100% Renewables on Your Grid Today

Presented by **Raymond de Callafon, *UCSD***
Chuck Wells, *OSIsoft*

PXiSE Energy Solutions, LLC
Sempra Energy
OSIsoft.

Meet the phasor applications development team

Raymond de Callafon, Chuck Wells, Wayne Isaacs, Michael Christopher

"We architected, and built a fast feedback and predictive control algorithm designed for the power grid": *Raymond de Callafon (UCSD)*

"We invented a precise and high-speed control technology that enables an electric grid to be powered by 100% renewable energy": *Chuck Wells (OSIsoft, LLC)*

"We accomplished highly efficient, robust, reliable phasor-based control in real time, using standard hardware": *Wayne Isaacs (OSIsoft, LLC)*

Remember when the grid was simple…

- Small number of large generators
- Cheap and plentiful fuel (oil and coal)
- Predictable availability
- Simple local speed control

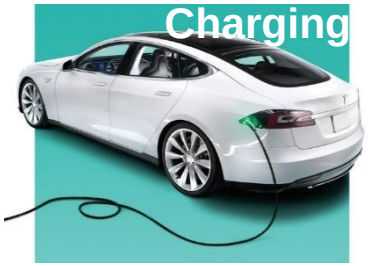
Grid control was easy: SCADA-based

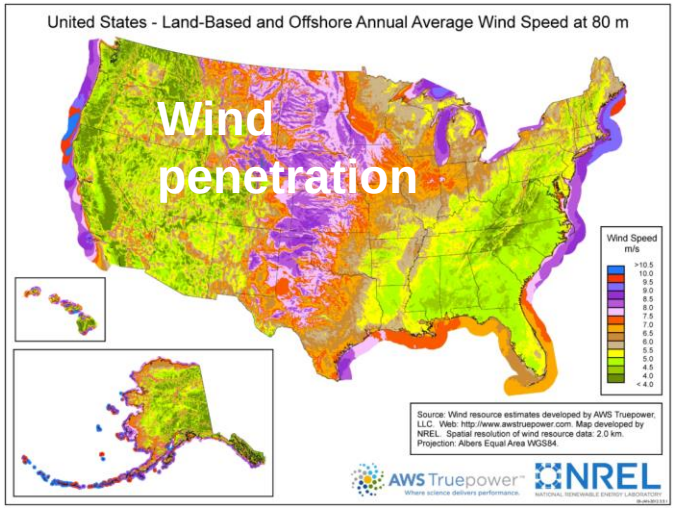
- **Frequency:** Measure 4 second intervals, wait for drop below a low threshold, then increase speed of generator/ reduce speed if above a high threshold
- **Voltage:** Measure slow intervals and add/remove capacitors to change voltage or change exciter voltage
- "Droop" control has been **used since 1920s** and is still in use in 2017…
(CERTS microgrid controller)

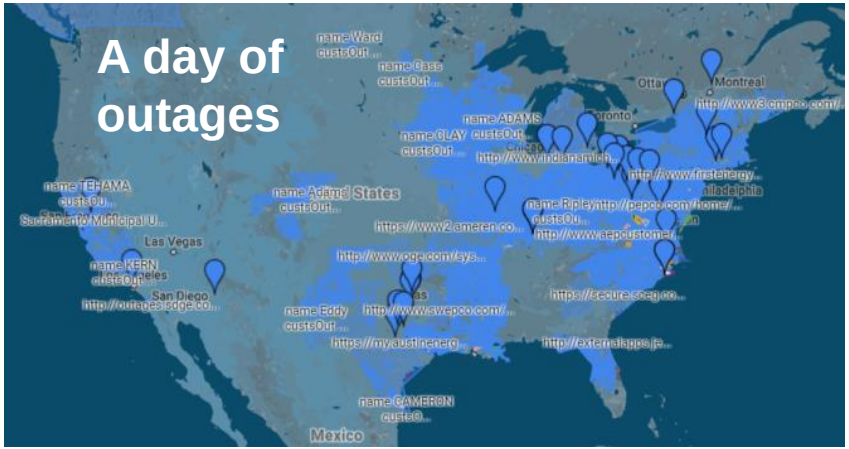
But the grid has changed…

The grid has changed a lot

- More renewable generation
- Older infrastructure not upgraded
- More EVs charging from the grid
- Power outages are more difficult to troubleshoot
- Less investment in power grid technology
- Shortage of experienced power system engineers







This has caused tremendous stress...

- Compliance of Renewable Portfolio Standards
- Achieve sustainable power at lower cost
- High levels of renewables in the distribution system

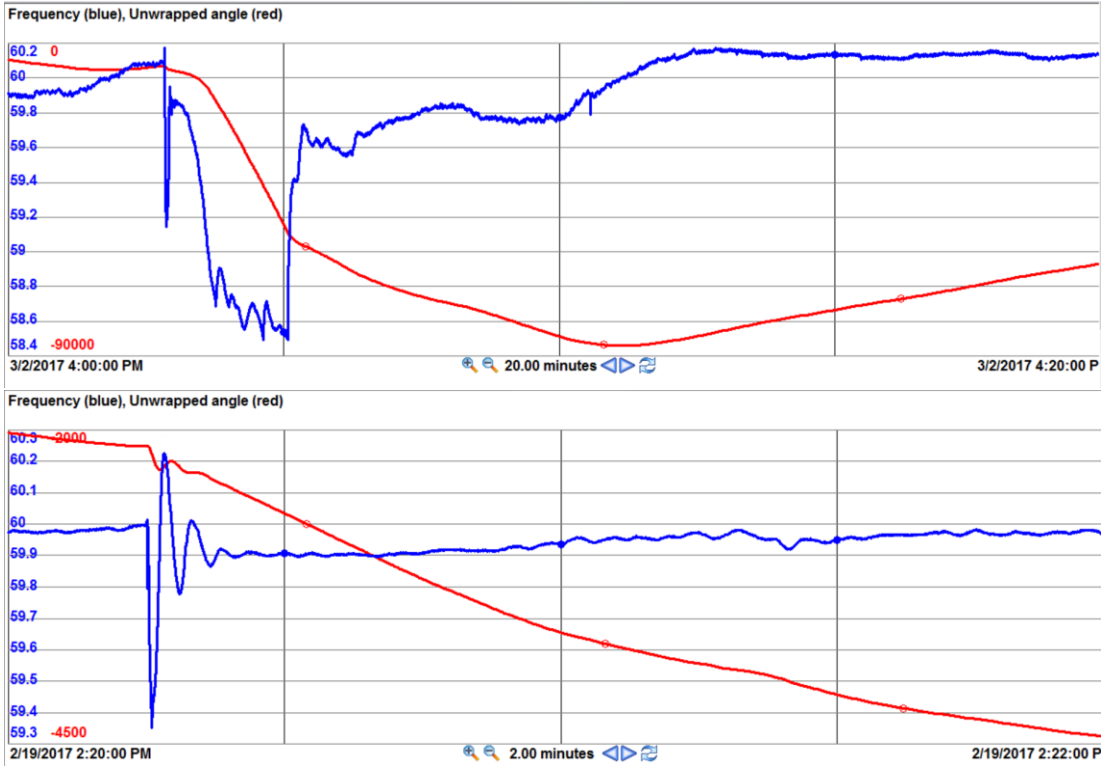
- Intermittent renewable power generation problems
  - Disturbances in the grid
  - Renewable generation not coincident with load
  - Spinning reserves still required

Grid control: Synchrophasor-based

- Have you ever thought about ***synchrophasor-based* control** of the grid?

- Were you thinking…
  - Too fast to handle: 60Hz sampling?
  - Too hot to handle: high volume of data?
  - What to do with angle information?
  - Mitigate high frequency oscillation?
  - Data dropouts?

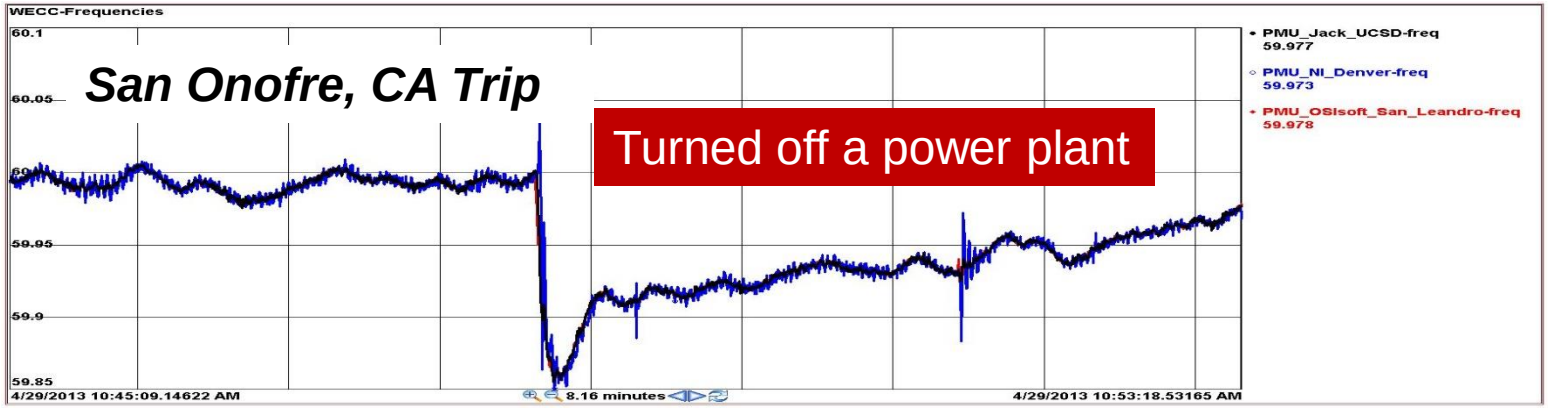
Illustration: Intermittent resources impact the grid

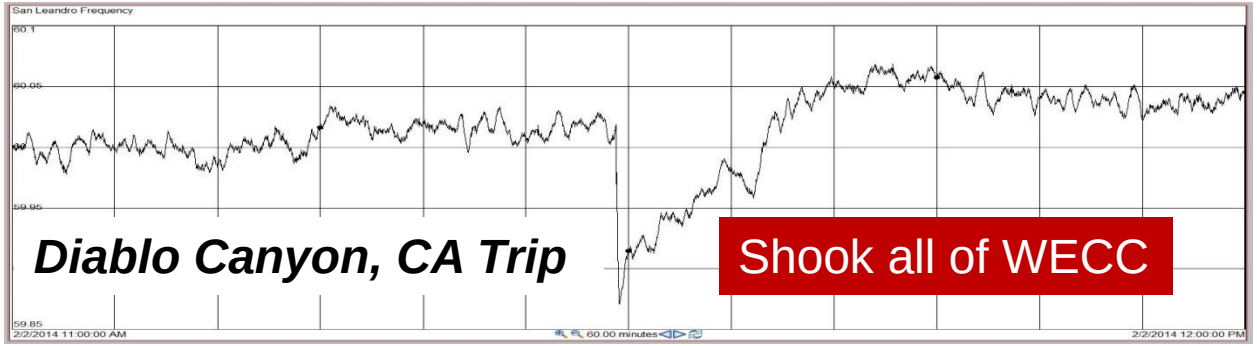


Relays trip, blackouts

Example: Island/microgrid oscillations at peak load = 140 MW

Illustration: sudden changes in the grid





Examples:
Western Electricity Coordinating Council (WECC)

Grid control: Synchrophasor-based

- Too fast to handle?
- **Real-time 60 Hz rates on low cost computers**

"You can't control what you can't measure"
-Lord Kelvin

- Too hot to handle?
- **Efficient method of storing configuration data in PI AF and control data in PI Data Archives**

- What to do with angle information?
- **PMU based 2x2 decoupled power feedback control and "state of the grid" (V, Θ)**

- Mitigate high frequency oscillation?
- **Able to control power flow direction in any grid with little or no inertia**

- Data drop-outs?
- **Real-time PMU data checking and ride-through for feedback control**

So what?

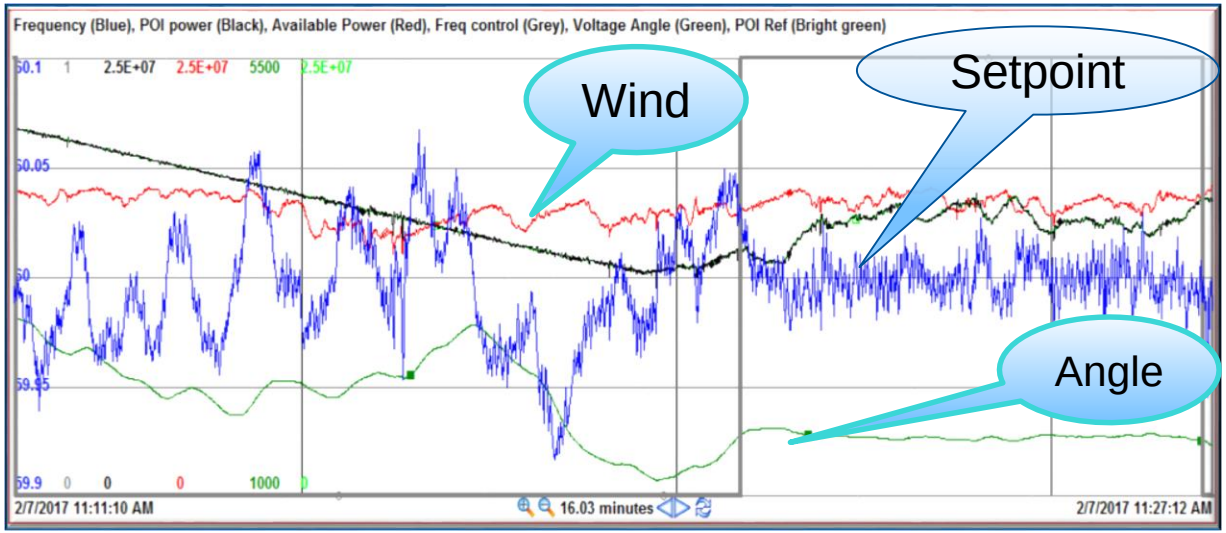
- *Less effective traditional controls causes:*
  - *Inadequate grid resources utilization*
  - *Curtailments of renewables (lost revenue)*
  - *Higher carbon emissions (fossil backup)*
  - *An increase in grid congestion and overloads*
  - *An increase in transmission losses*

Solution…

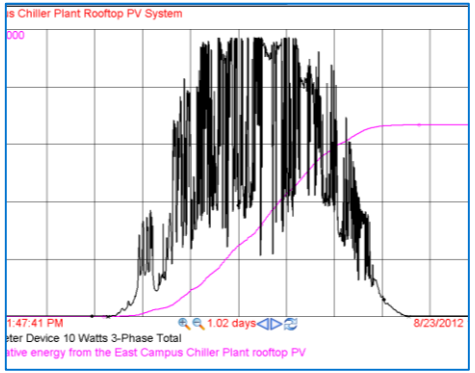
Advanced synchrophasor precision closed-loop control system closely tied to the OSIsoft PI System: PXiSE

Bottom Line:

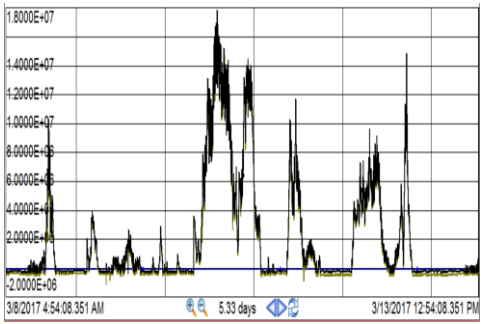
- Renewable generation has large variability
- Electric vehicles: not “grid-friendly” unless mitigated



Solar variability

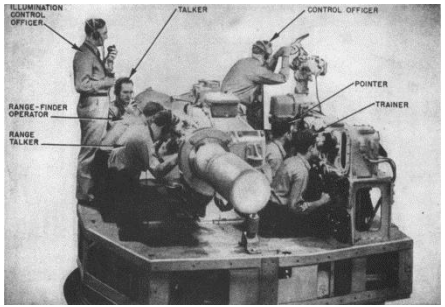


Wind variability



We aren’t alone - other industries use closed-loop controls

- Navy ship fire control system
- Army tank weapons firing control system
- Aircraft auto pilot (roll, pitch, yaw, direction, altitude)
- Hydrocracker controller makes gasoline (Pat Kennedy patent)
- Basis weight and moisture in paper machines



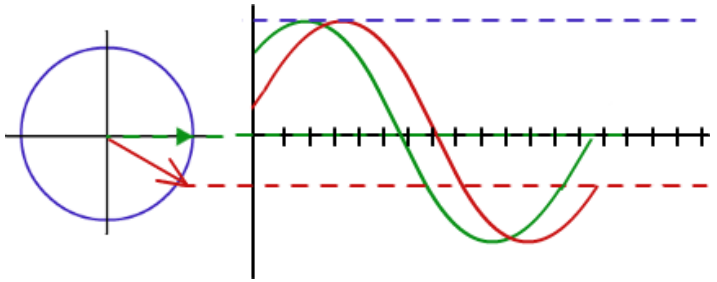
The time is right to use closed-loop control on the grid

- But how?

- Some applications of closed-loop controls in the power grid exist today
  - Power system stabilizers (difficult to tune, and often mis-tuned causing forced oscillations)
  - Russia, uses exactly same PSS on all generators

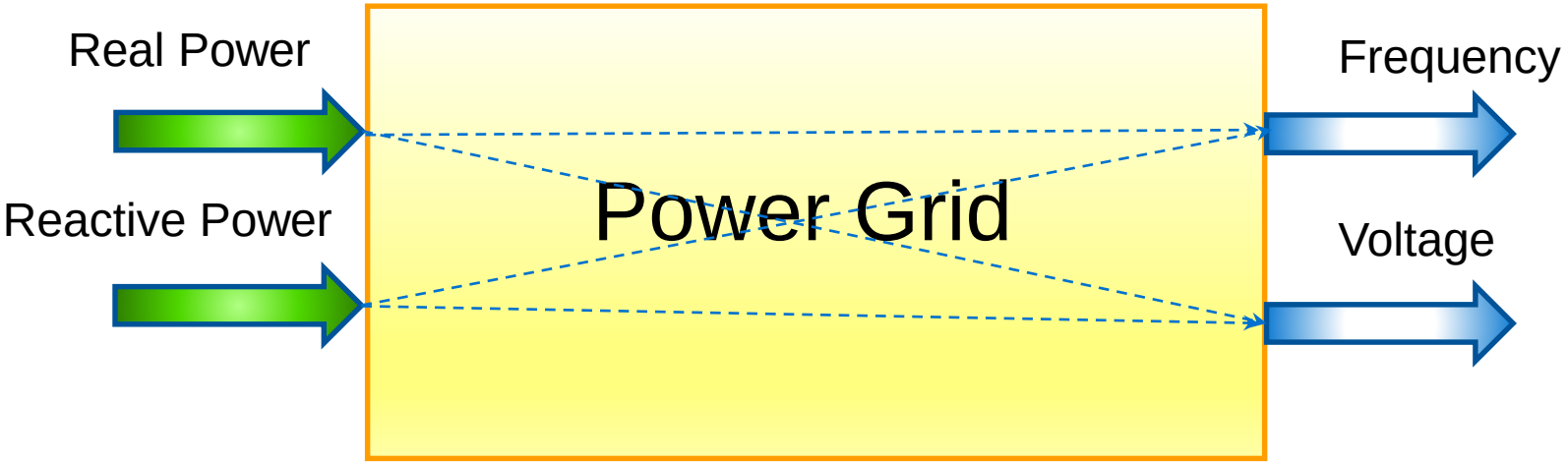
Fast measurements: synchrophasor data

- Sampling rate should be 60 Hz – *faster than blink of eye*
- Sampling should be time synchronized
- Data should be accurate
- Time stamps should be accurate
- IEEE C37.118 standards
  - Time accuracy 1 microsecond
  - Data accuracy 1%
  - Faster than one second slew rate
- These data are available from most protection relays



What operational issues should we be concerned about?

Remember Ohm's Law…



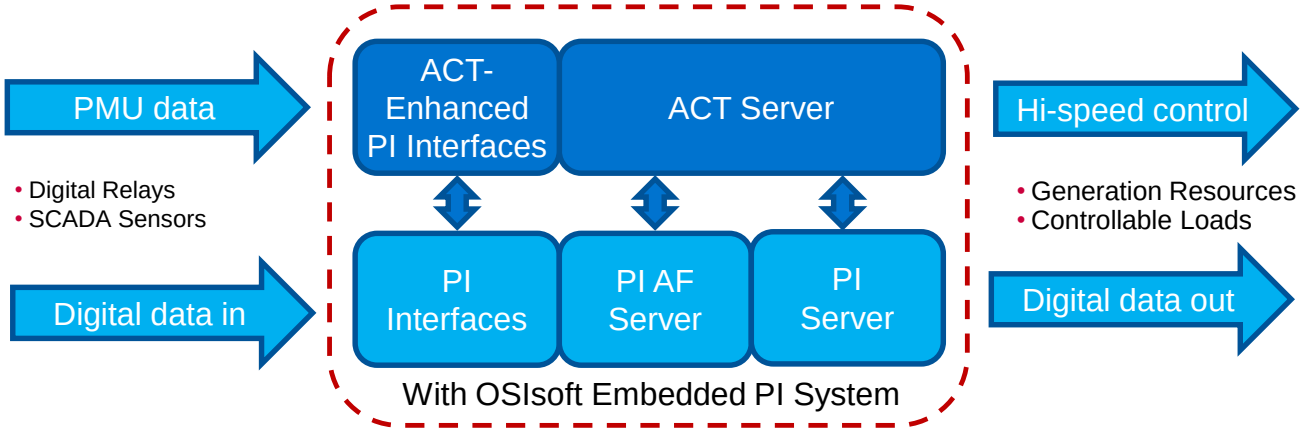
Decoupling control is needed to control grids with low inertia

Key elements of PXiSE Synchrophasor Control Solution

- PMU based 2x2 decoupled closed-loop control
- Hierarchical control system using same basic control blocks for control
- Control of “state of the grid” (V, Θ)
- Able to control power flow direction in any grid
- Control systems with little or no inertia
- Executes at 60 Hz rates on low cost computers
- Efficient method of storing configuration data
- Efficient method of archiving process and control data

“You can’t control what you can’t measure”
-Lord Kelvin

Our advanced control technology (ACT) solution: integrated software built upon a proven data platform



Implemented on Field Proven Hardware

PXiSE Advanced Control Technology (ACT)

PXiSE Energy Solutions, LCC

Sempra Energy

OSIsoft.

Advanced Ramp and Frequency Control in Action at a Windfarm

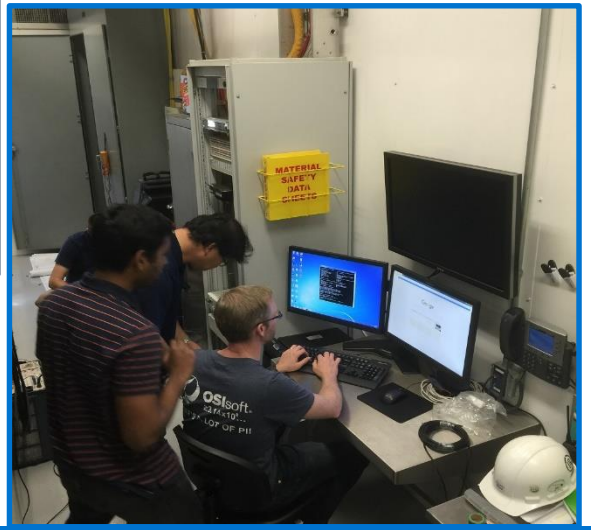
PXiSE Energy Solutions, LCC

Sempra Energy

OSIsoft.

Fast Substation Commissioning

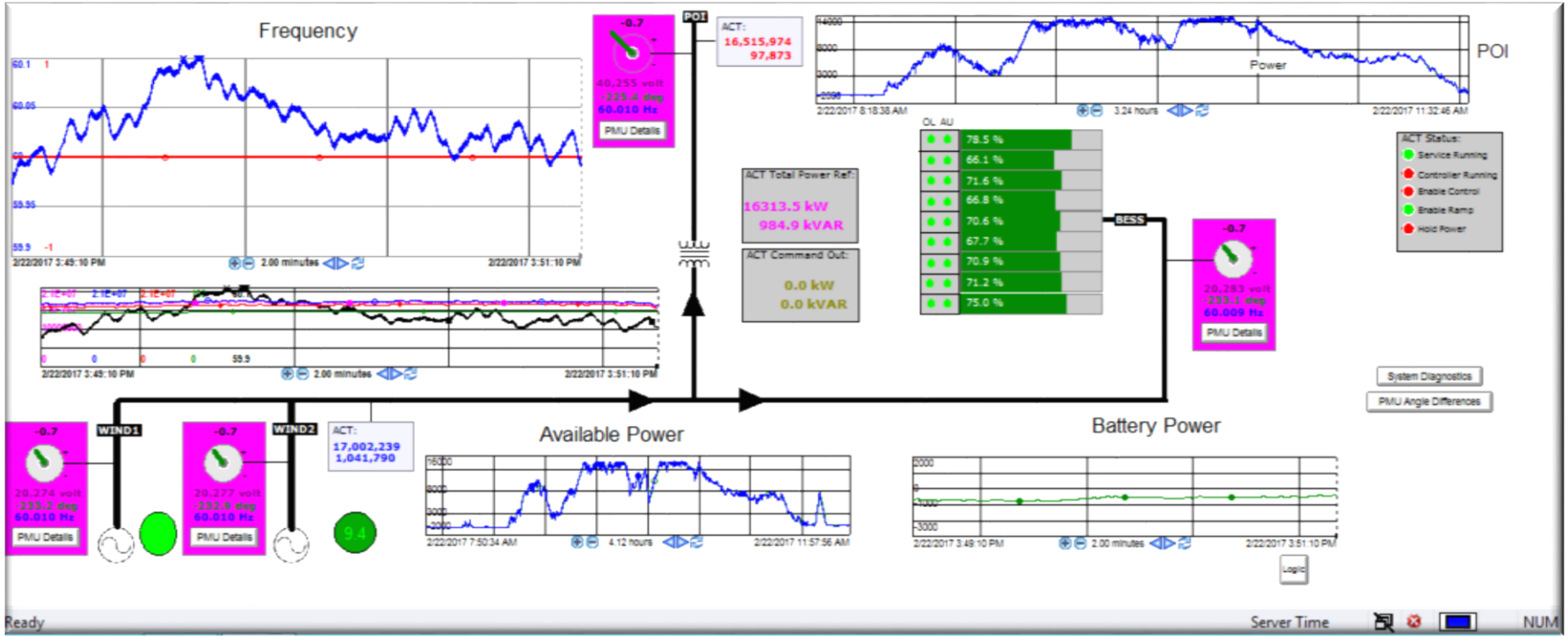
1. Mount Controller Computer & Connect Network Cable
2. Validate PMU and Data I/O
3. Tune Controller
4. Place PXiSE ACT in Service



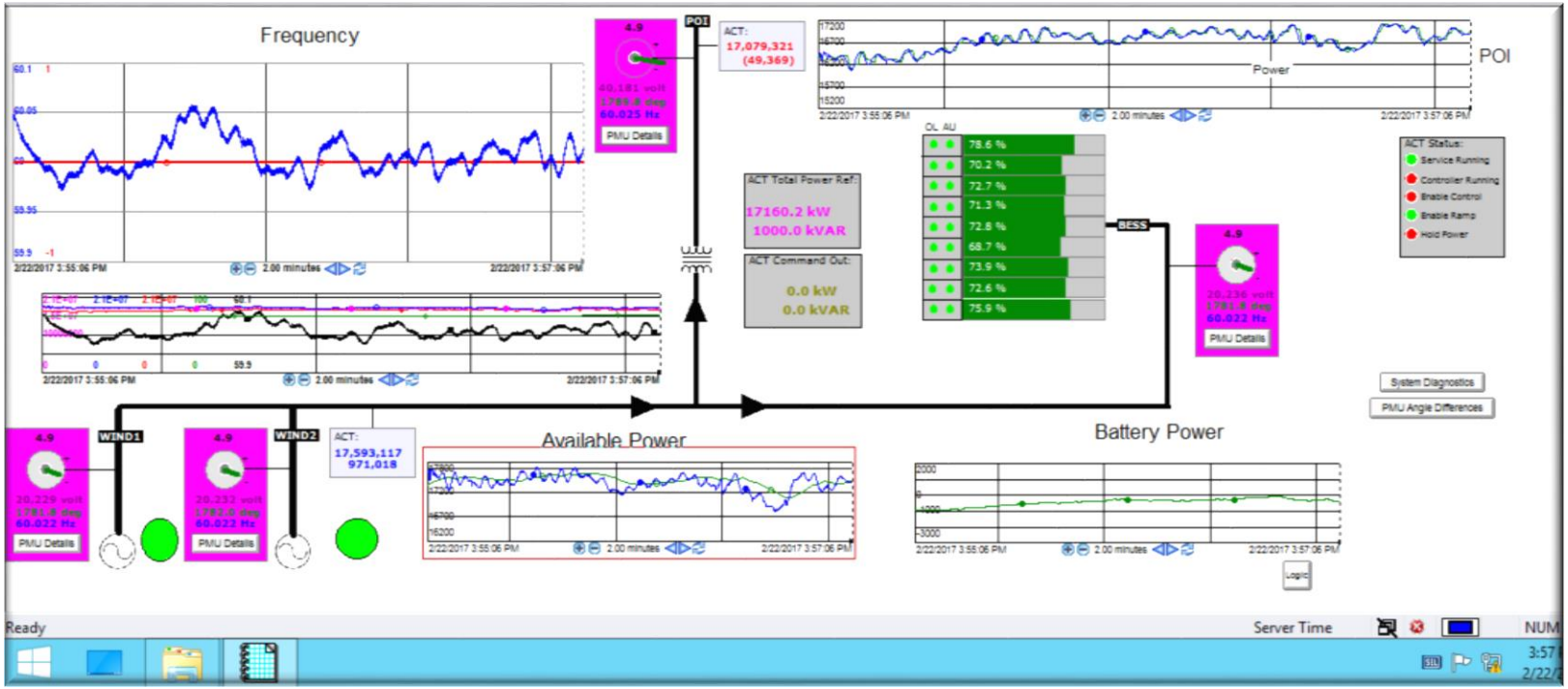
Use existing platforms
Standard equipment
Set-up in 2-3 days

PMU Based High Speed Controller

at a Major Windfarm with Battery Storage



Variations over a 2 minute period



Demonstration

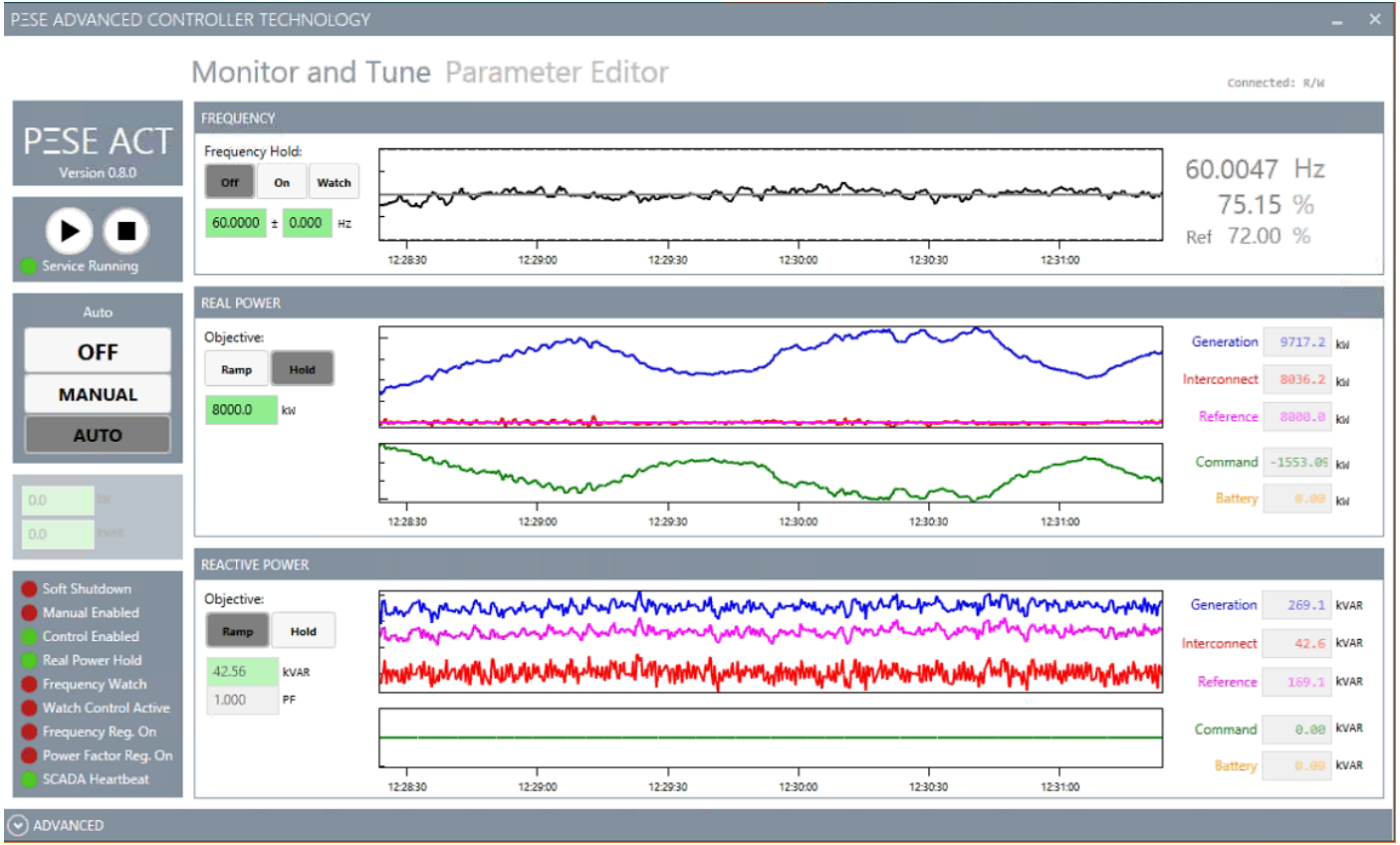
High Speed Precision **Real Power “Ramp Rate” Control**

Mitigates Wind Power Variability!

Demonstration

High Speed
Precision
Real Power
“Hold Steady”
Control

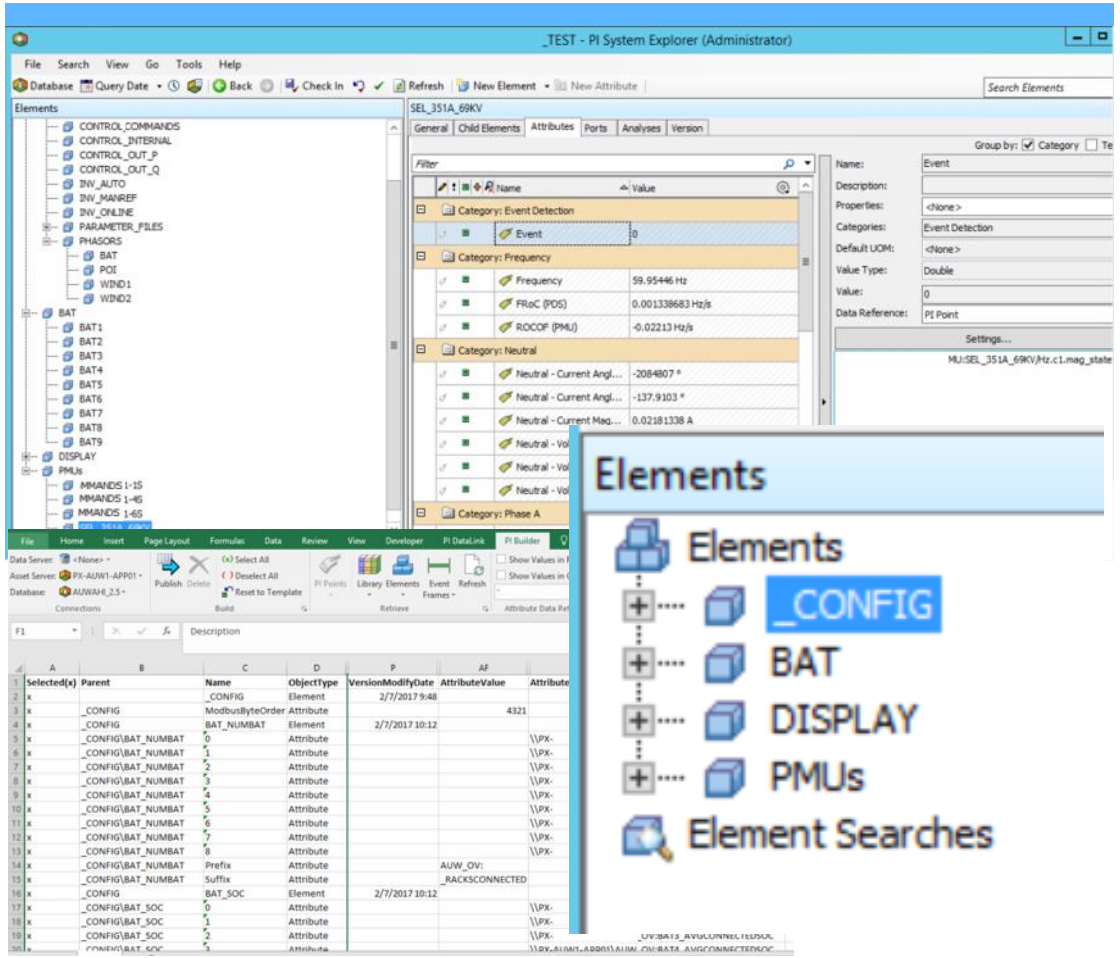
Follow any
power demand
(islanding
if demand = 0)!



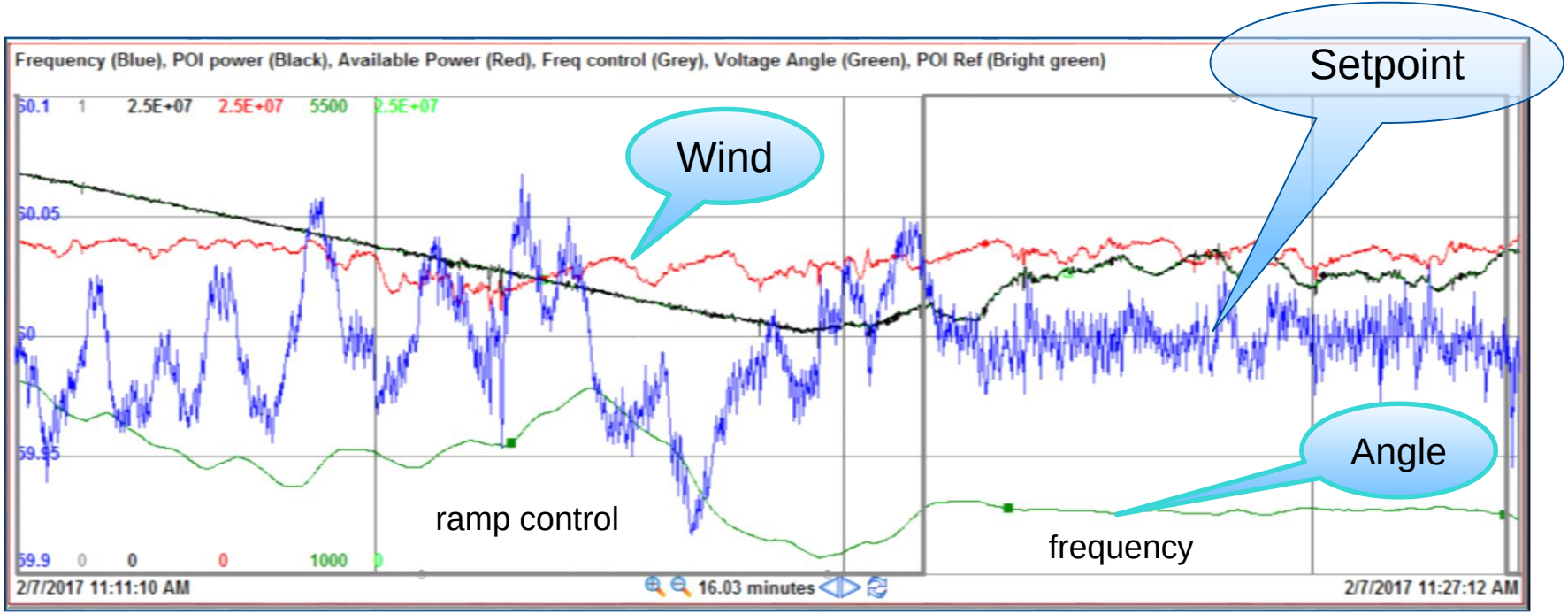
Using PI AF to reduce configuration time

(XML model import via CIM or CSV files)

- General data model
- Import from external files
  - CIM
  - CSV
- Configuration standard PI System tools
- Incremental updates
- History of:
  - configuration data
  - tuning data
  - process data
  - diagnostic data



Comparison of ramp control and frequency control



Ten times lower frequency variation using frequency control

What have you learned so far?

- Synchrophasor data in a real-time control system
- Effective use of your investment in PMU installation
- Even more use out of your PI System!
- Control capabilities are almost endless:
  - Control of grid systems with low inertia
  - Control of frequency of an entire island with a battery
  - Control of angle at a point of interest in a grid

Applications are endless!

Advanced controls from PXiSE enhance performance of many DERs *as a whole system**

Wind Resources

Solar Resources

PXiSE

PXiSE Advanced Controller

Energy Storages

Thermal Generations

- Time-synchronized, and precise coordination and control of DERs
- Optimized power scheduling according to characteristics of DERs
- Fast and precise frequency regulation
- Coordinated reactive power management
- Fast disturbance mitigation to ensure reliability and service quality

* All applicable from macro to micro-grids

Better Value and Performance than other Power Control Solutions

Traditional Controls

- Slow SCADA and legacy controls result in **lower performance**
- Slow coordination among DERs with pre-determined set points result in **poor system responses**

Traditional Controls Performance

- Basic power and energy scheduling to deliver a **minimum level** of asset utilization, revenue, and cost savings
- Legacy frequency and voltage controls **limit revenue** potential and put operational **compliance at risk**

PXiSE ACT

- 200x **faster, integrated and precise** control solution ensure performance
- Fast **dynamic response to real and reactive power**, frequency and voltage changes

PXiSE ACT Value and Performance

- Fast and precision power and energy scheduling to deliver **better utilization of asset, and higher revenue and cost savings**
- Advanced frequency and voltage controls offer **new revenue** potential and **meet operational compliance** requirements

Takeaway – PXiSE Synchrophasor Control Solution

Power Quality Control

- Fast and precise mitigation of power fluctuations
- Fast and precise power demand tracking
- Islanding conditions via control for zero power flows

Financial Benefits

- Supports high penetration of renewable generation
- Increase revenue by selling ancillary services
- Reduce energy cost by managing demand and time of use
- Faster return on investment of renewable microgrid assets

Summary

COMPANY and GOAL

PXiSE formed to offer the most advanced solution to manage the increasingly complex and dynamic power grid.

Goal = enable smooth and rapid transition towards a more distributed and clean power grid using fast, precise, time synchronized feedback control technologies.

PXiSE Energy Solutions, LLC

CHALLENGE

Control of frequency and voltage in grids with no or low inertia.

- Droop controls inadequate
- Inverter controls beat against each other
- Slow data sampling
- No feedback control

SOLUTION

Use phasor measurements from existing relays for decoupled controls in the power grid

- Use existing relays for measurements
- Handle latency and data dropout
- Fast decoupled feedback control
- Implement controls in low cost PC

RESULTS

Improved frequency and voltage control, better utilization of energy storage capacity, increased energy surety, improved ROI via ancillary services

- Reduction in frequency variation by factor of ten
- Fast frequency control can be done using batteries rather than fossil generators
- Demand control allowing sale of ancillary services

Questions?

Let’s talk more

- Visit our booth today and tomorrow
- Prof. Raymond de Callafon, callafon@ucsd.edu or callafon@PXiSE.com
- Dr. Chuck Wells, cwells@osisoft.com or Chuck.Wells@PXiSE.com

Questions

Please wait for the **microphone** before asking your questions

State your **name & company**

Please remember to…

Complete the Online Survey for this session

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谢谢

Danke

Merci

Gracias

Thank You

ありがとう

Спасибо

Obrigado