Synchrophasors at

OG&E

Austin White P.E.

Oklahoma Gas & Electric Company

IEEE PES GM 2016

IEEE PES Power & Energy Society®

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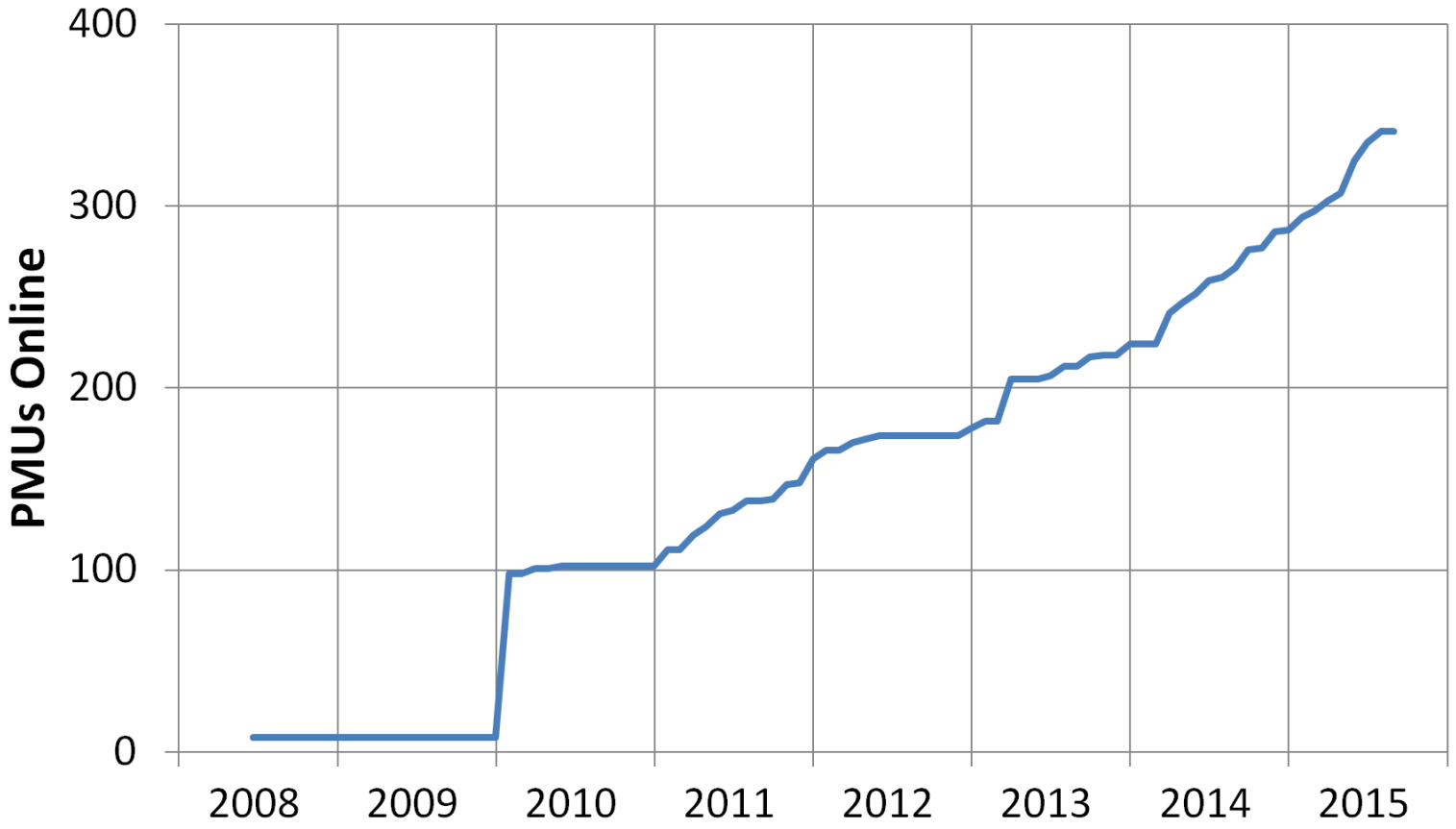
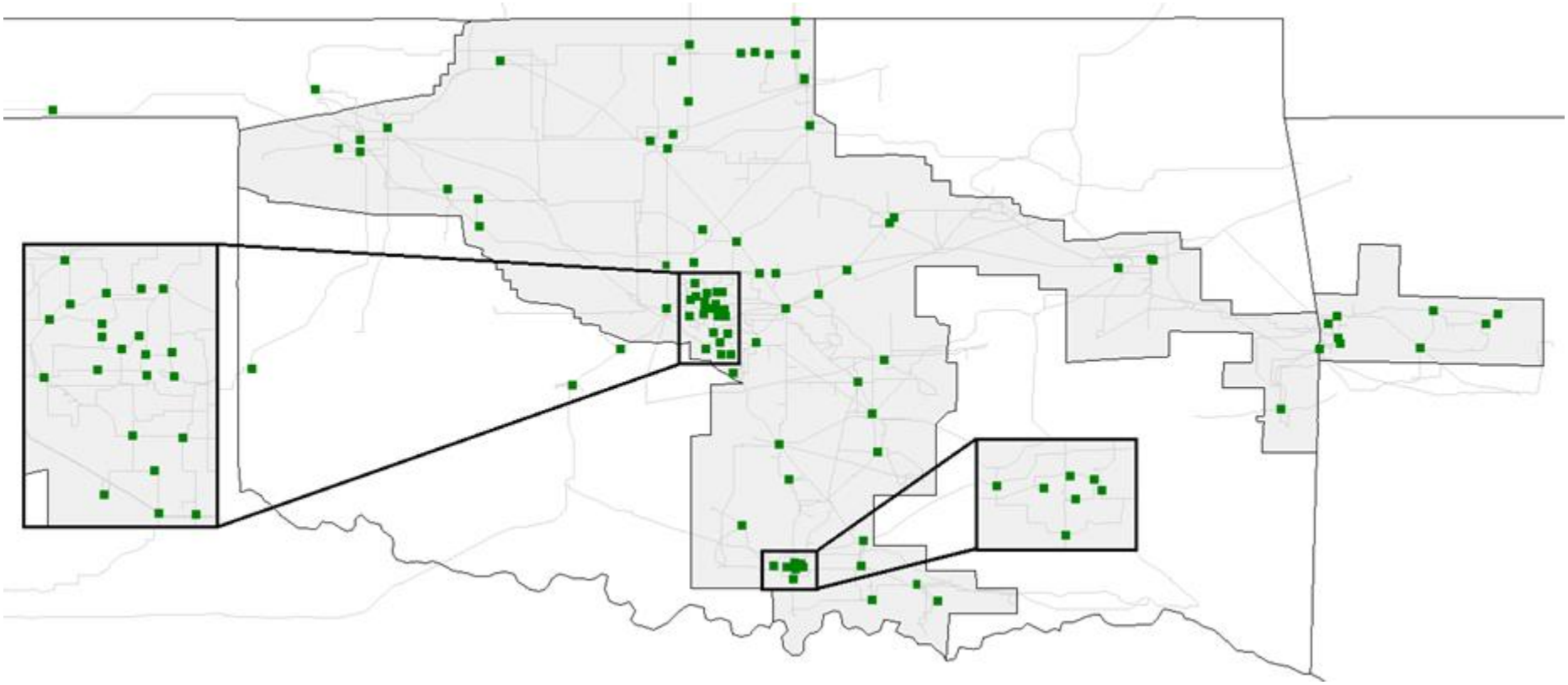
Outline

- OG&E Background
- Synchrophasor Applications
- Example Events
- Synchrophasor Based Protection
- Renewables Integration

PMU Deployment 2008-2015

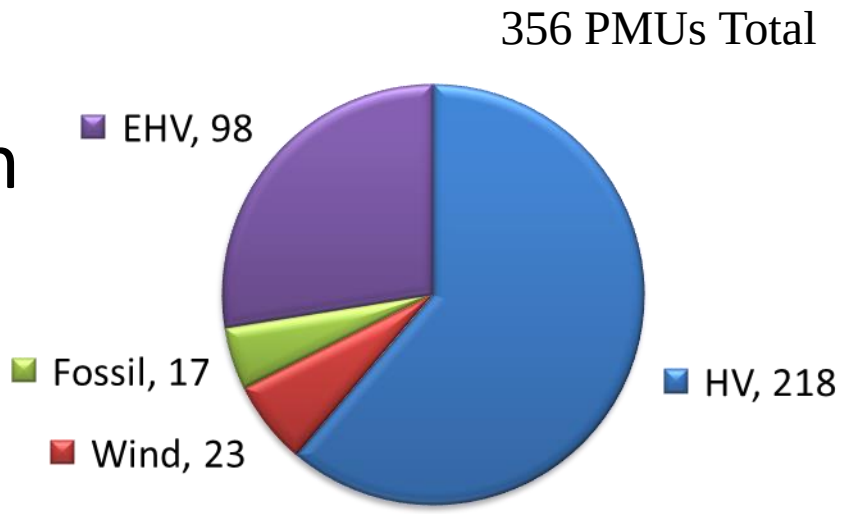


PMU Locations

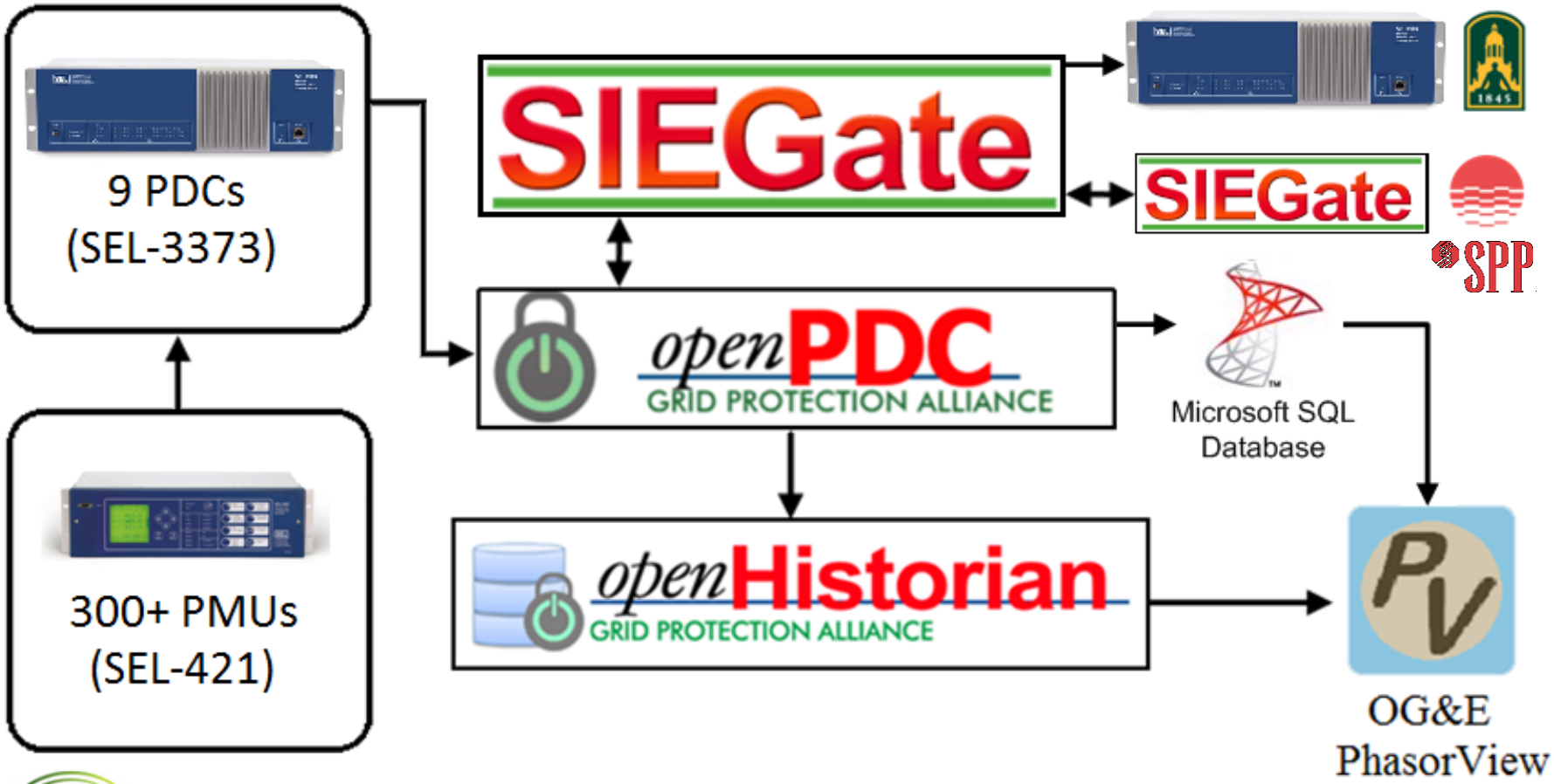


PMU Coverage Stats

- 100% of EHV System
  - 79 Line Terminals, 19 Autotransformers
- 100% of Wind Farms
  - 4053MW, 23 Plants
- 90% of Fossil Generation
  - 6200MW, 17 Units
- 37% of HV System
  - 218 Line Terminals



Simplified Architecture



Large Deployment Challenges

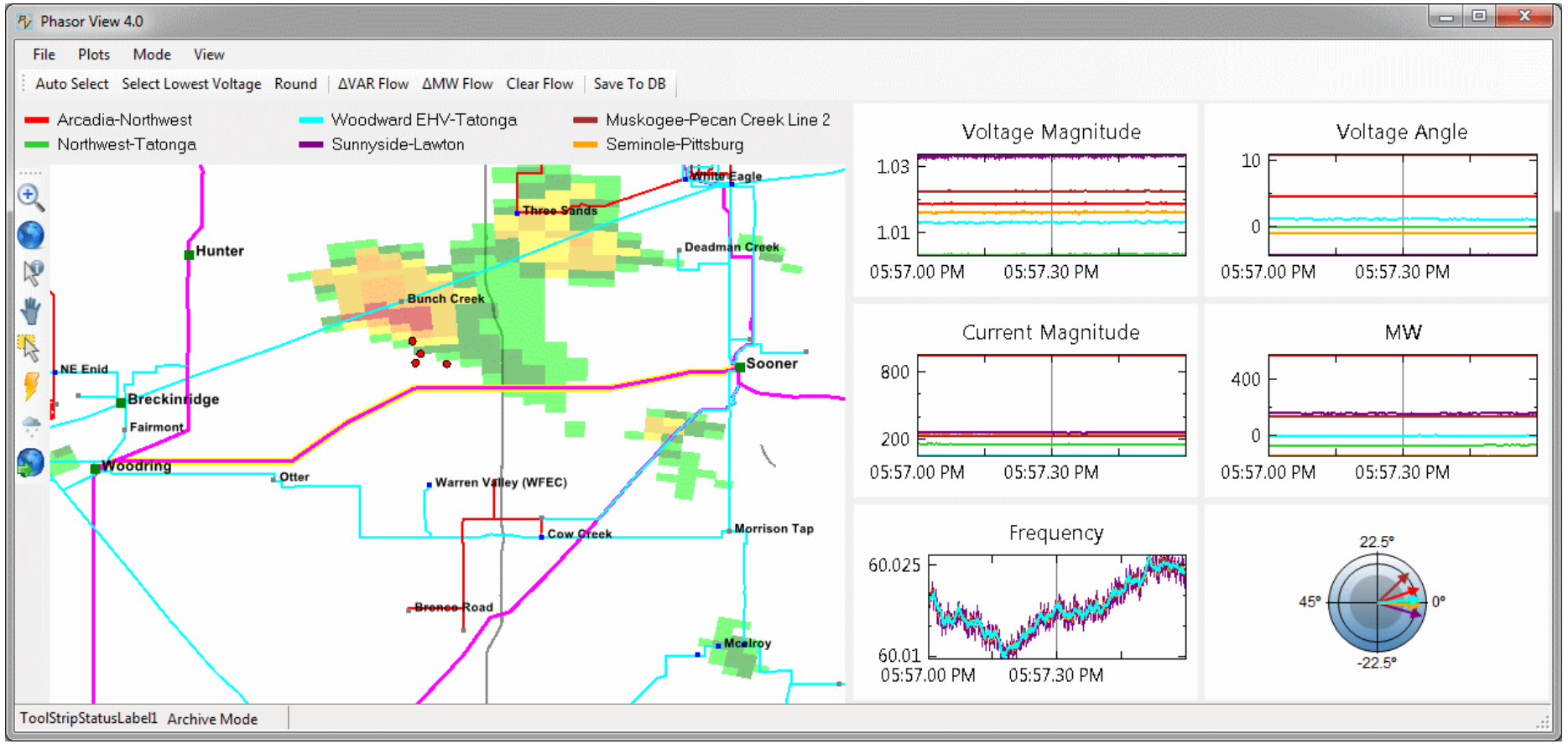
- Protocols – C37.118 limited to ~150 PMUs, no security, frame based
- Performance – PDC limits are CPU burden starting at ~300 PMUs
- Data Storage – 350 PMUs, positive sequence need 15GB/day comp, 50GB uncompressed
- Network Bandwidth – Circuit needs 64kbps per PMU, no data caps, low latency

Research Partners

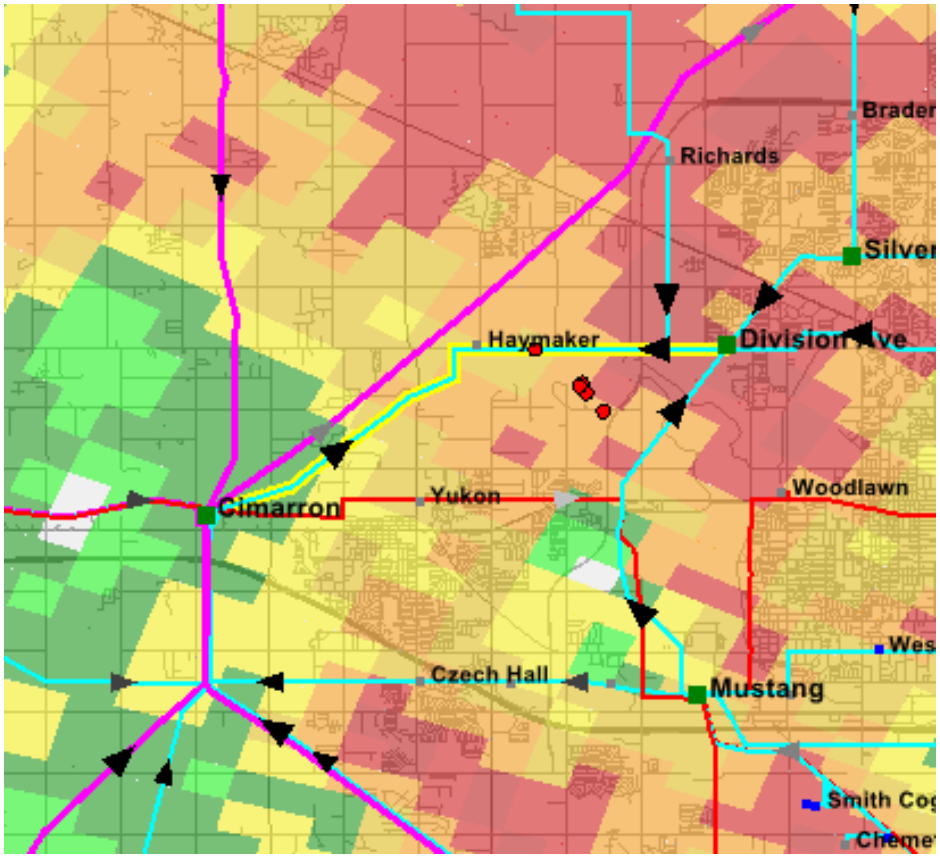
Synchrophasor Applications

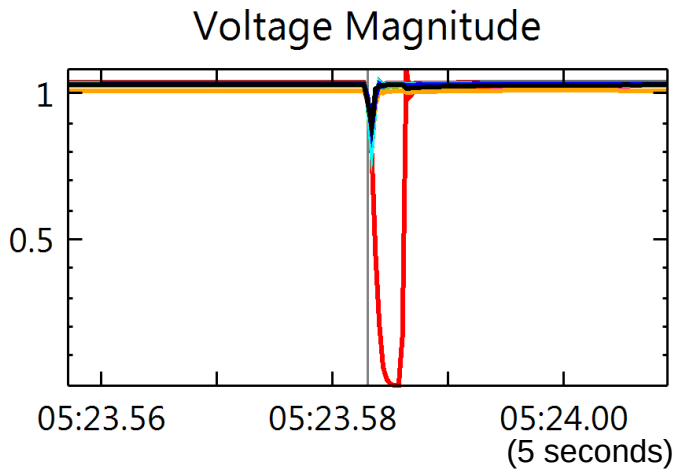
- Situational Awareness
- Disturbance/Misoperation Analysis
- State Estimator Enhancement and LSE
- Voltage Recovery Assessment (reactive reserves, FIDVR)
- Proactively Find Equipment Problems
- Stability Assessment
- Renewables Integration/Monitoring

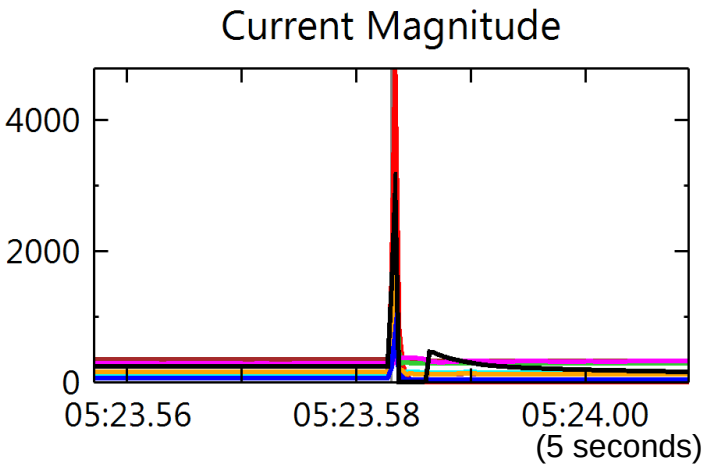
Situational Awareness



Disturbance/Fault Location

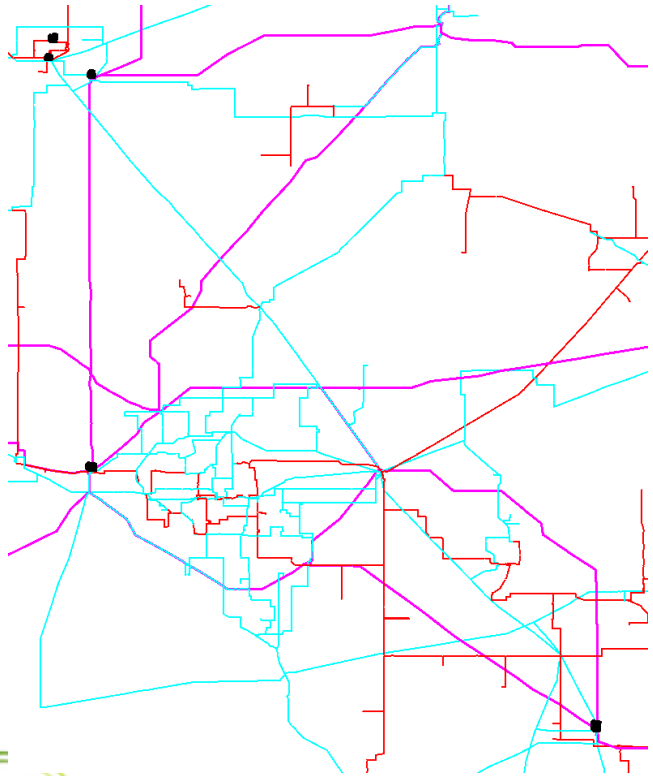


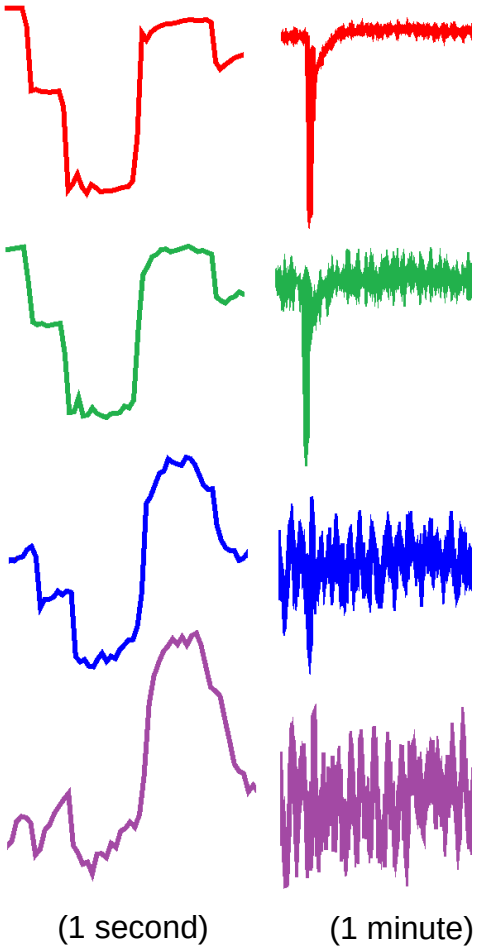




Fault Visibility

- 0.7 Second, 12.5kV Distribution Fault





(69 KV 3 Miles Away)
Delta Volts 2.1%

(138 KV 8 Miles Away)
Delta Volts 0.7%

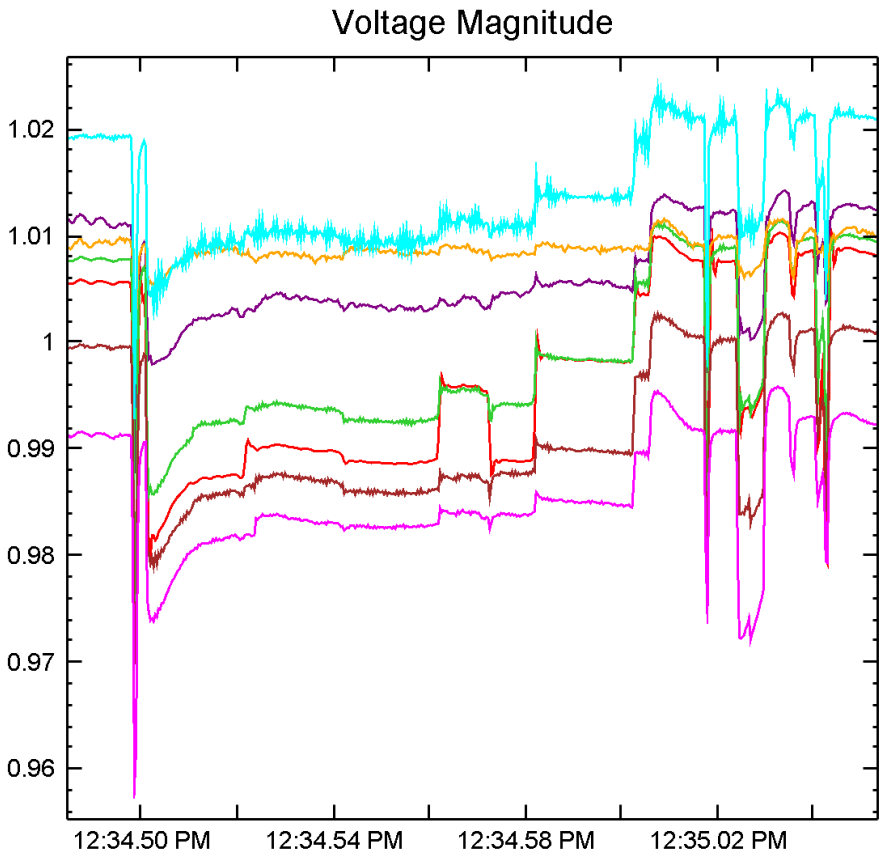
(345 KV 65 Miles Away)
Delta Volts 0.06%

(345 KV 140 Miles Away)
Delta Volts 0.02%

(1 second) (1 minute)

Long Duration Fault Events

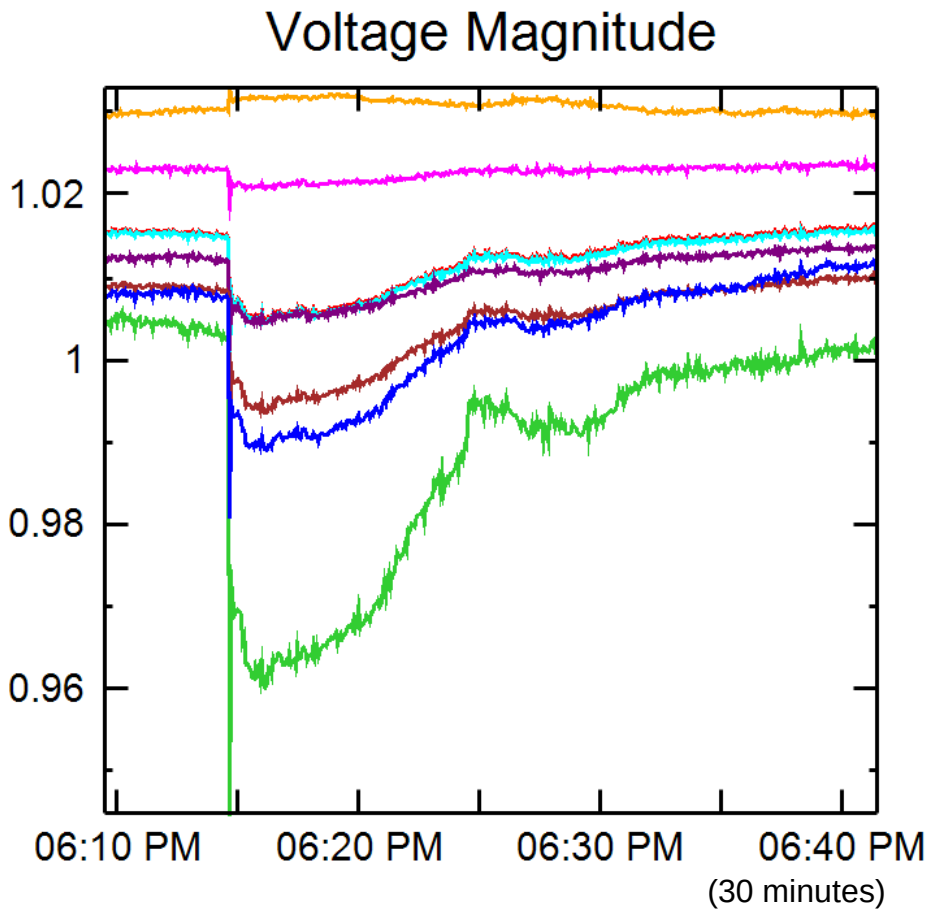
- EM Relay failed to detect a permanent ground fault (problem with polarizing CT circuit)
- Took 19 breakers to remotely clear fault.
- Finally cleared when the fault went phase to phase
- 32,000 Customers effected
- 2hr 17min restore time
- 4.38 Million CMI
- Continuous recording needed!



(16 seconds)

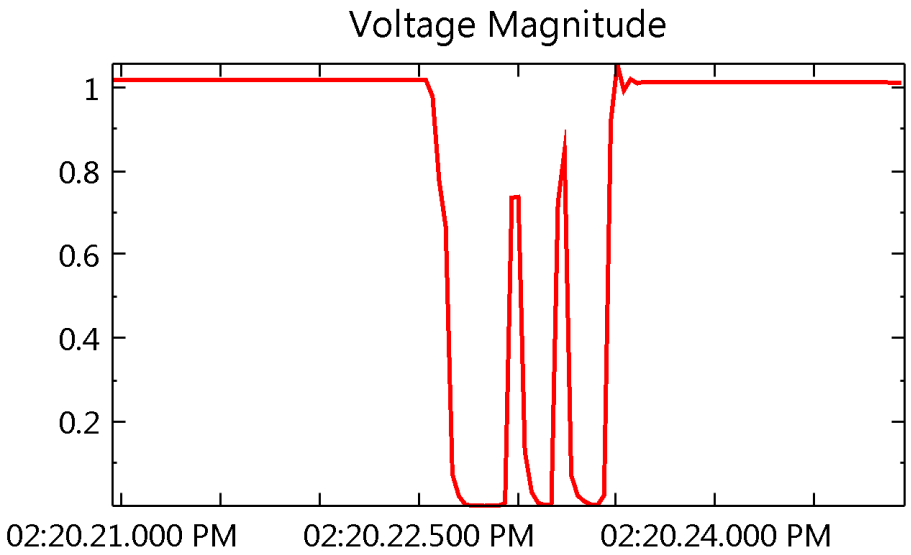
Voltage Recovery Assessment

- 6/11/2009 – A 520MW generator tripped on SPS system in the Texas Panhandle (Tolk)
- Caused low voltage in southern Oklahoma, which involved multiple transmission owners
- Loss of generation was over 300 miles away



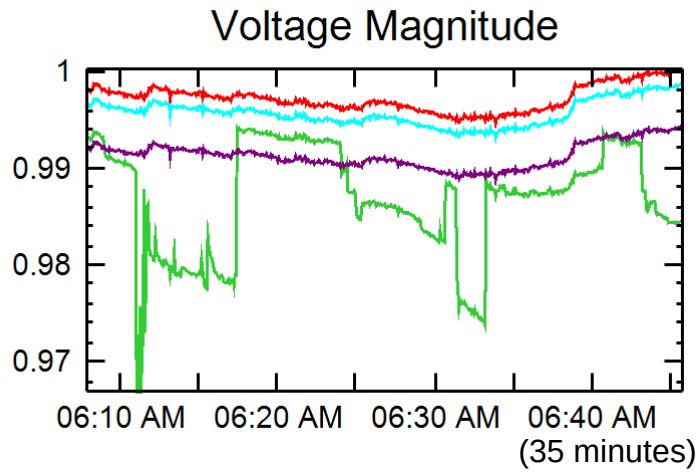
Failed EHV Reclosing Attempt

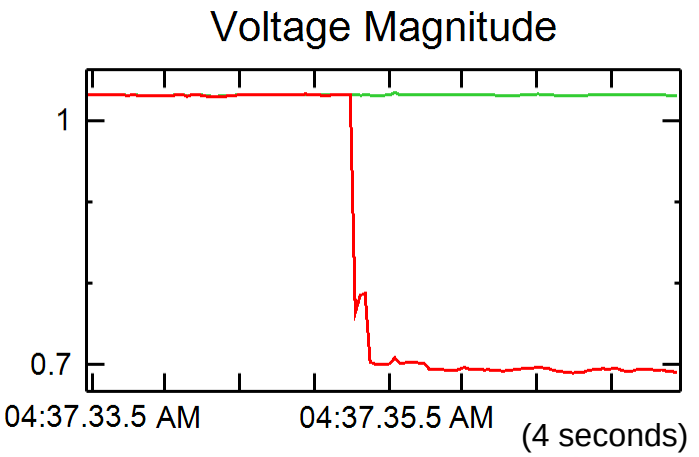
- Observed an unusual reclosing event following a fault on a 345kV line
- Able to diagnose multiple reclose attempts when only one reclose was expected
- Recent construction work changed the configuration
- Found that relay settings were not properly updated



Discovery of Failing Equipment

- Discovered many loose connections in the potential circuits at fuses or terminal blocks
- This has caused misoperations in the past (relays get confused)
- Proactively finding these helps prevent future outages and misoperations





PT Problem Report

- Our daily PT Problem report performs a dV/dT to help identify abnormal voltage fluctuations

PT Problem Report

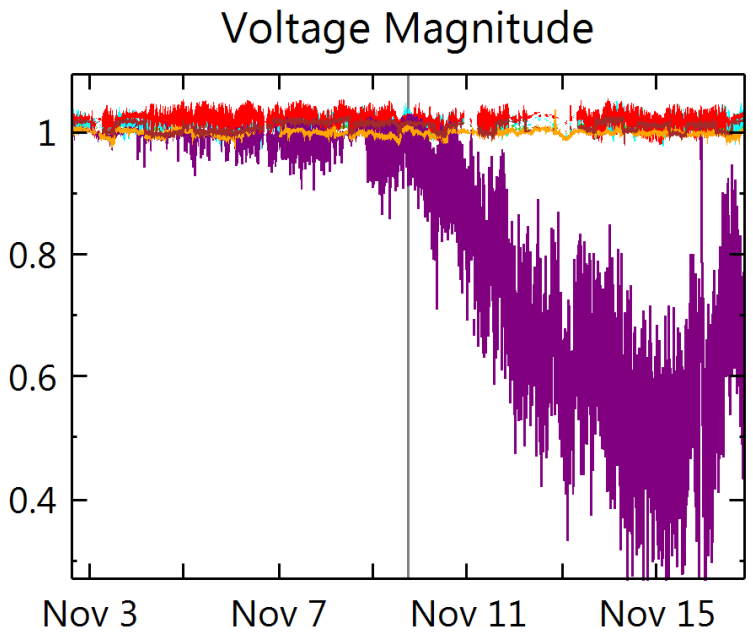
PhasorServer@oge.com

This message may contain extra line breaks.

Sent: Thu 11/17/2011 7:05 AM

To:

6 - Cimarron-Draper
5 - Cimarron-Minco
5 - Cimarron-Northwest
181093 - Cimarron-Woodring
1 - Cimarron-Cornville
1 - Cimarron-Division
1 - Cimarron-El Reno

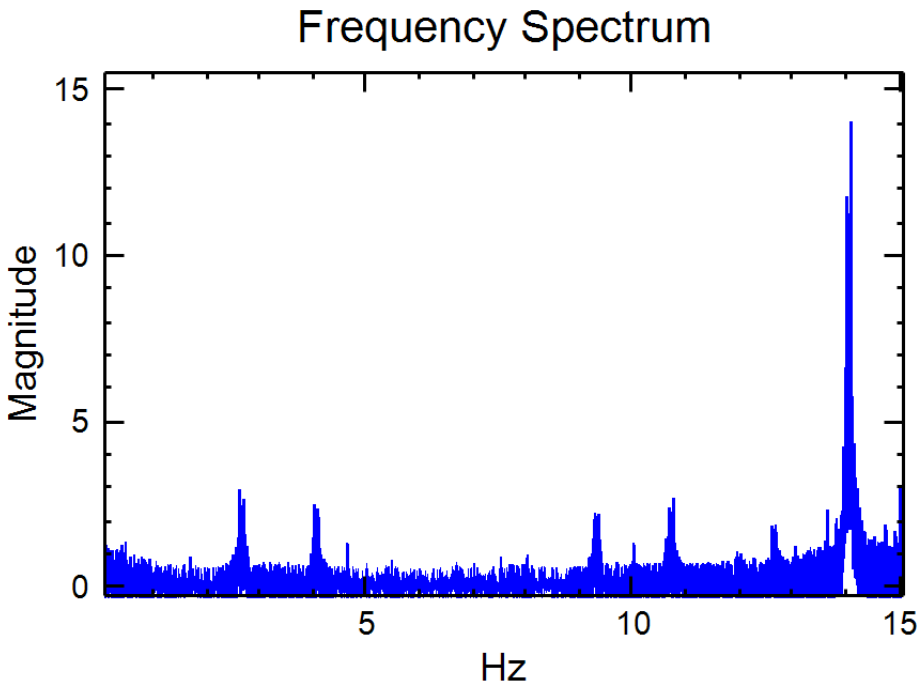


(2 weeks)

Failing analog input

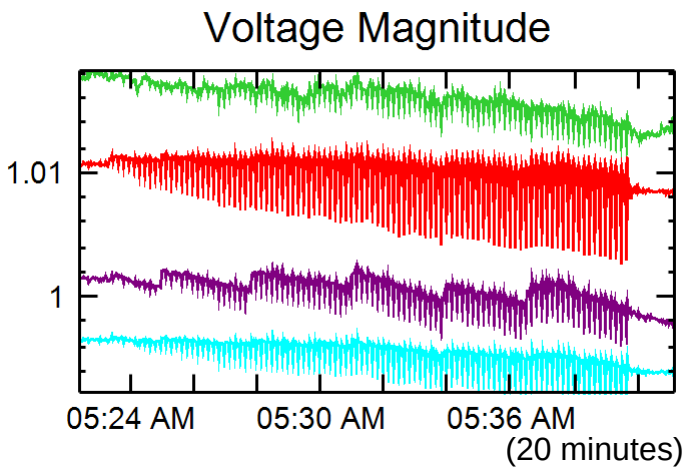
Stability Assessment - FFT

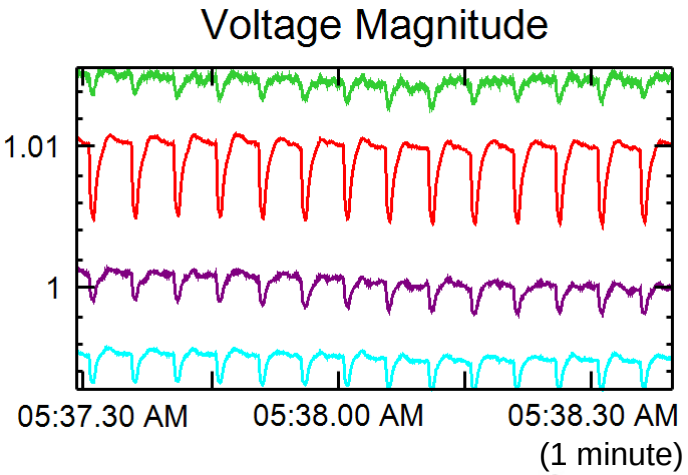
- FFT algorithm used to detect oscillations
- Sends email or text message when the oscillations reach an objectionable level
- This wind farm PMU shows many undesirable components, the worst at 14Hz



Stability Assessment - Redbud Oscillations

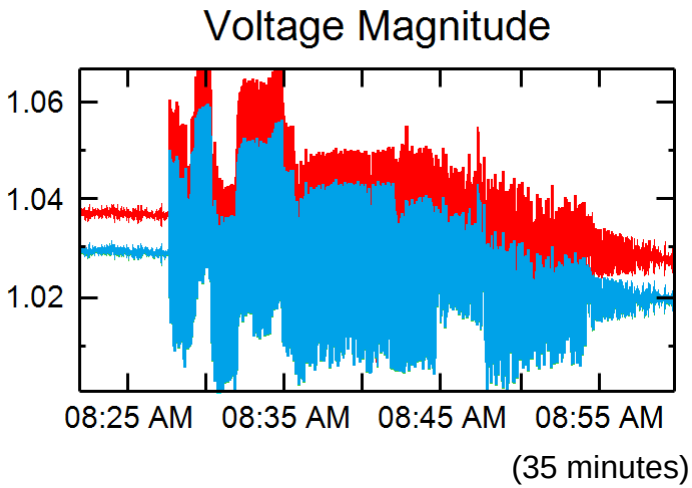
- Discovered voltage oscillations on EHV system (0.2Hz)
- Signal is most pronounced on the MVAR plot
- Suspected a generation problem
- Determined to be a problem with Redbud Unit 4 when in VAR control mode
- VAR control mode used during unit startup, oscillations stop when operator switches to voltage control scheme

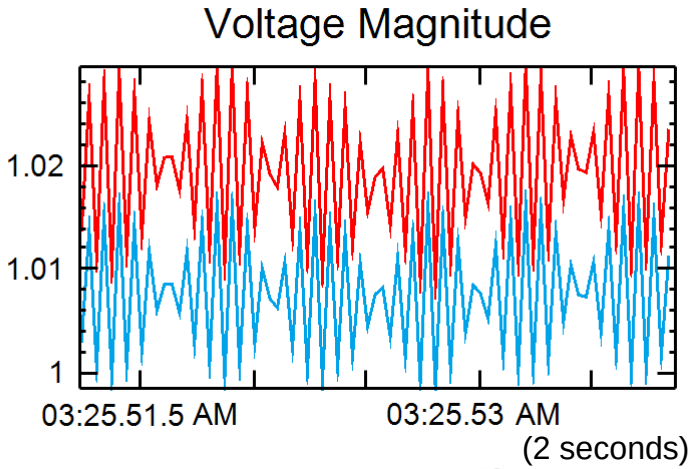




Wind Farm Oscillations

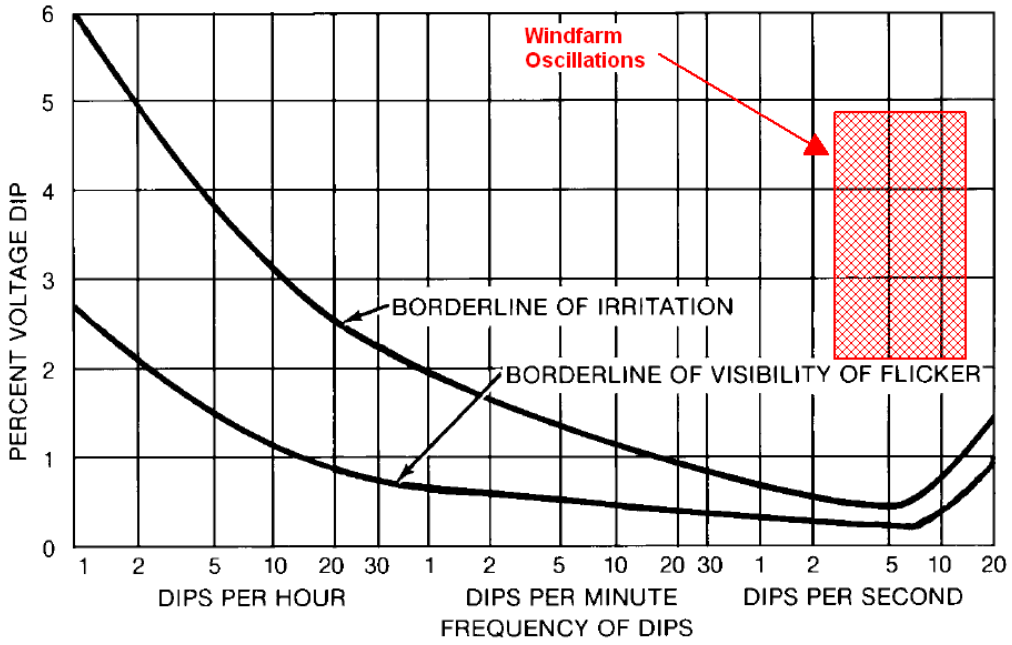
- Only during high winds
- FFT analysis shows 13-14Hz
- Voltage fluctuations as high as 5%
- Interaction between wind farms?
- Switching performed to electrically isolate the wind farms
- Determined it was a problem at different wind farms with the same turbine model
- The only solution was to curtail output





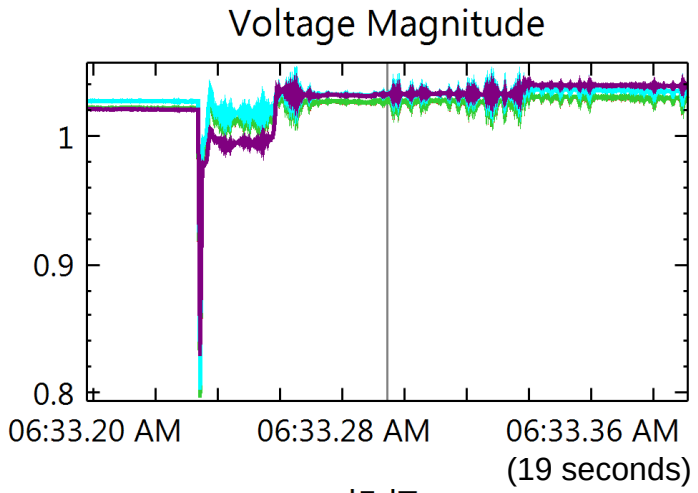
Customer Impact

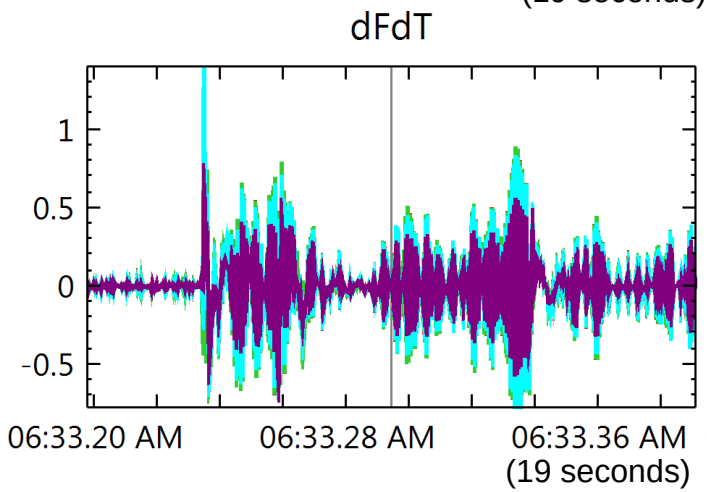
- Using IEEE 141, the oscillations were well into the objectionable flicker zone
- Called the Woodward service center to ask if they could see the lights flickering
- They confirmed visible flicker and noted numerous customer complaints
- We successfully worked with the manufacturer to resolve the issue



Sensitivity to System Changes

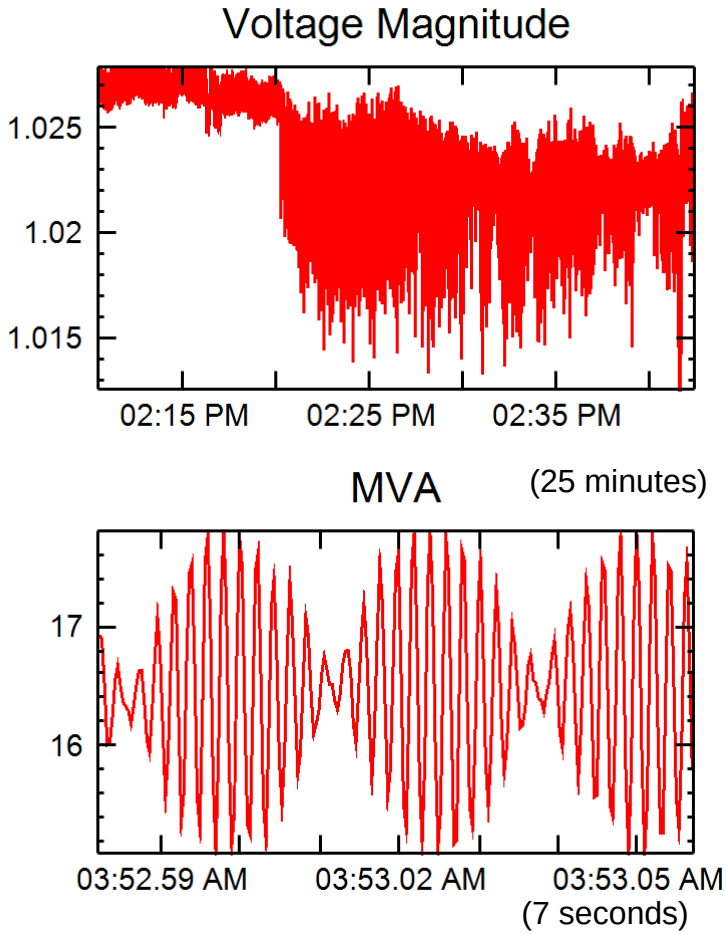
- One line was out of service for maintenance
- Fault on another line started the oscillations
- Had to curtail output to stop oscillations
- Shows wind farm sensitivity to system impedance changes



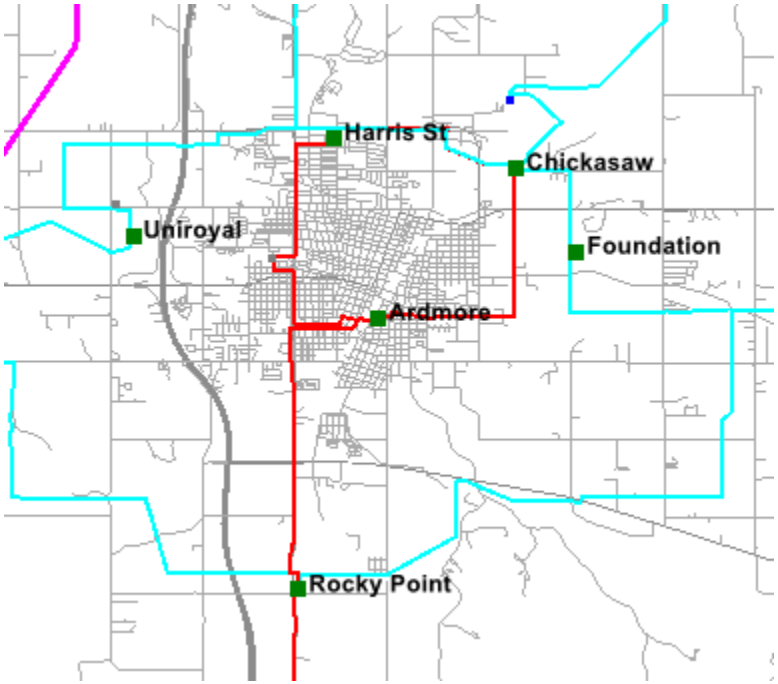


Monitoring Power Quality

- It has been observed that large loads inject noise onto the system
- Large refineries and arc furnaces are the worst offenders
- Synchrophasors allow for real time power quality monitoring

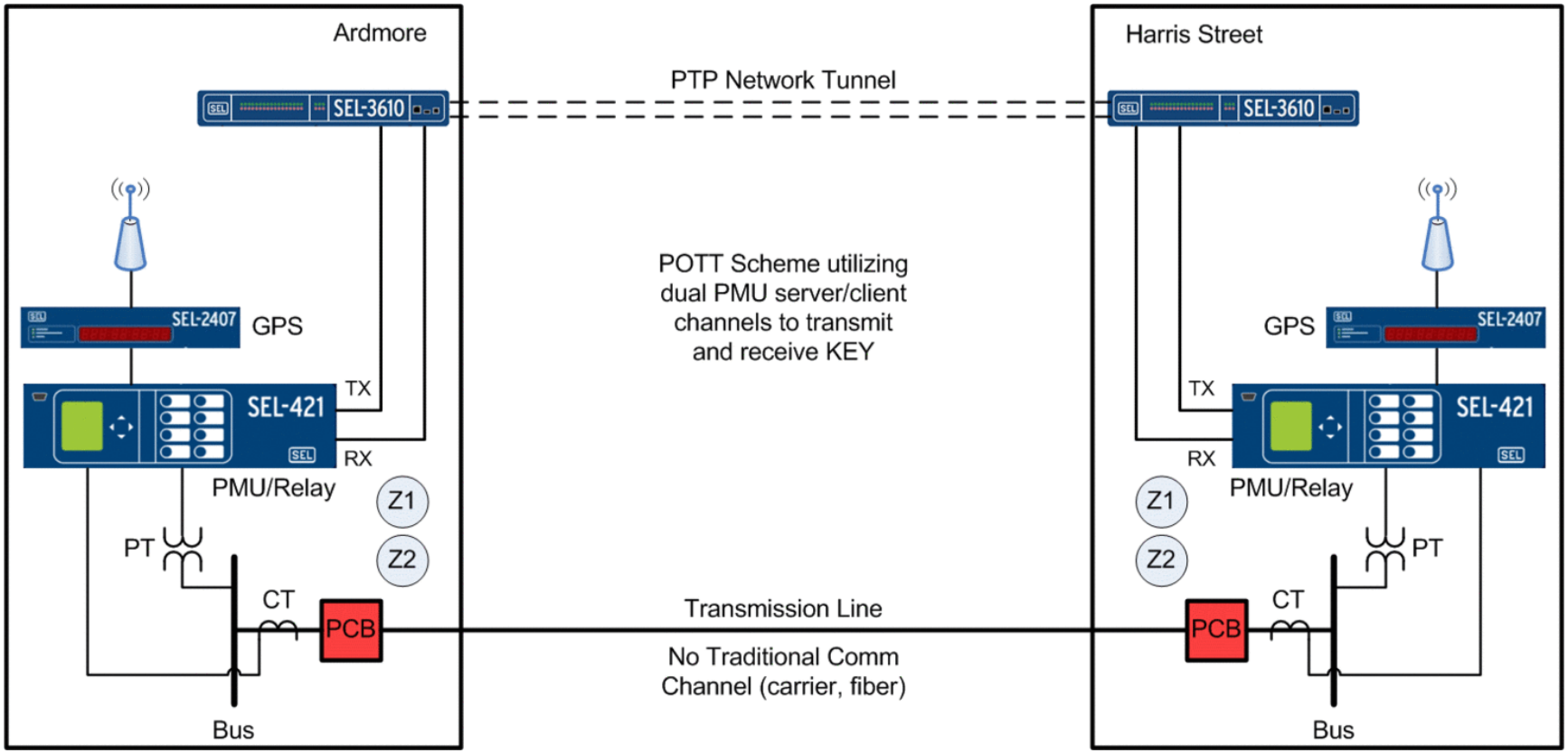


PMU Assisted Tripping

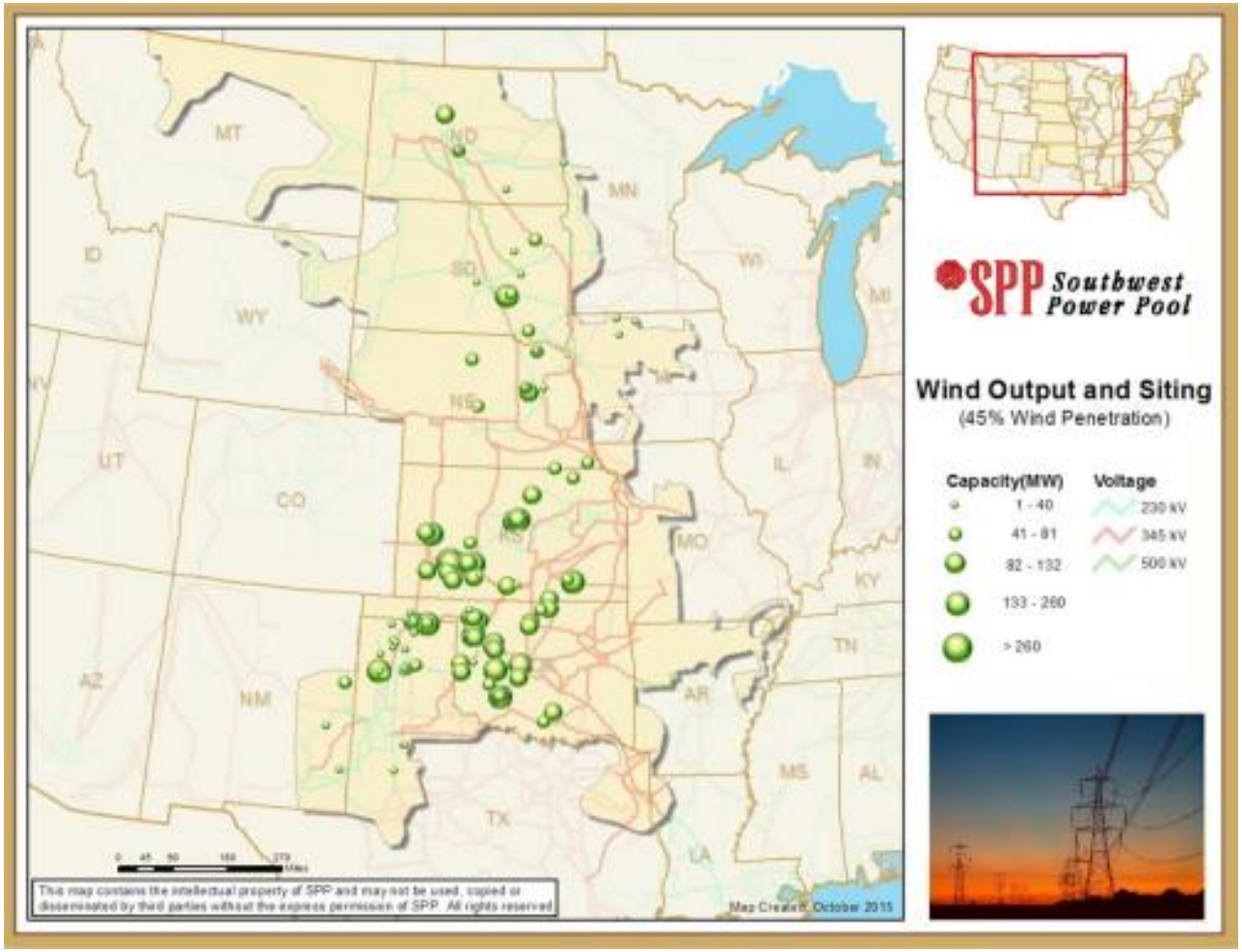


- 69kV loop around Ardmore, OK
- Sensitive Industrial customers
- No traditional carrier/fiber tripping (0.5 sec step distance)
- Network available
- New relays available
- Why not use synchrophasors to speed up tripping 5x?

PMU Assisted Tripping

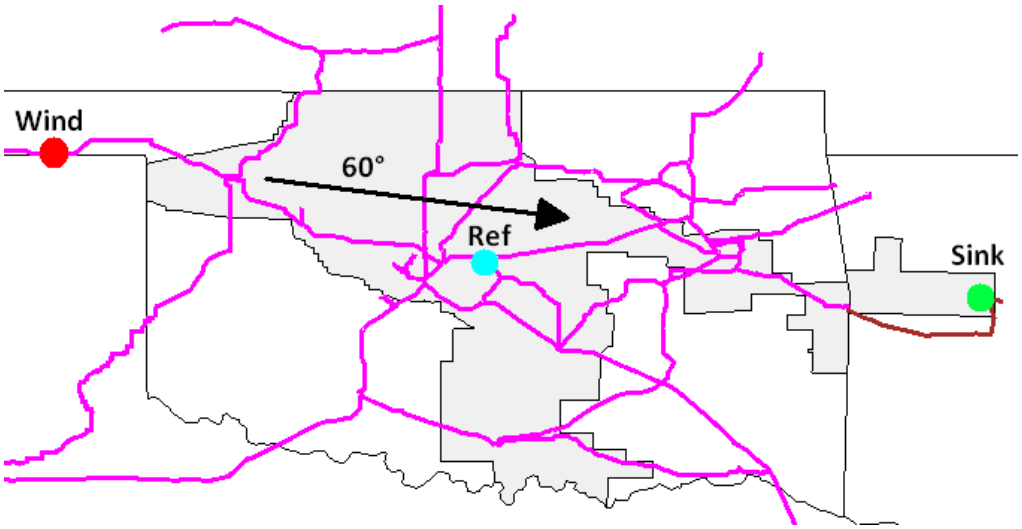


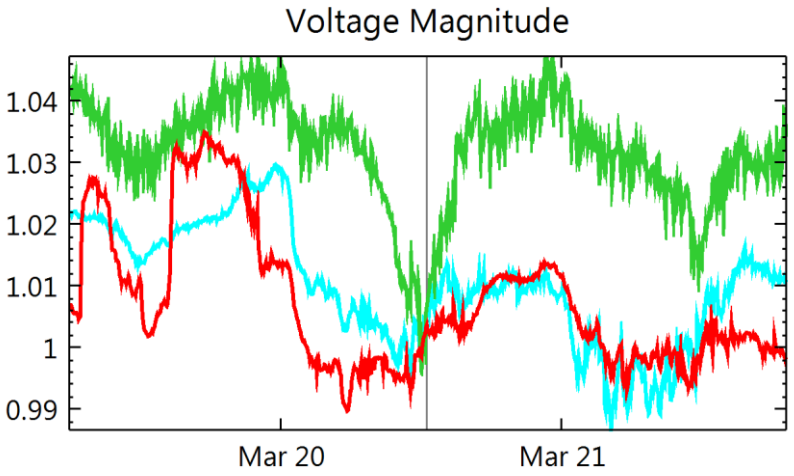
Wind Resources in SPP

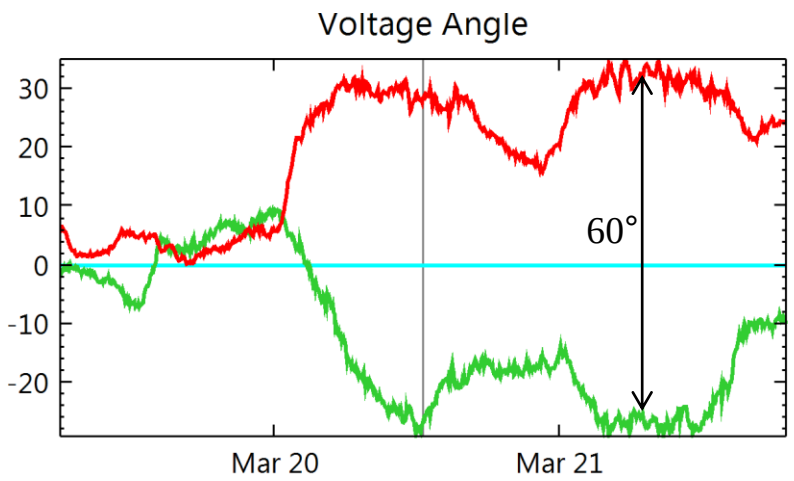


OG&E Wind Penetration > 4000MW

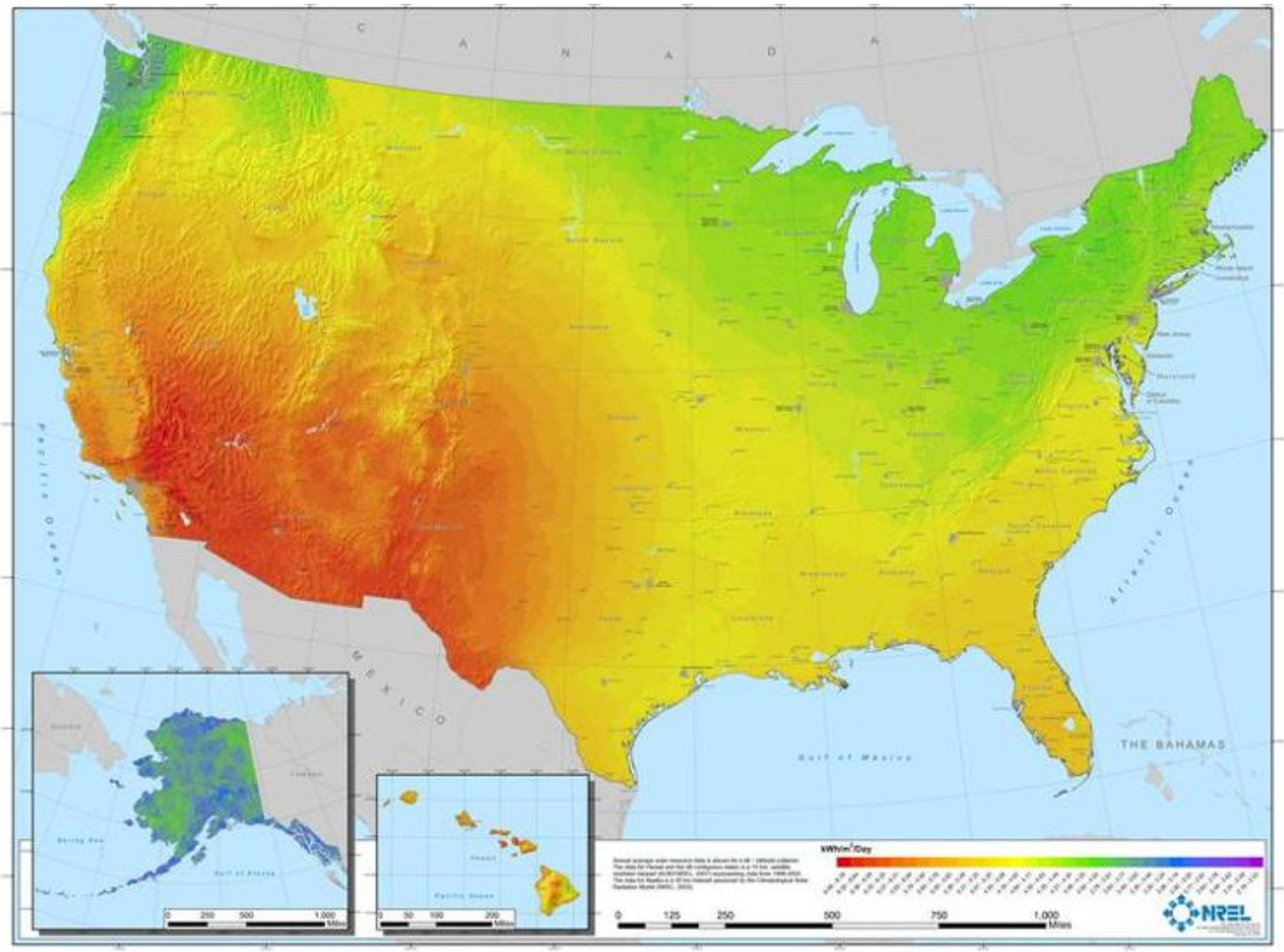
- SPP record peak of 45% and 10,783MW on 3/21/2016
- 60° angle spread across OG&E from west to east





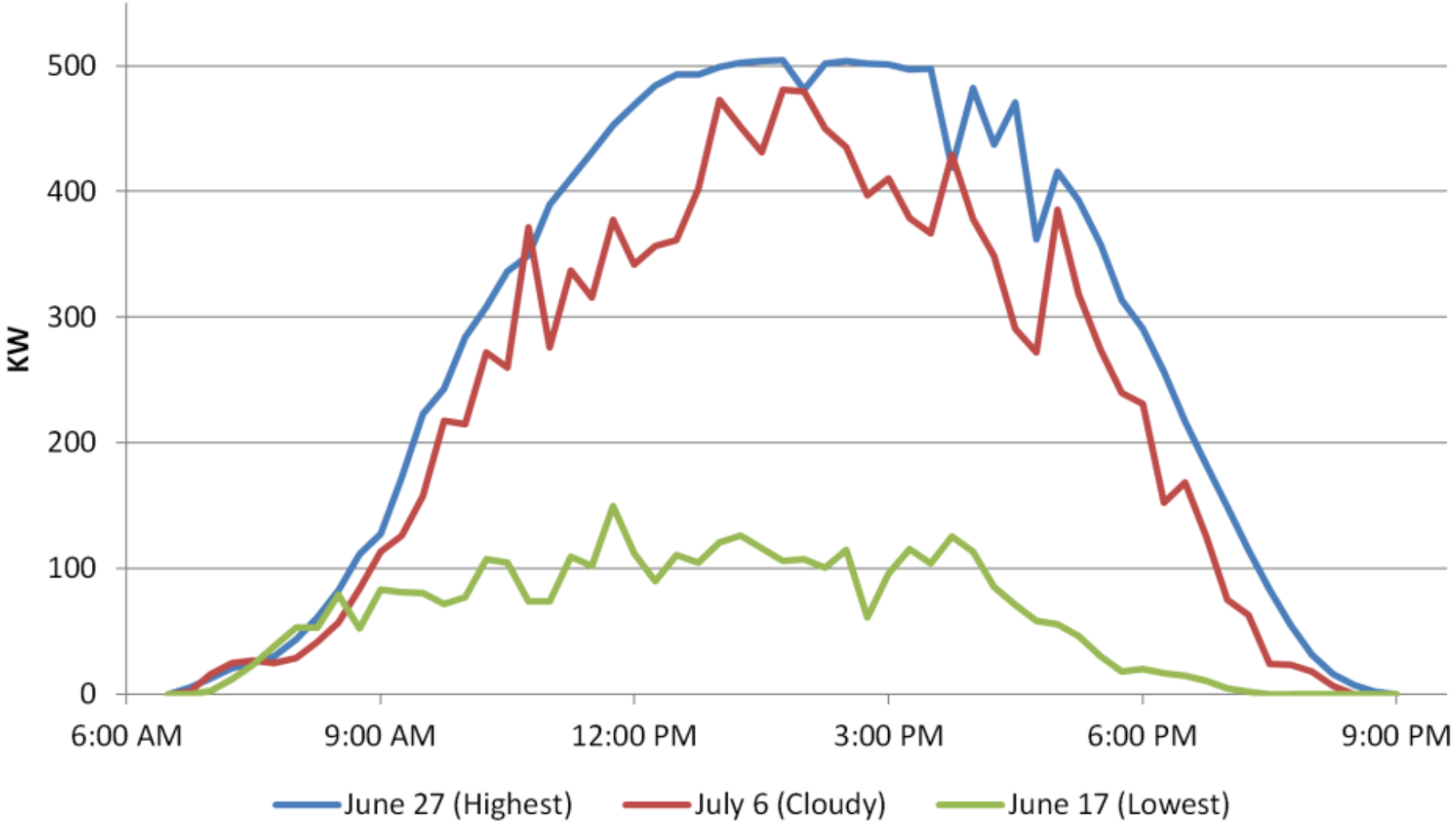


Oklahoma Ranks #7 in Solar Potential

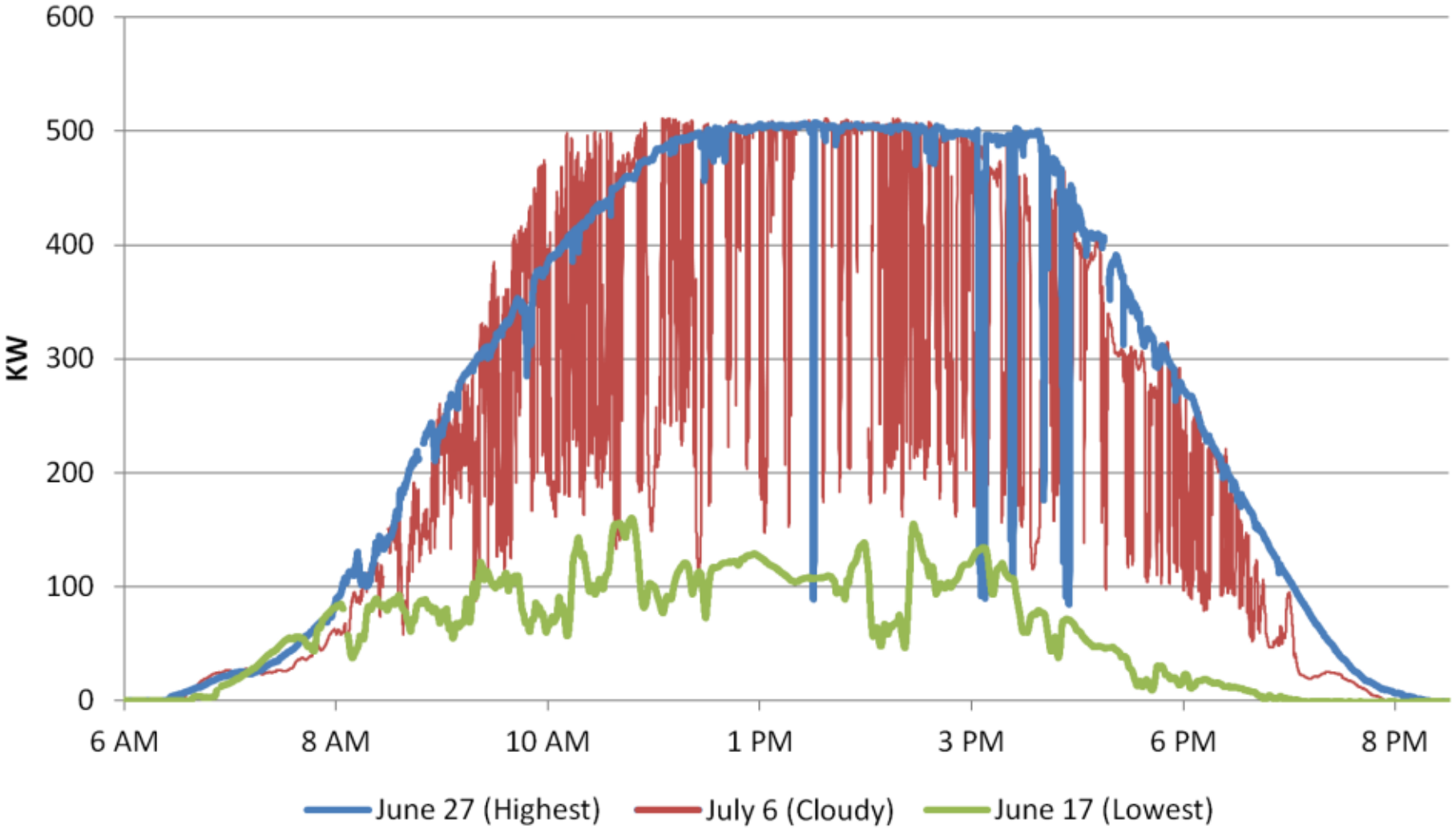


Utility Scale Solar 2.5MW Pilot at Mustang

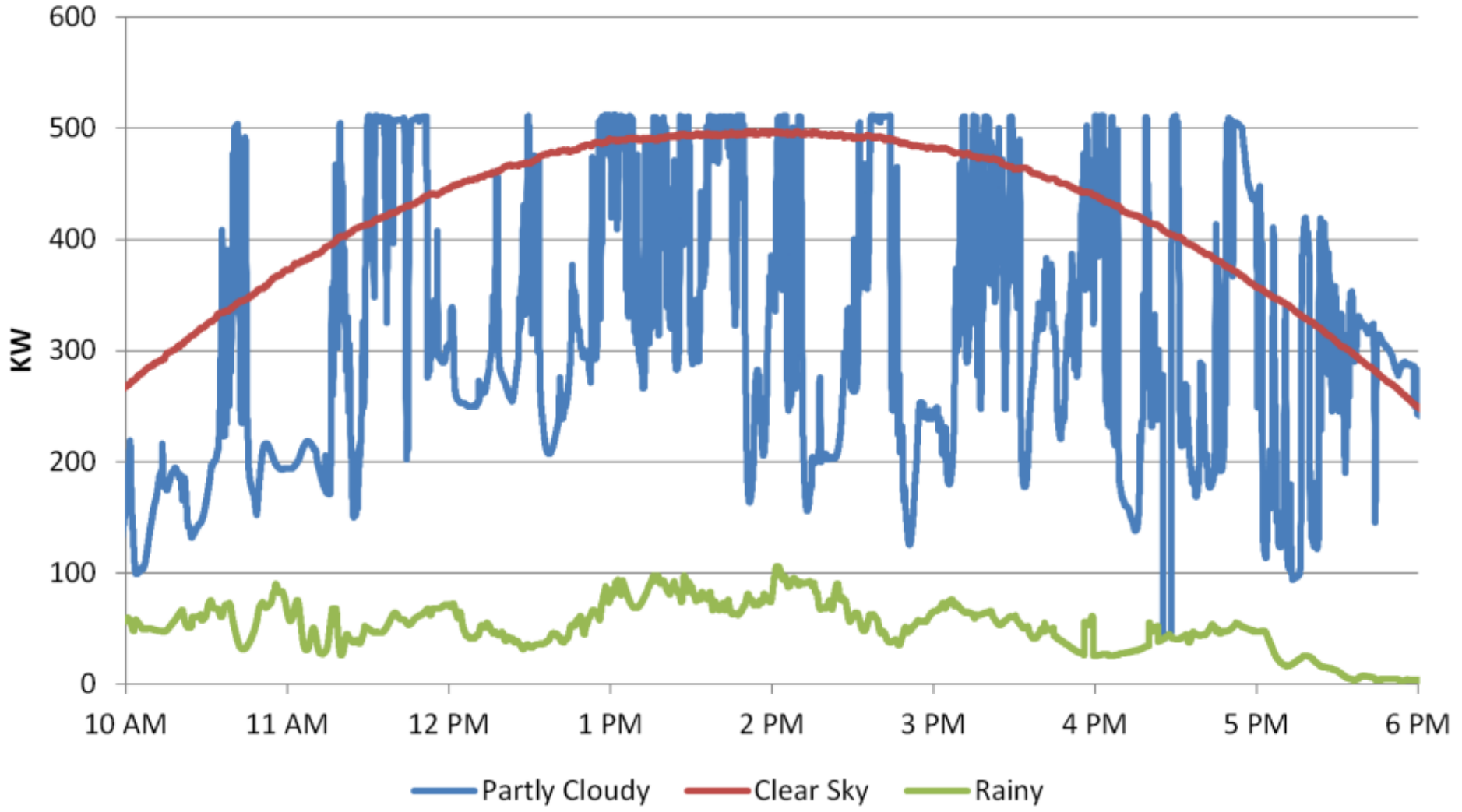
Comparing Days (Meter Data)



Comparing Days (Synchrophasor Data)



Output With Cloud Coverage



Questions?

- Thanks! Feel free to contact me if you have any questions.
  - Austin White
    - whitead@oge.com (405-553-5996)

OG&E's PhasorView