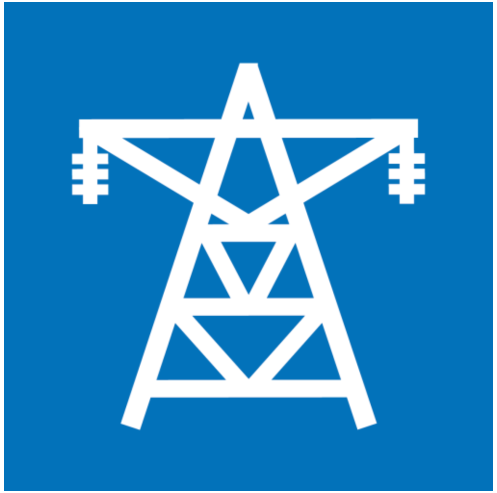


Microgrids; what they are and the value they bring

Presented by **Chuck Wells, OSIsoft, LLC**

Outline:

- *Definition of microgrids*
- *What types of applications*
- *Microgrid use cases*
- *Microgrid control issues*
- *Approached to microgrid control*
- *Current DOE and CEC Microgrid projects*

Definition of microgrids

- Interconnected loads and DER sources
- Acts as a single controllable entity
- Provide high reliability to critical loads inside the microgrid
- Automatically connects and disconnects to/from the grid
- Can operate autonomously in island mode

Type of applications

- Hospitals
- Universities
- Small communities
- Military bases
- Commercial buildings
- Government buildings

Typical sizes

- Large
  - 40 MW University campus
- Medium
  - 10 MW small community with critical loads
- Small
  - 1 MW commercial building

Standards governing microgrid

- IEEE 1547.4
  - Interconnection specifications
  - Internal behavior of the microgrid
- IEEE 2030.7
  - Microgrid control system
  - Multi-level control system

Benefits from microgrids

- 20 percent reduction in carbon emissions
- 20 percent increase in efficiency of delivering power to critical services in the microgrid
- 98 percent reduction in power outages to critical facilities in the microgrid
- Reduce energy purchased from connected grid
- Sell ancillary services to grid
  - Fast regulation market (result of FERC Order 755)
  - Demand response
  - Curtailment
  - Spinning reserve
  - Black start
  - Voltage regulation

FERC Order 755

- Pay for Performance
- Why was this rule passed
  - Providers of ancillary services were unable to get paid a fair price for services offered
  - eg. Beacon Power (flywheels)

Fast regulation markets

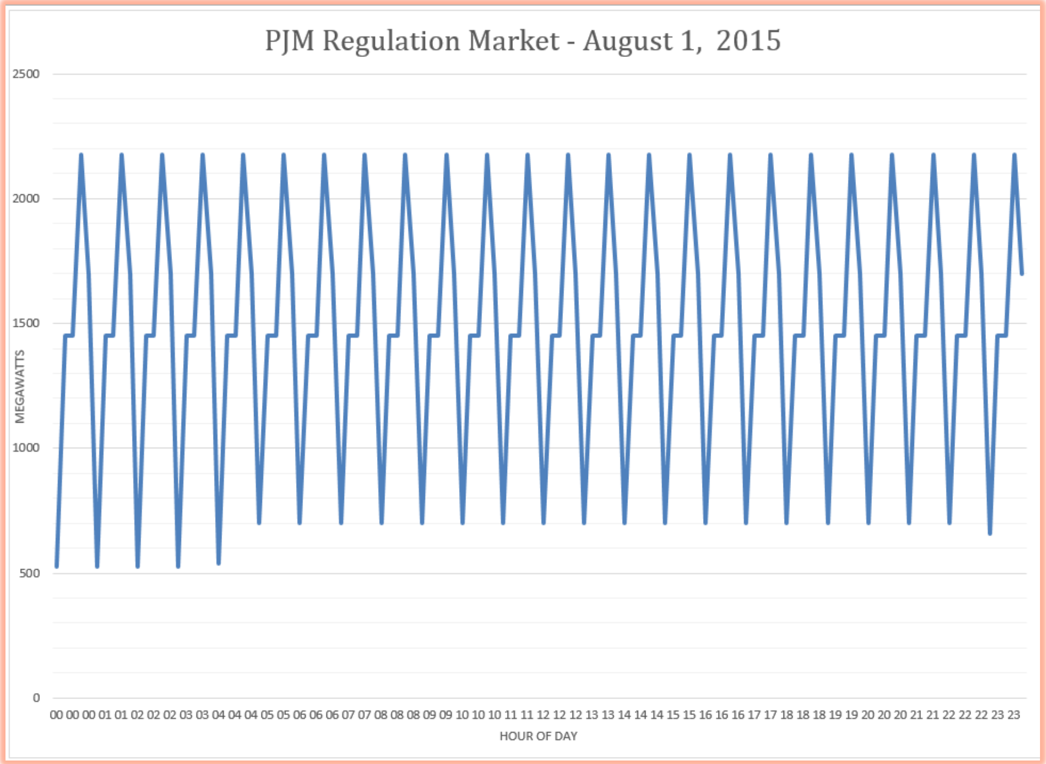
- California ISO (Mileage Market)
- PJM
- MISO
- ERCOT

Size of Markets (storage)*
[storage should be inside microgrids]

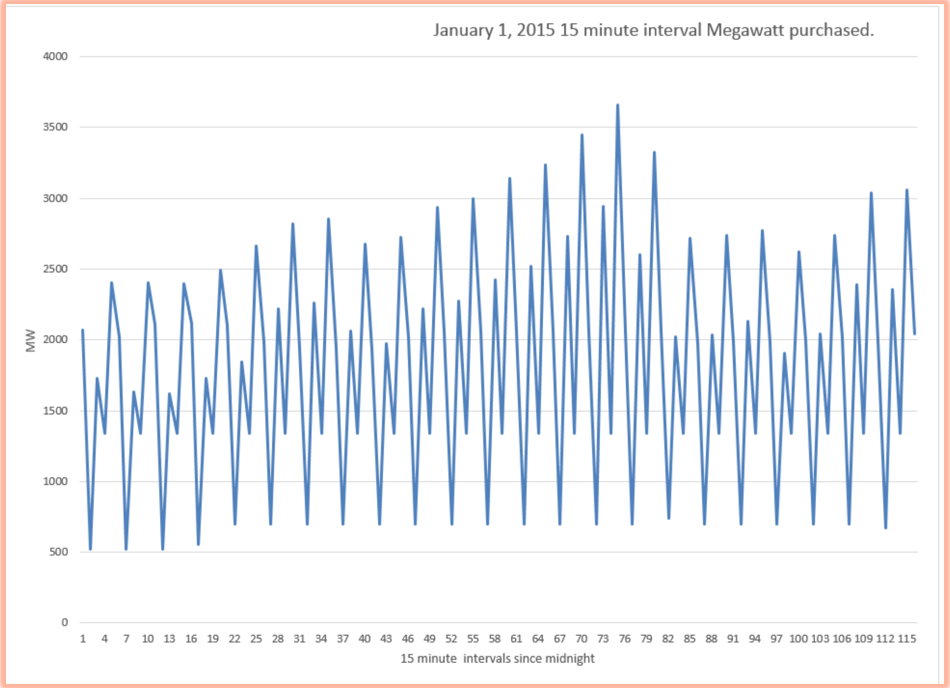
- 100 MW PJM (now)
- 1300 MW CAISO (required by 2020)
- 3000 MW ERCOT(required by 2020)
- 400 MW MISO (now)

- *Great Plains Institute*
- *Steve Dahlke*
- *Nov 18, 2014*

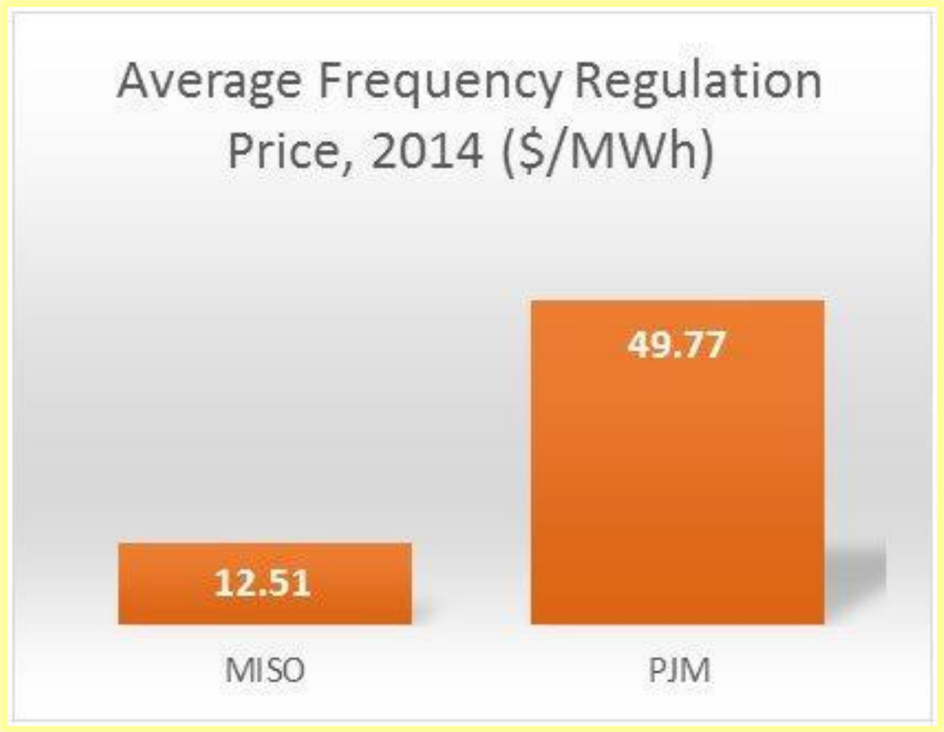
Example of PJM Regulation market



January 1, 2015



Comparison of Clearing Prices



Microgrid control issues

- IEEE standards
- Observations of dynamic behavior of microgrid

Microgrid control issues (IEEE 1547.4)

- Voltage stability
- Phase imbalance
- Small signal stability
- Fault current compensation
- Reconnection rules
  - Angle difference tolerances at reconnection

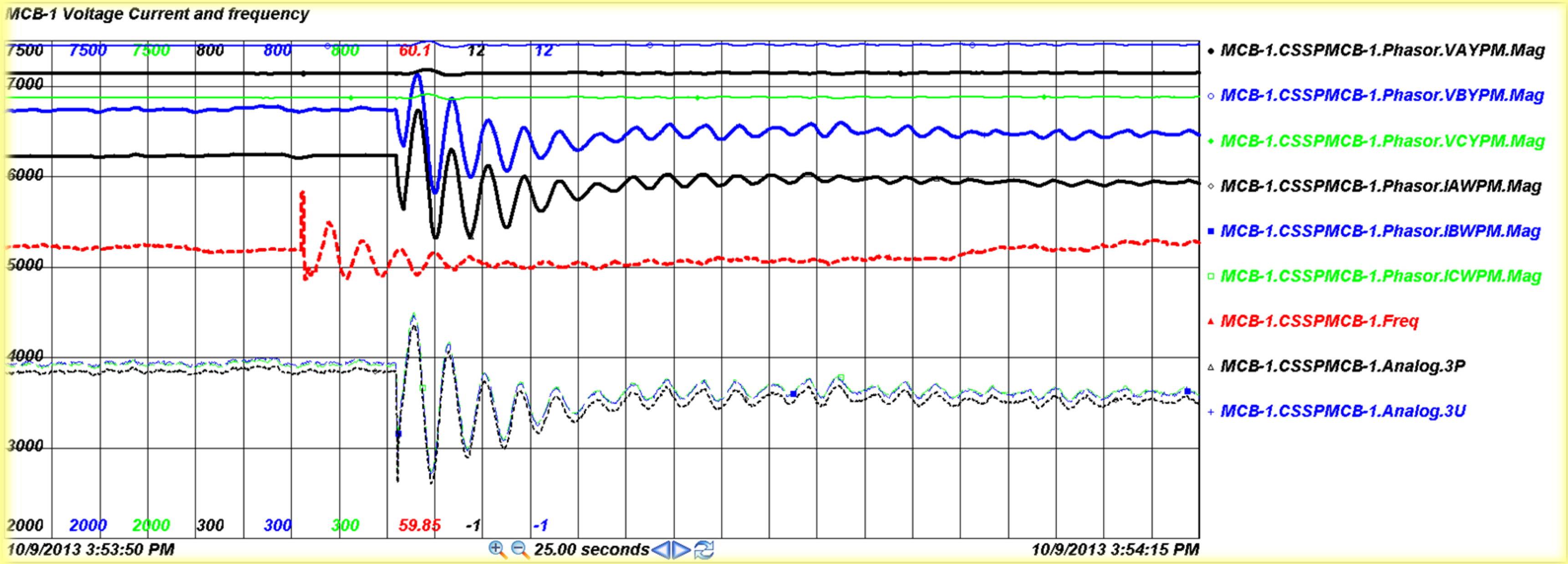
IEEE 2030.7 specifications

- Control of multiple DERs
- Control of the PCC
- Control of voltage and frequency in island mode
- Optimization of microgrid in island mode

Actual control issues

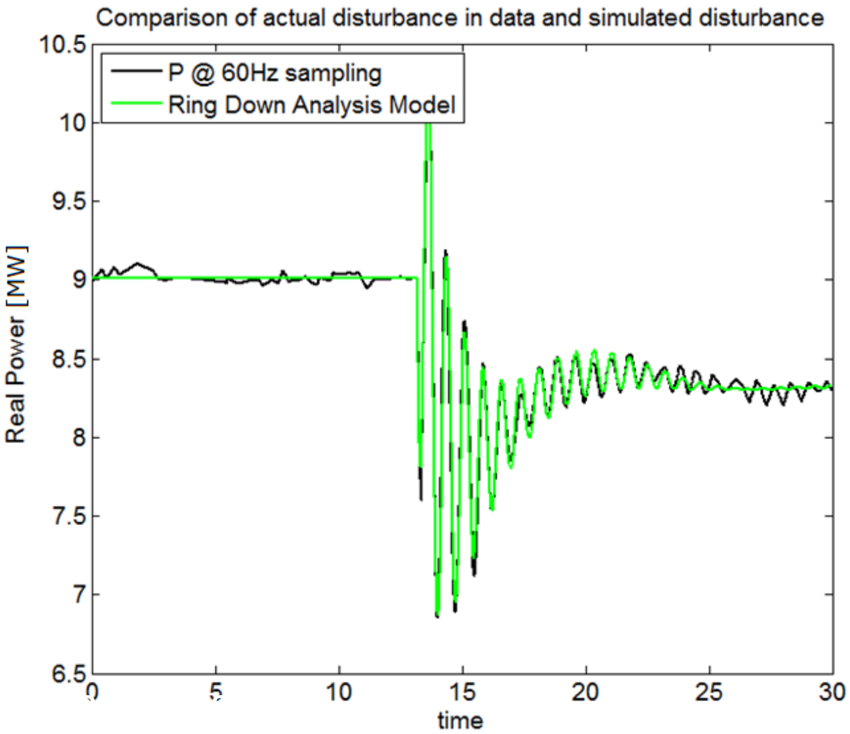
- Low inertia microgrids
  - Examples from UCSD (a large microgrid)
    - 42 MW peak
    - 30 MW internal CHP
    - 2 MW solar
    - 2.8 MW fuel cell
    - 2.5MW/5MWh battery
    - Three ~100 kW battery systems
    - 4 major internal substations and 17 12 kV feeders
    - 125 buildings

October 9, 2013



Oct. 9 UCSD microgrid event

Realization Algorithm




```
Fn = 0.094653 Hz, D = 0.450955, P = 3.208795%
Fn = 1.353568 Hz, D = 0.044507, P = 85.795740%
Fn = 1.461354 Hz, D = 0.026519, P = 10.995465%
```

UCSD

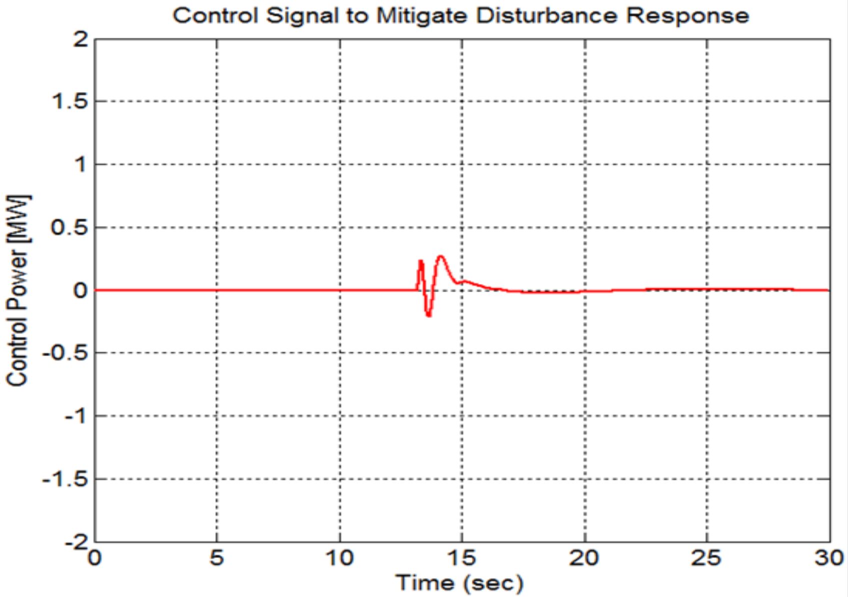
Mitigation of UCSD microgrid dynamics

UNIVERSITY OF CALIFORNIA, SAN DIEGO

Jacobs School of Engineering

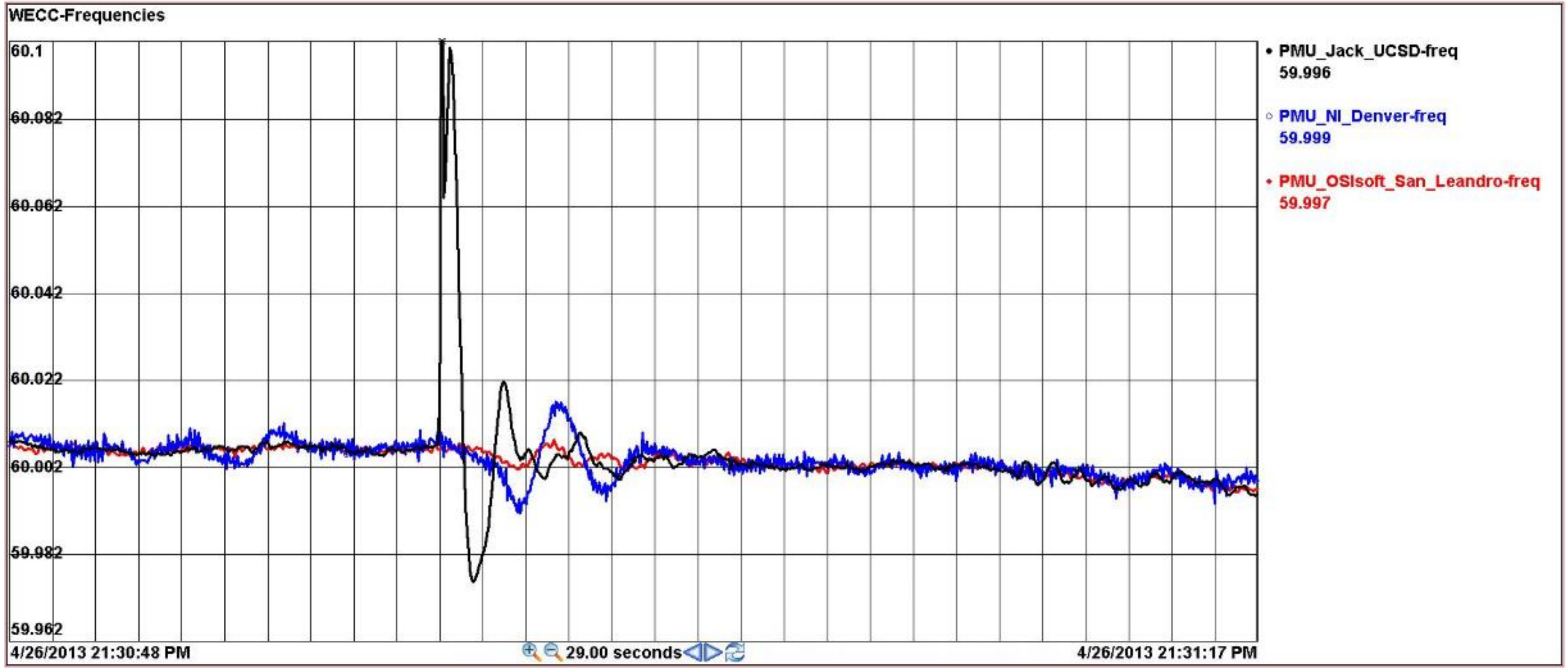
Effect of Control Algorithm:

- For comparison, control power plotted at same scale a disturbance in real power
- Disturbance almost +/- 2MW
- Control power only +/- 0.25MW for mitigation

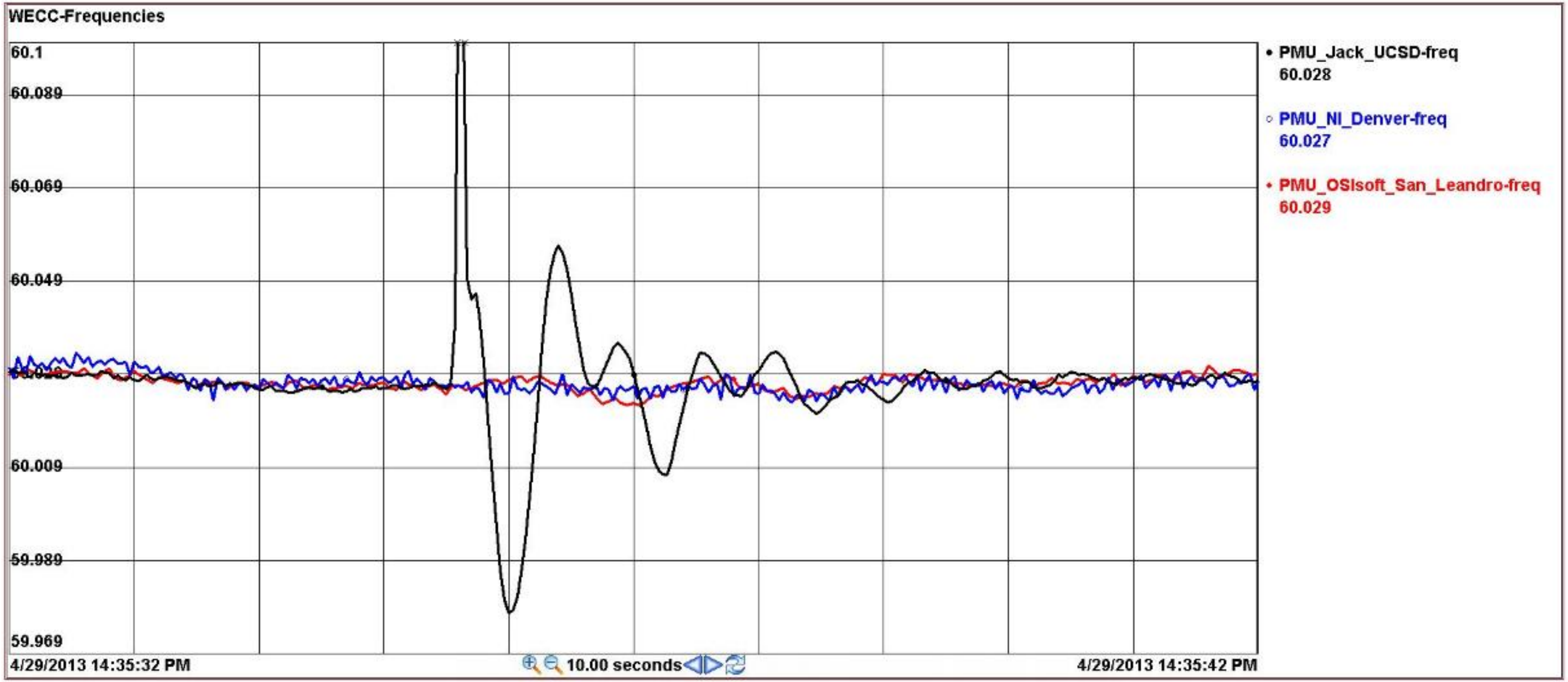


- Results scale with size of disturbance and increase of damping

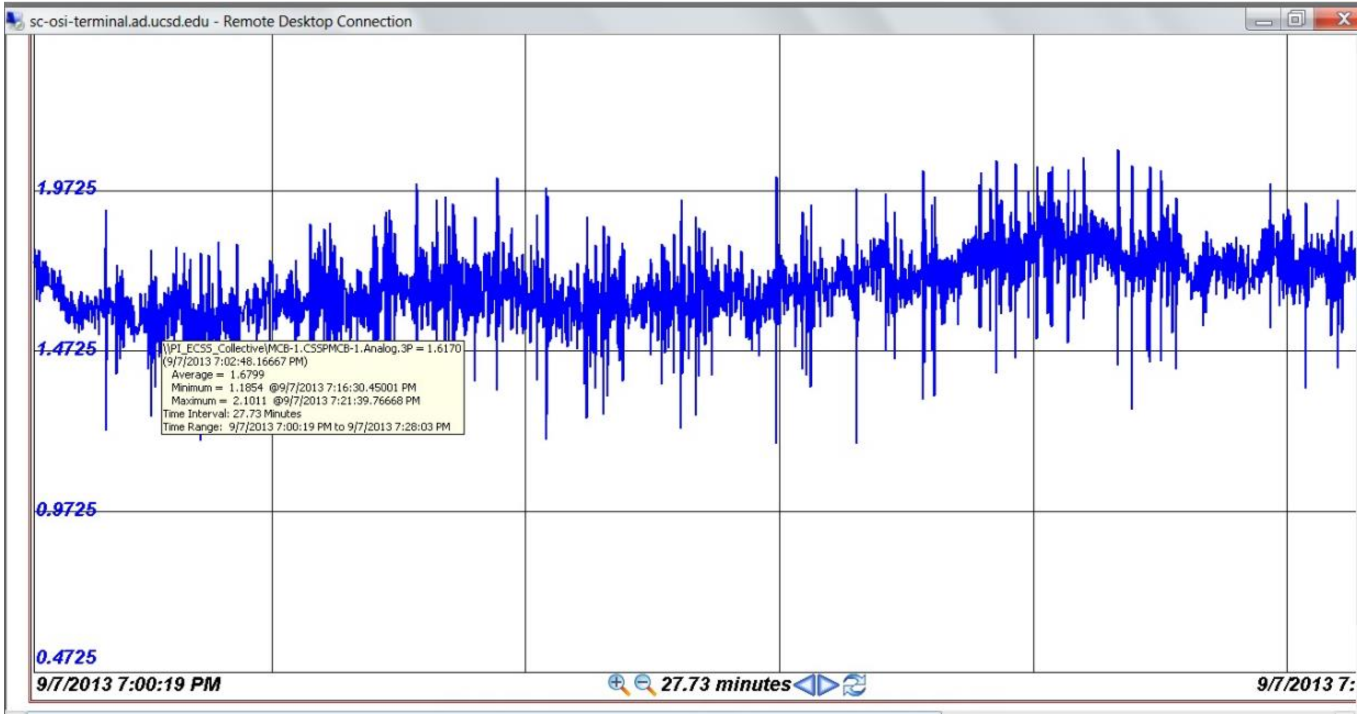
April 26, 2013



April 29, 2013



Swarms of Power Oscillations



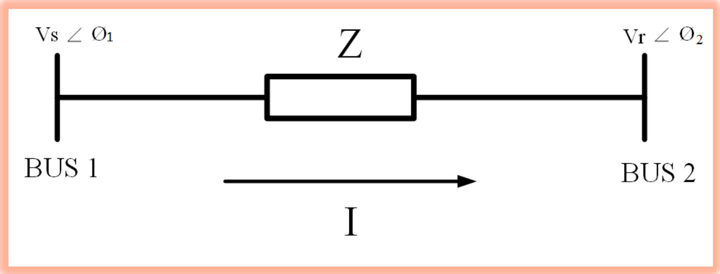
Conclusions

- Large microgrids have low inertia
- Fast disturbance mitigation might be required
- Voltage and frequency control should have fast dynamic response
- Distributed controls are required

Approaches to control

- Three levels of control
  - Decoupled control of DERs
  - Decoupled control of P and Q for the Microgrid
  - Optimizing control for ancillary services

Decoupling principle

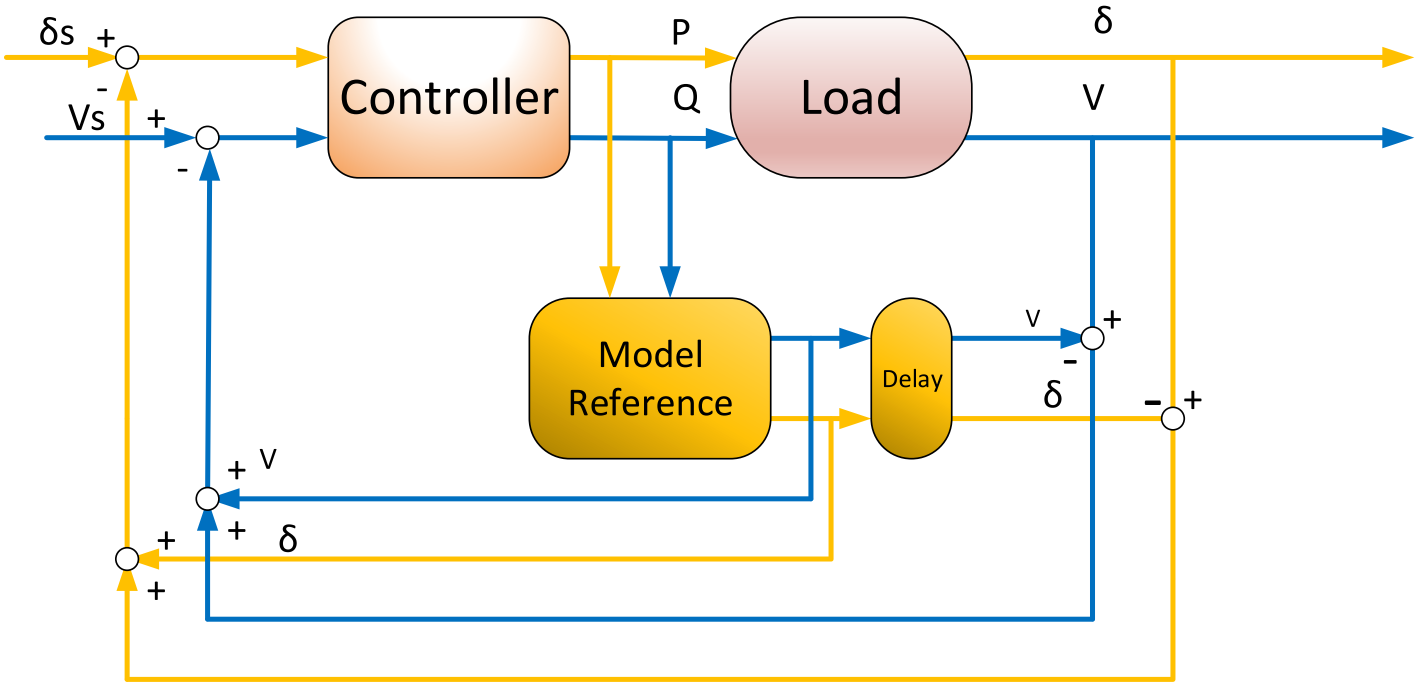


$$\bar{S} = \bar{V}_r I^*$$

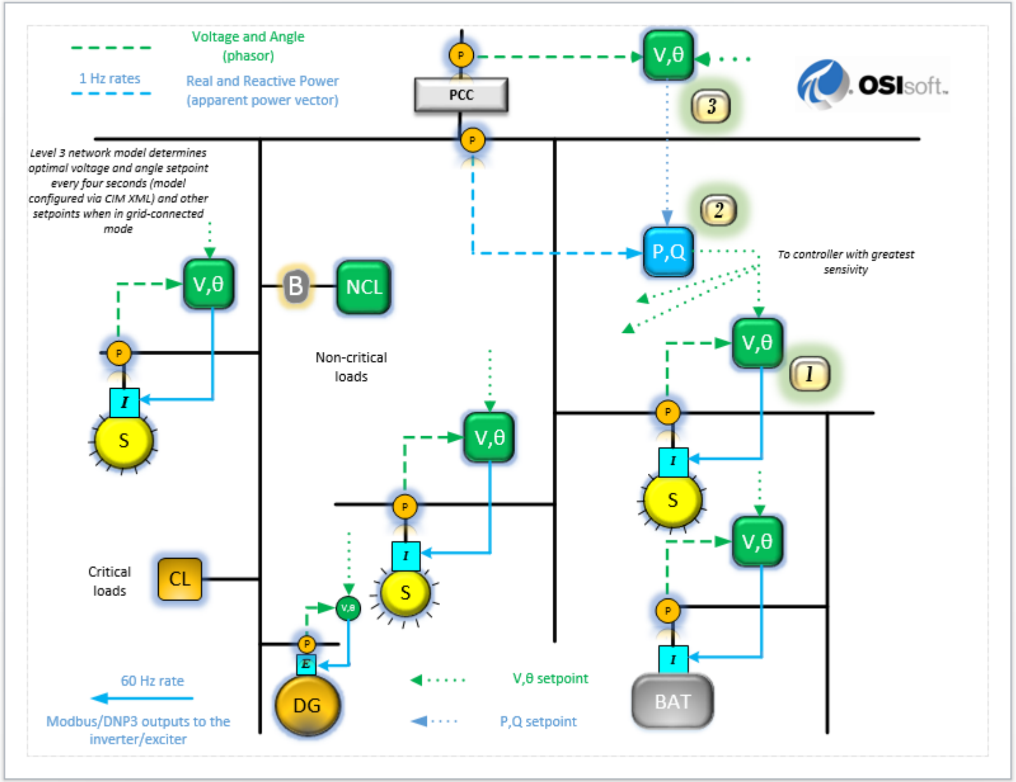
$$P = \frac{V_r V_s}{Z} \cos(\delta - \theta) + \frac{V_r^2}{Z} \cos(\theta) \qquad (1)$$

$$Q = \frac{V_r V_s}{Z} \sin(\delta - \theta) + \frac{V_r^2}{Z} \sin(\theta), \qquad (2)$$

One approach to decoupled control



Microgrid control system



Projects underway

- DOE-IIT-Bronzeville, ComEd
- CEC-Borrego Springs, SDGE
- CEC-Chemehuevi Reservation, UCR
- CEC-RM Winery, UCD
- CEC-John Muir Hospital, ChargeBliss
- CEC-Inverter testing Lab, SunSpec/UCSD
- CEC-Orange/San Diego, UCR

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THANK YOU

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