCMIL, underground cable, 2459 ft.

LBNL Installation (2)

- LBNL 2 (a6 bus1):
  - 7.2kV-120V x 3 0.3 Class PTs
  - 1.2 Class CT 1200:5A, PSL precision CT
  - 5A:0.333mV
- LBNL 3 (bank 514):
  - 480V/208VL-L
  - 1.2 Class CT 9600:1A, PSL precision CT 5A:0.333mV
- LBNL 3 is connected on the low side of a distribution transformer with the following specification
  - Delta Y-G
    1500/2000 KVA, AA/FA, 12.47kV/480Y-277V,
  - Z=5.75%

BTrDB – Massive Energy System Analytics



http://btrdb.io/

- Archiver / Database
- Stores (T, V) pairs
- Nanosecond precision
- Fault tolerant
- Highly scalable
- **Unique abstraction**
  - query range (ver)
  - insert values => ver
  - delete range => ver
  - query statistical (ver)
  - compute diff(v1, v2)

Michael Anderson ARPA- E Slide

Four Transformative Advances

- Immense time series data base bandwidth in the cloud
  - 60M inserts per second (ips), 120M queries per second
  - All 1,700 PMUs in North America generate 2M ips
  - 300M smart meters generate 0.33M ips
  - Stream ALL the data to the cloud, innovate on analytics
- Distillation infrastructure with extremely fast change set identification
  - Operate real-time on many streams, with holes, out-of-order, etc.
- On-the-Fly statistical summaries
  - Over a multi-resolution store
- Multi-resolution search and process
  - Find 'needle' events in immense haystacks instantly
  - Drill down exponentially to analyze
  - WITH algorithm innovation at the core
- Now in commercial use with PingThings

Time scales of measurement and operations are diverse

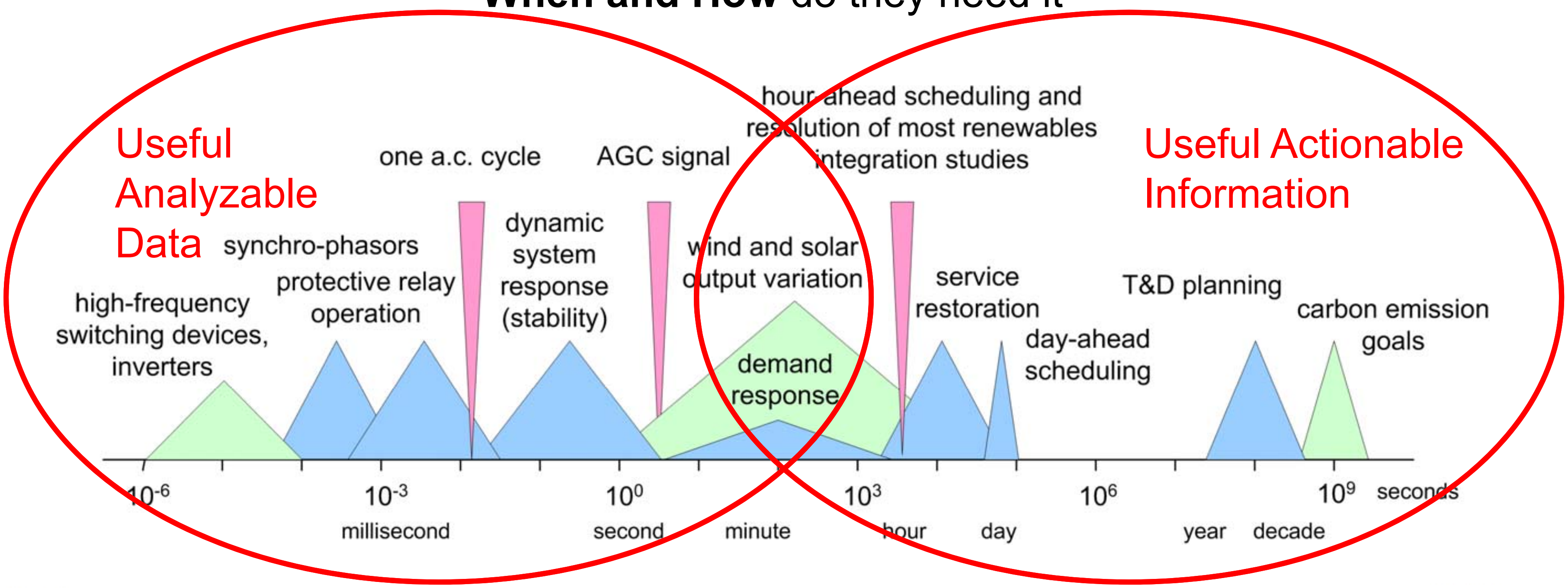
Key Questions for both research and industry

What measurements do we need?

Where do we need the measurement and analytics?

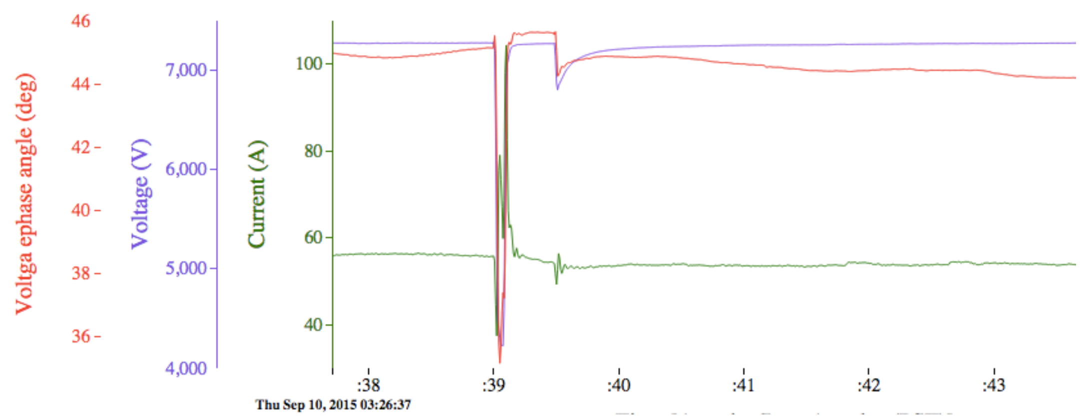
Who needs the information?

When and How do they need it

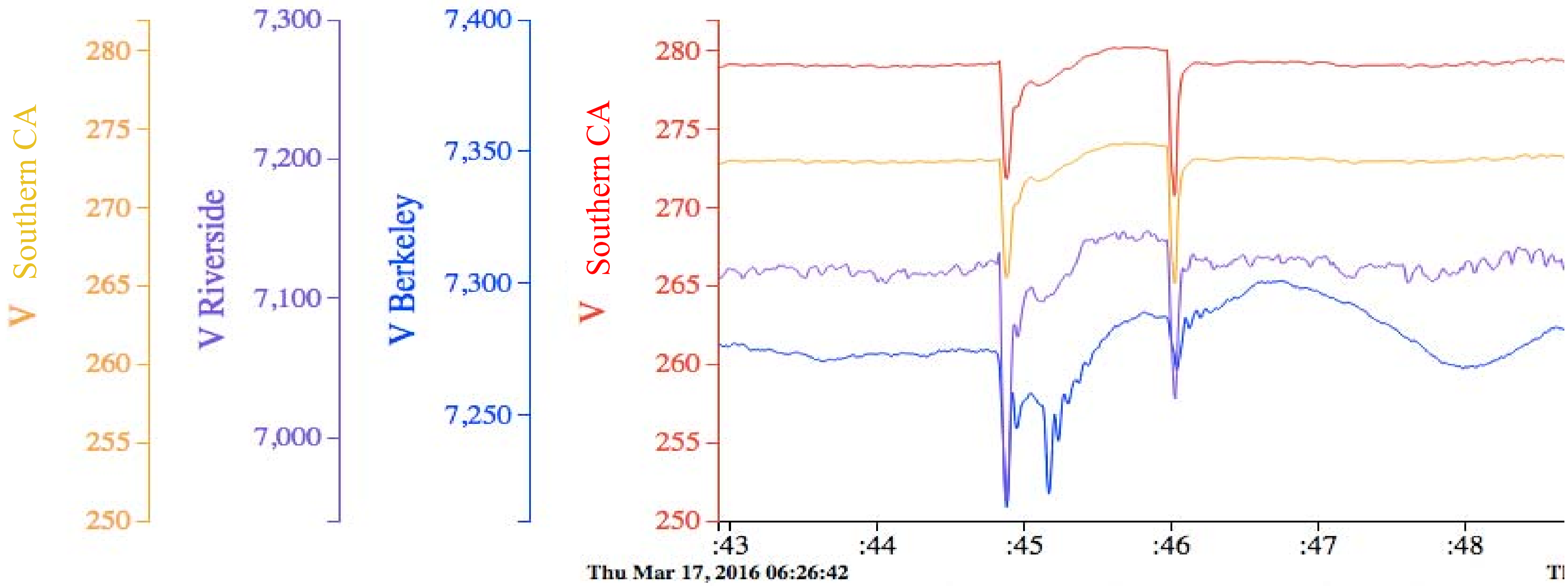


Proven Use Cases on Real Data

- Large PV Site Behavior Tracking – State of the PV report – impacts analysis
- Disaggregation of behind the meter generation (with one sensor)
- Load, Impedance and PV Model validation for distribution planning
- High Impedance Fault Detection
- Advance prediction of transformer/equipment failure
- Future: Control and DER Management system integration for ops



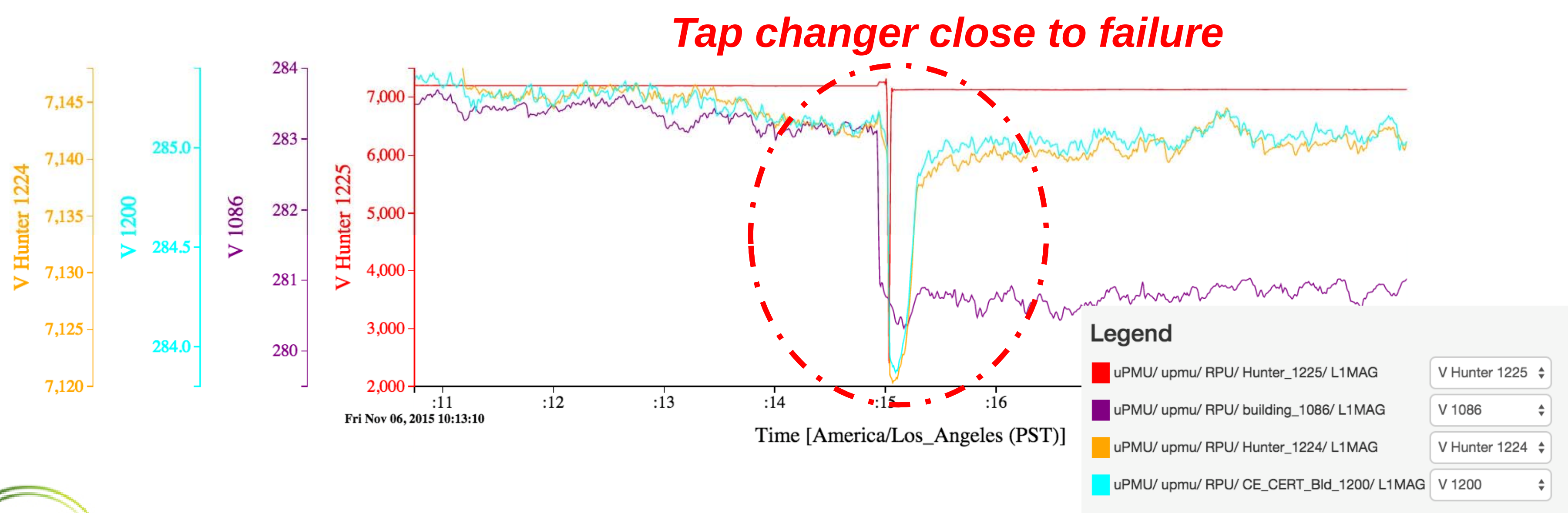
Use Cases: Locating both system and local events



Voltage sag observed at Northern and Southern CA locations – same event 500 miles apart

Incipient Failure Detection for Transformers (and other equipment)

- In the US – transformers are in general a big point of failure in the aging distribution system – when the fail, they cause an outage and $$ to replace
- Application picked up the signature below multiple times
  - Tap change followed by voltage sag – multiple times
  - We can only see this relational information with synchronized datasets from the uPMU
  - Tap changer oil leak – signature is evident before normal warning of failure



IEEE PES Power & Energy Society®

IEEE

Summary

- Data Citation: Stewart E.M., et al "Open µPMU: A real world reference distribution micro-phasor measurement unit data set for research and application development," LBNL Technical Report 1006408, October 2016.

- Other publications:
  - Stewart E.M., M. Stadler, C. Roberts, J. Reilly, D. Arnold, J. Joo, “Data Driven Approach for Monitoring Protection and Control of Distribution System Assets using MicroPMU technology” CIRED 2017, Glasgow Scotland
  - Alexandra von Meier⇤, Emma Stewart†, Alex McEachern‡, Michael Andersen§, and Laura Mehrmanesh, 2017, Precision Micro-Synchrophasors for Distribution Systems: A Summary of Applications, **IEEE Transactions on Smart Grid**
  - Mahdi Jamei, Emma Stewart, Ciaran Roberts, Alex McEachern, Anna Scaglione, Sean Peisert, Online Thevenin Parameter Tracking Using Synchrophasor Data, IEEE PES GM 2017

Contact Information

- Emma M Stewart (general questions): LLNL stewart 78@llnl.gov
- Michael Andersen (BTrDB): m.andersen@berkeley.edu
- Sean Peisert (powerdata specific questions): LBNL, sppeisert@lbl.gov

Micro-synchrophasors (μPMUs) for disibution systems

Three-year, \$4.4 M ARPA-E OPEN 2012 project (2013-2016)

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

Field installations at Riverside Public Utilities, Southern California Edison, Pacific Gas & Electric, Alabama Power, Georgia Power, Tennessee Valley Authority