Successful Deployment and Application of Distribution PMU's

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Intro: Success Stories

- How did we get to here?
- Success During the ARPA-E RPU Project
  - The big wins – PV disaggregation, papers, demonstration, event detect
- Follow on projects – DOE integration, cyber, physical, CA EPIC
- Overall Deployment

Micro-synchrophasors (μPMUs) for distribution systems

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

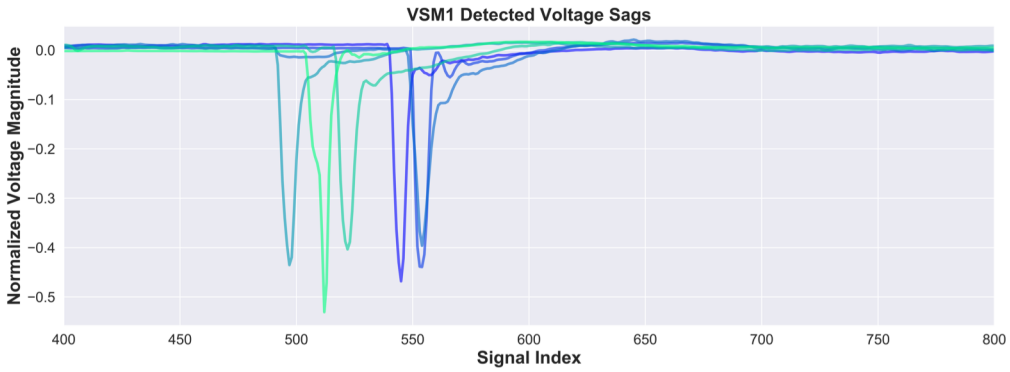
Research partners CIEE, UC Berkeley, Lawrence Berkeley Lab, Power Standards Lab, Lawrence Livermore Labs

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

The Start…use cases and deployment

- Event Labeling – solving the labeled dataset issue
- Forensic investigation – event analysis
- Control and visualization – operational integration
- Research and development future

Development of a Supervised Training Dataset with expert user input (Success 1)



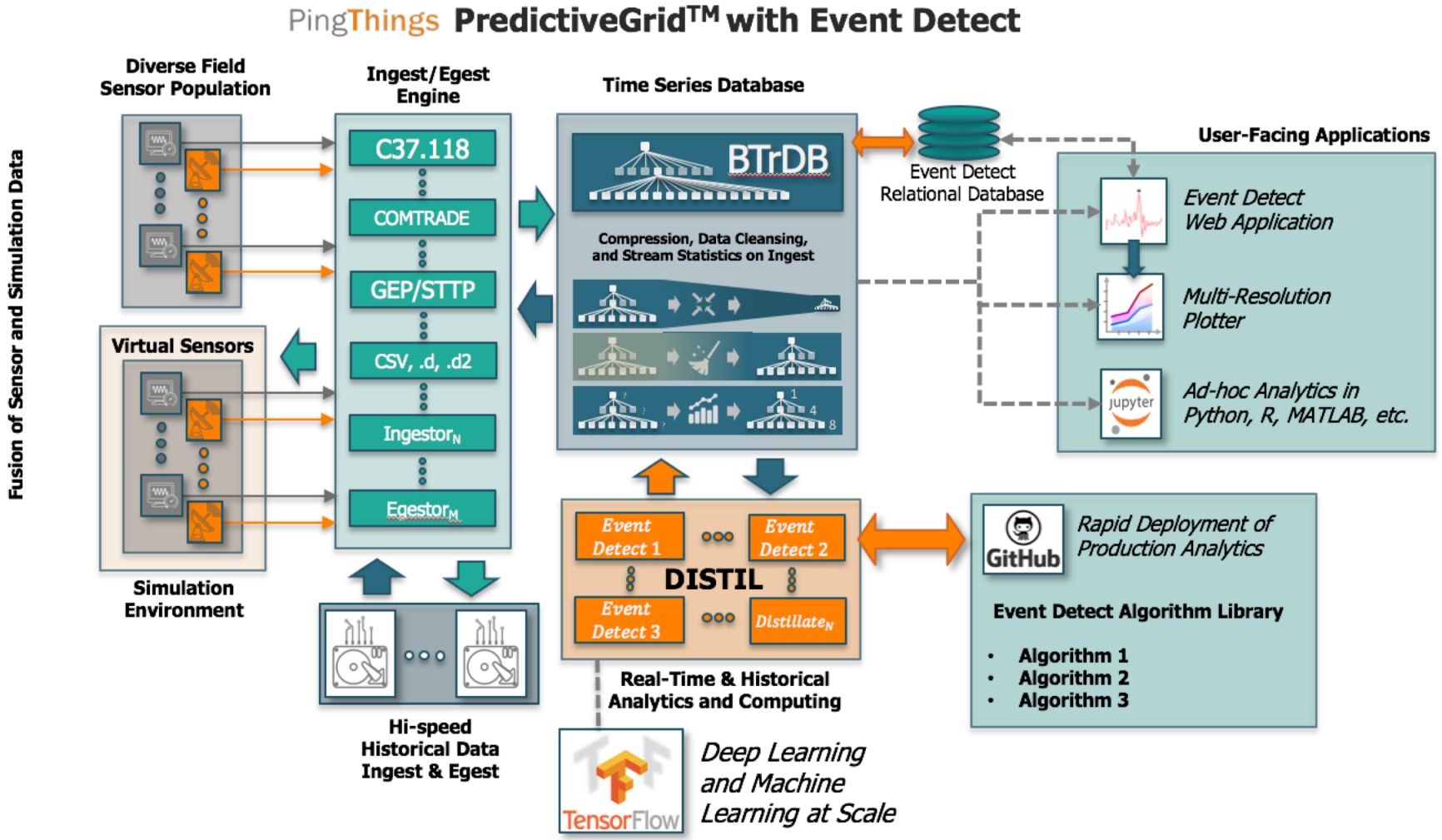
Answering a key “need” for application of supervised ML to grid data

- “what are the events and how do we label them”
- “we don’t know what we are looking at”
- “I need a dataset labeled by knowledgeable power systems engineers”

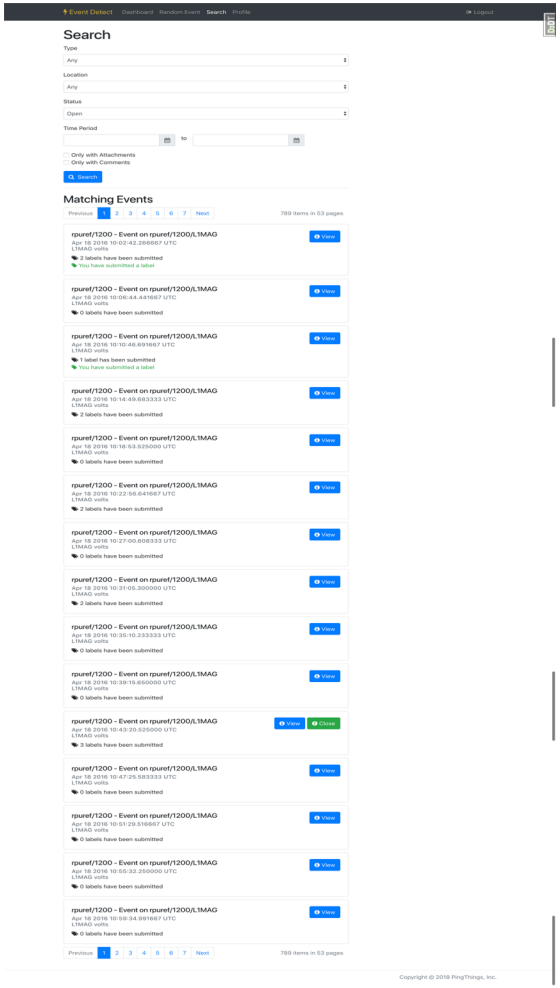
Reduce need for large volumes of historical data and very complex unsupervised algorithms

No way for engineers to view “anomalous” events in a systematic manner for labeling – especially in new datasets

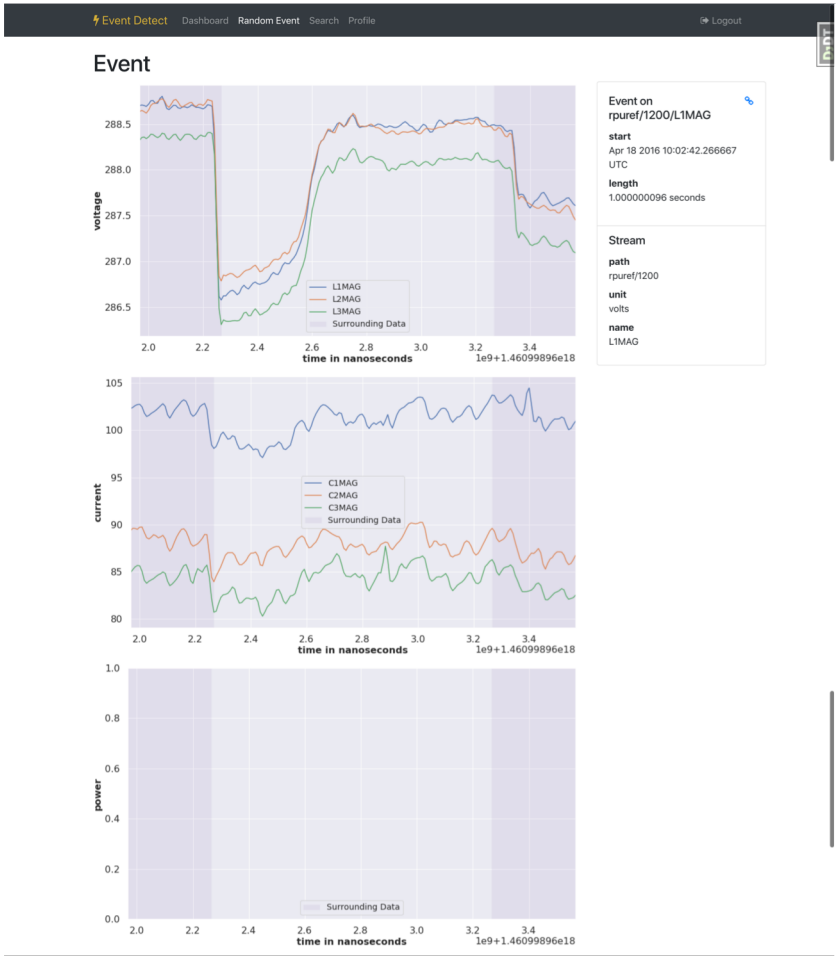
EventDetect Structure: Event Labeling

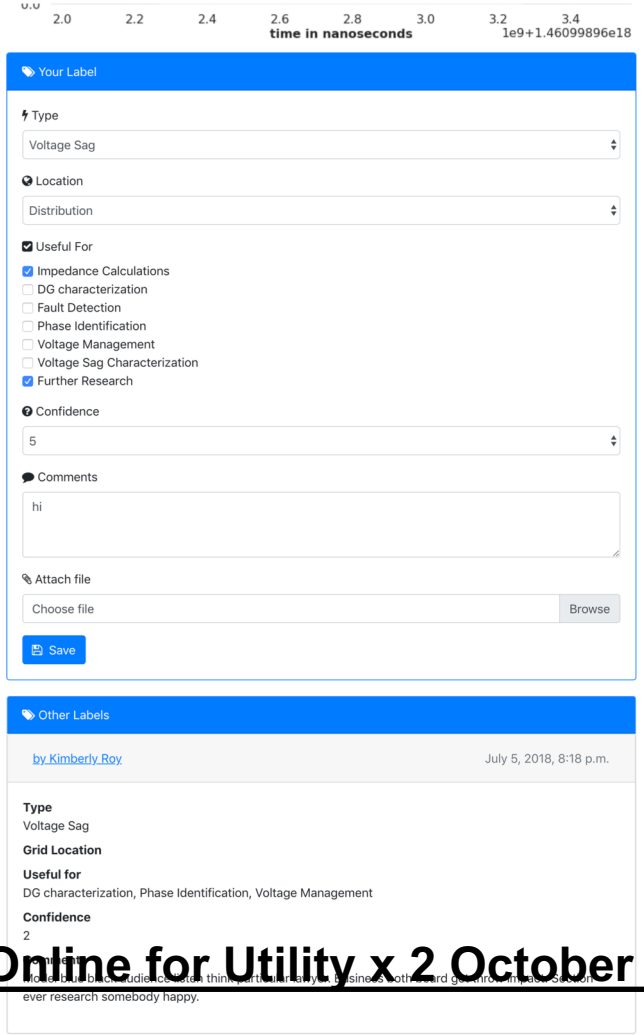


User Profiles, Stats, and Dashboards, Event Searching



Event Labeling





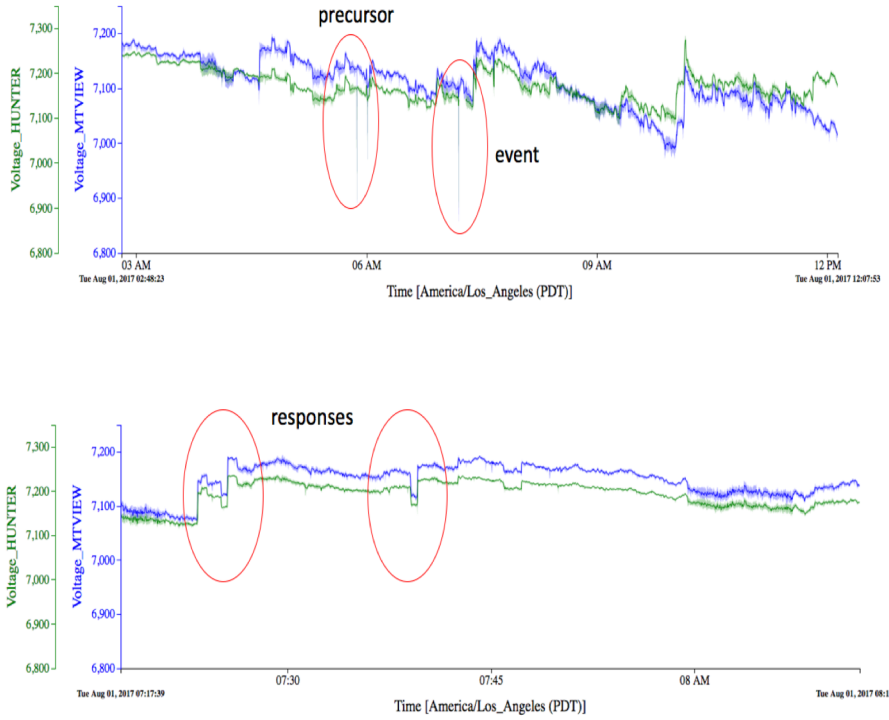
Online for Utility x 2 October 2018

Incident Analysis for Utility Partners (Success 2)

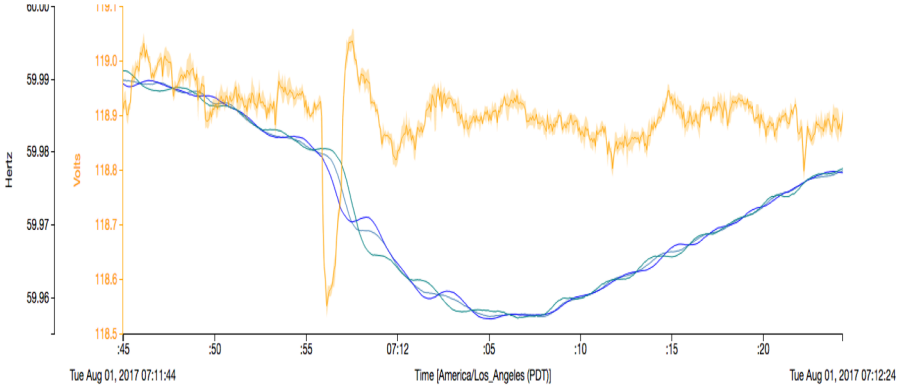
- Question from the utility partner: We had two outages today, storm or transmission system - SCADA doesn't show anything to help us with root cause, help?
- Anomaly Detection had pulled the two incidents into our "eventdetect" system
- Determined one system wide, one local… determined errors in control system response within utility
- Doing this requires data science and grid expertise… can't do one without the other

Analysis Event 1 (System Wide Event)

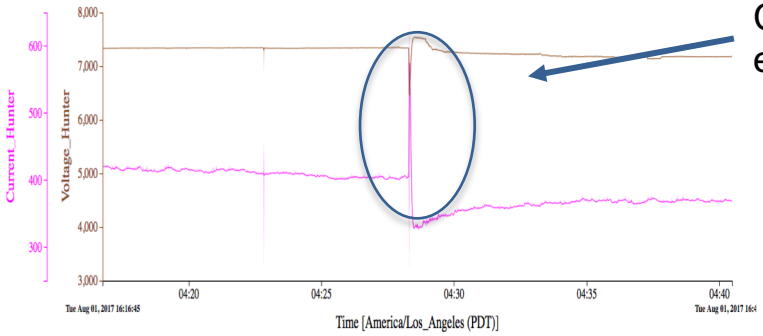
Early Morning Event & Response (System Wide Voltage Deviation plot of Voltage & Current measured in Riverside, CA)



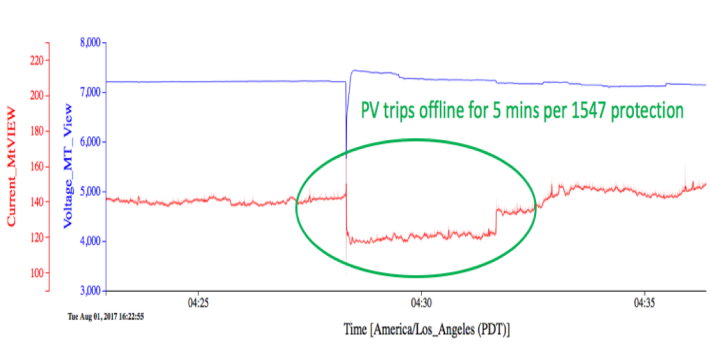
frequency across N & S CA, 10 sec oscillation in response to Voltage event



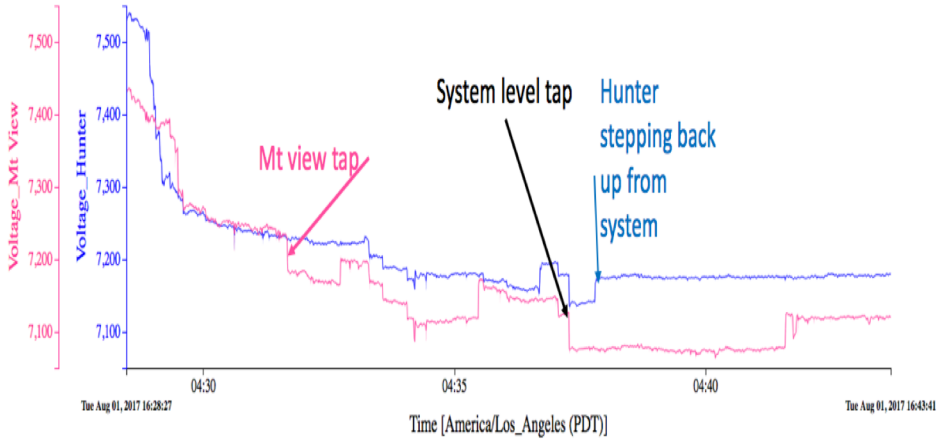
Analysis Event 2 (local event)



Current Response & Energy of event locally indicated lightning



PV Systems all tripped – Current measured at Hunter & Mt View
Voltage sag measured at Hunter and Mt View (Blue & Brown)



Voltage control response error

DER Control Demonstration at RPU (Success 3)

- Demonstrate how µPMU data can be used to improve network planning, operational monitoring, and control
- Validate the results of the power system analysis study performed last summer against a live deployment at the Hunter circuit at UCR
  - Integrate µPMUs with SGS Active Network Management (ANM) platform
  - Integrate SGS ANM with the PV Inverters
  - Perform Voltage Angle Constraint Management test cases

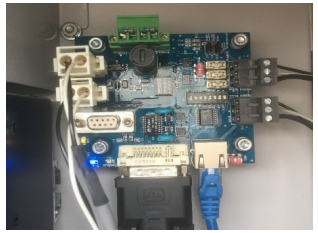
Phase Angle from multiple µPMU as a control signal demonstration (Success 3)

smarter grid solutions

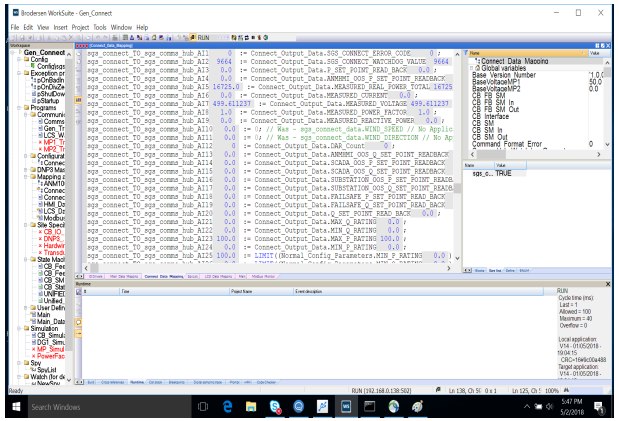
- Validated assumptions that we could minimize down time for RPU's customers during maintenance by monitoring voltage angle constraints and controlling PV inverters to address any breach.
- Demonstrated that by manipulating the set-point of PV inverters, voltage angle at a NOP can be adjusted.
- Further analyzed historical data and observed that the voltage angle do get breached at least once a day.

- sgs connect controller was setup as a Modbus Client
- sgs connect successfully read values (real power, reactive power, voltages, etc.)

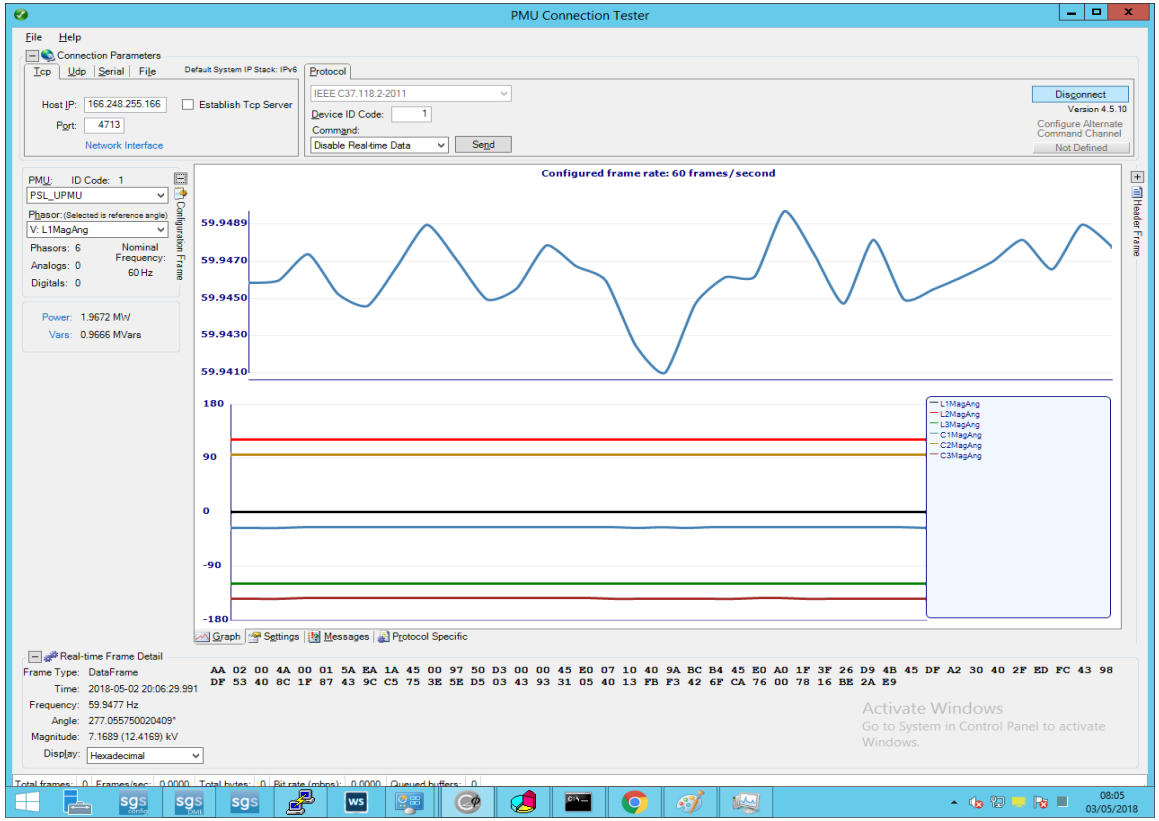
PV Inverter Modbus Communication Module



sgs connect reading values from PV inverter



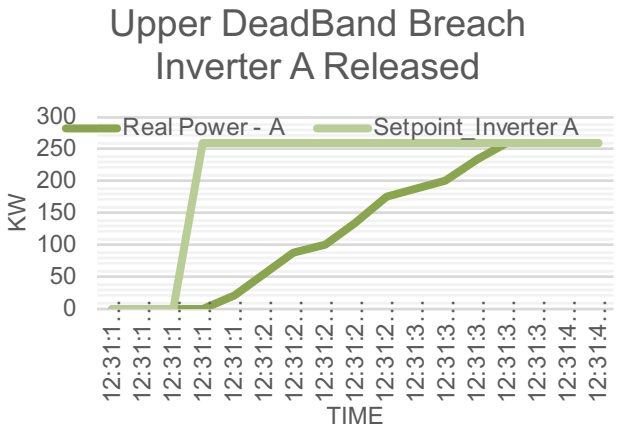
µPMU Communication Test

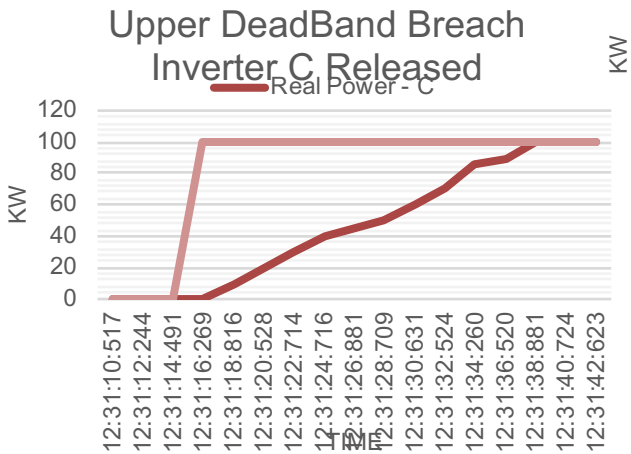


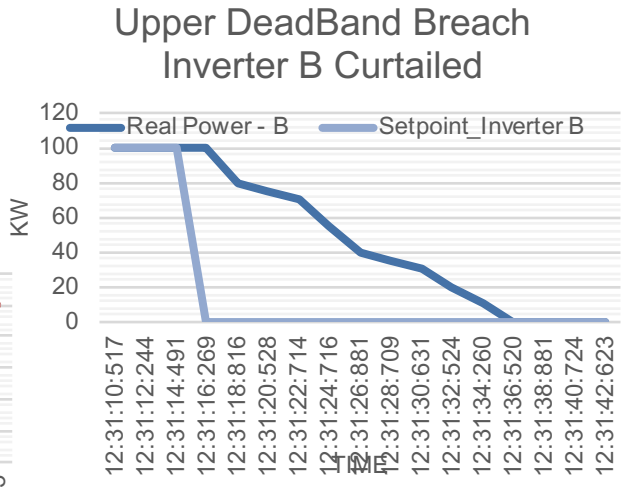
- Successfully established communication with the µPMU for feeder 1225. All voltage magnitude and angle data were successfully polled to the SGS Strata and recorded by the SGS Data Historian service.

Upper DeadBand Breach Use Case

The three PV controllers react to the breach in 5 second issuing new setpoints **fully releasing Inverters A and C** to **100 kW** and **260 kW**, respectively; and **curtailing Inverter B** to **0 kW.**

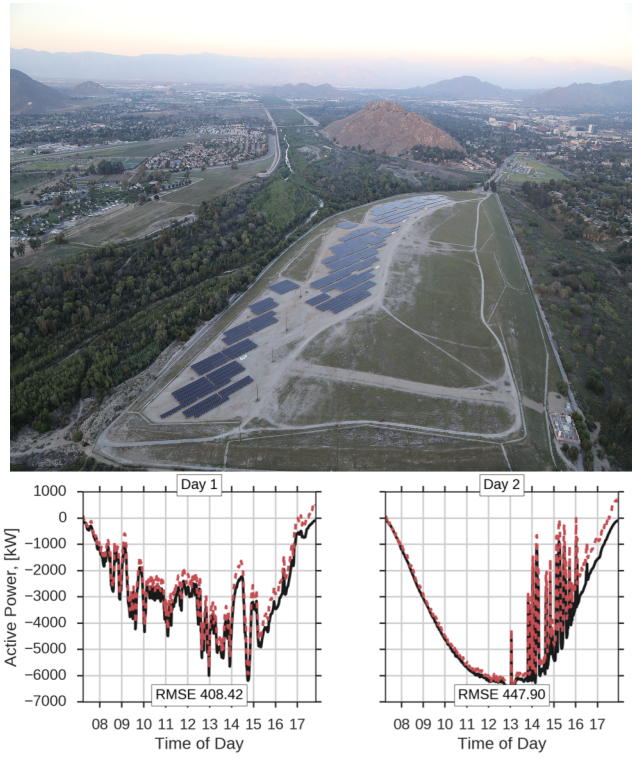






PV Disaggregation Integration with µPMU data to SGS ANM Platform (Success 4)

- Motivation:
  - Most existing forecast and real time disaggregation algorithms rely on:
    - Irradiance measurements
    - All inverters communication (similar to smart meter readings)
- Why is this an improvement?
  - Actual performance based analysis – if PV is disconnected can be accounted for
  - Feeder performance is synchronized and correlated with PV behavior for analysis of root cause for power quality or voltage control issues
  - Full visibility with small number of sensors



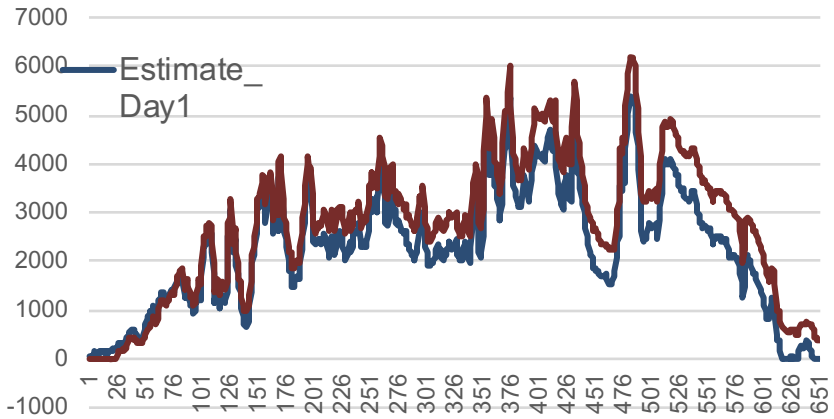
Integration to an operational environment of contextually supervised generation

uPMU Driven Algorithm Implementation in SGS ANM Platform

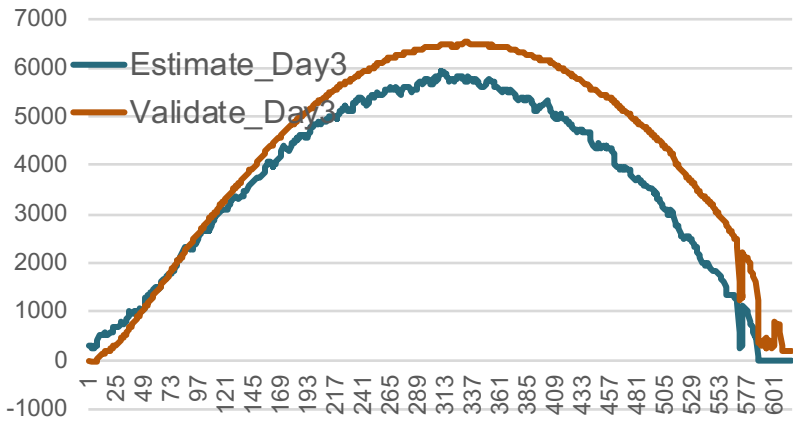
LBNL CSGE Algorithm had <6% RMSE on 1 minute data
R + D 100 Award 2017
Patent awarded

- Goal of follow on activity:
  - *Implemented the LBNL PV disaggregation algorithm in ANM pre-processor*
  - *Tested/validated with live utility data over 3 days*

Comparison of PV_{val} with PV_{est} (Day 1)



Comparison of PV_{val} with PV_{est} (Day 3)



Future of Deployments, Implementation and Research

- Success: transition to the R + D and commercial community
- Integration into DOD and DOE Projects:
  - DOE GMLC: CleanStart DERMS – intentional islanding and
  - DOE CEDS: cyber intrusion detection, gps spoofing
  - DARPA RADICS
  - DOE OE Sensors FOA
  - DOE SETO Projects: ENERGISE analytics integration
  - CA EPIC: demonstration of DER and protection/line drop detection

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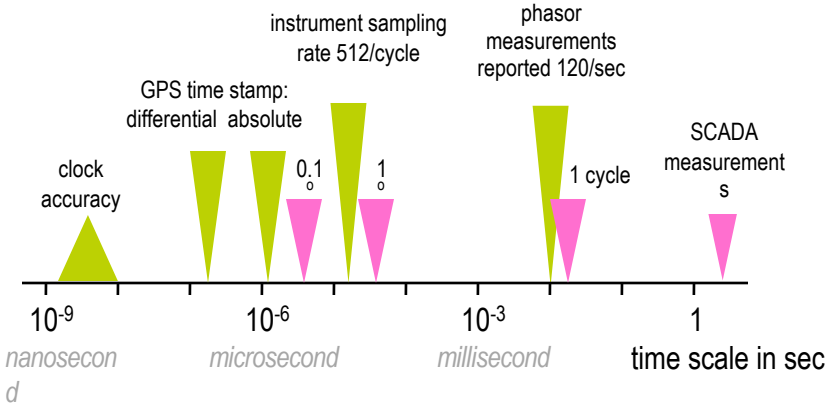
Power Standards Lab µPMU

- built on PQube3 power quality recorder
- capable of power quality mode with 512 samples per cycle
- time stamping to ns precision, µs accuracy with GPS
- measures voltage & current, magnitude & angle (12 channels)
- 100V ~ 690V input
- 120 samples per second in PMU mode (each channel)
- local data buffering + batching (2 min), backup storage
- connectivity via Ethernet, 4G wireless



PSL

www.powerstandards.com