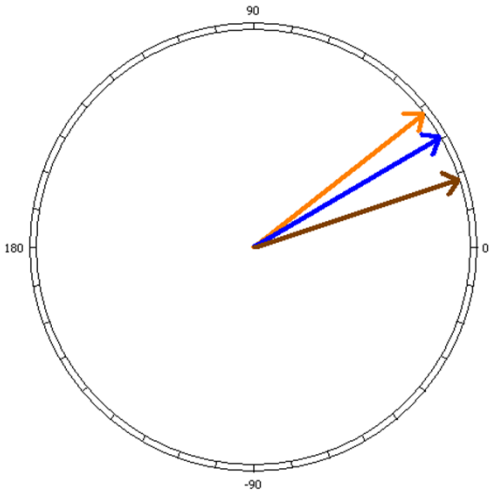
SynchroPhasor use at OG&E

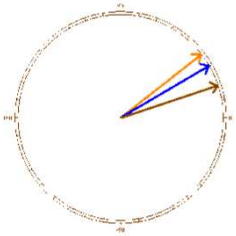


Austin D. White P.E.

Steven E. Chisholm

Oklahoma Gas & Electric

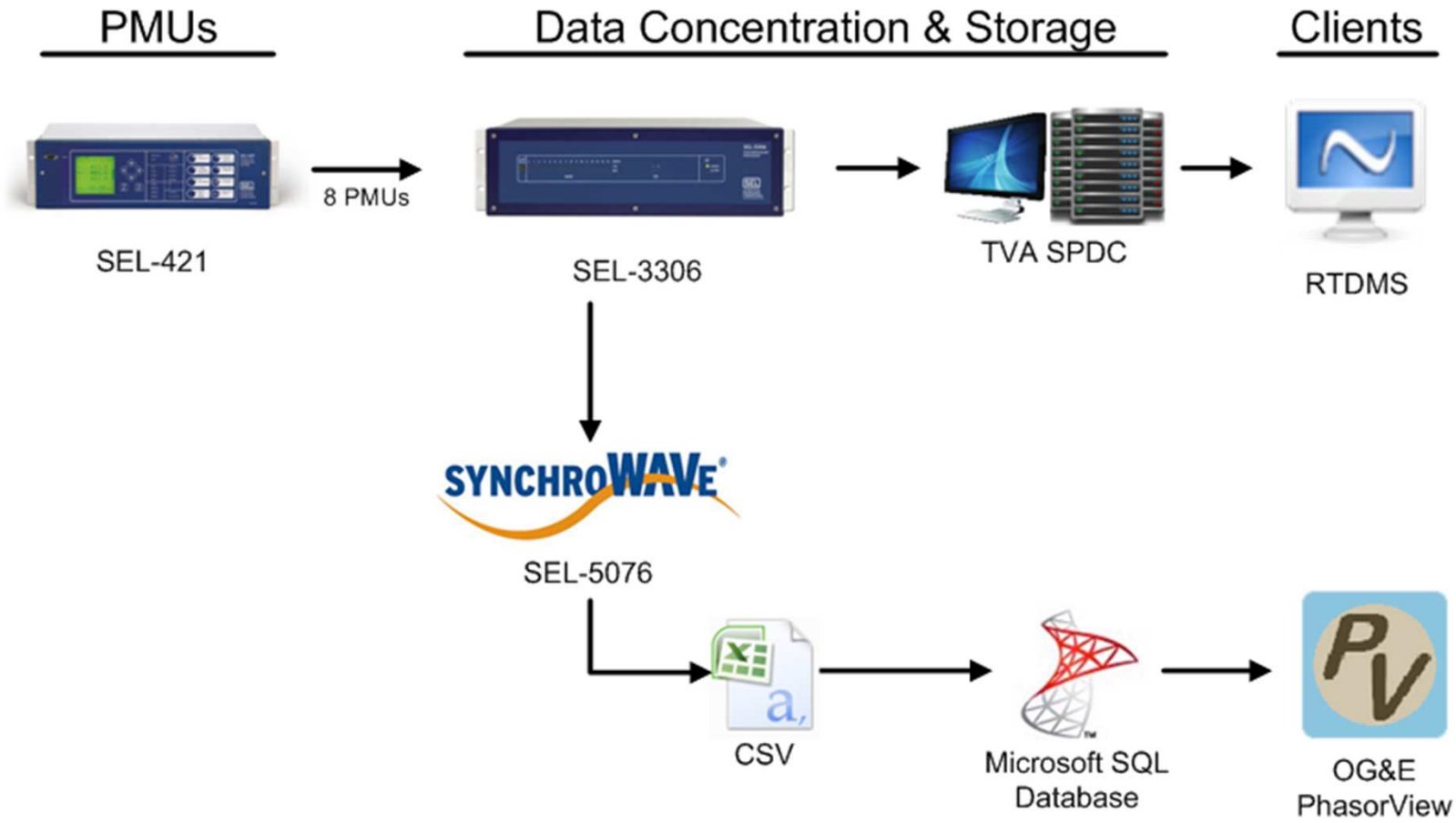
OG&E



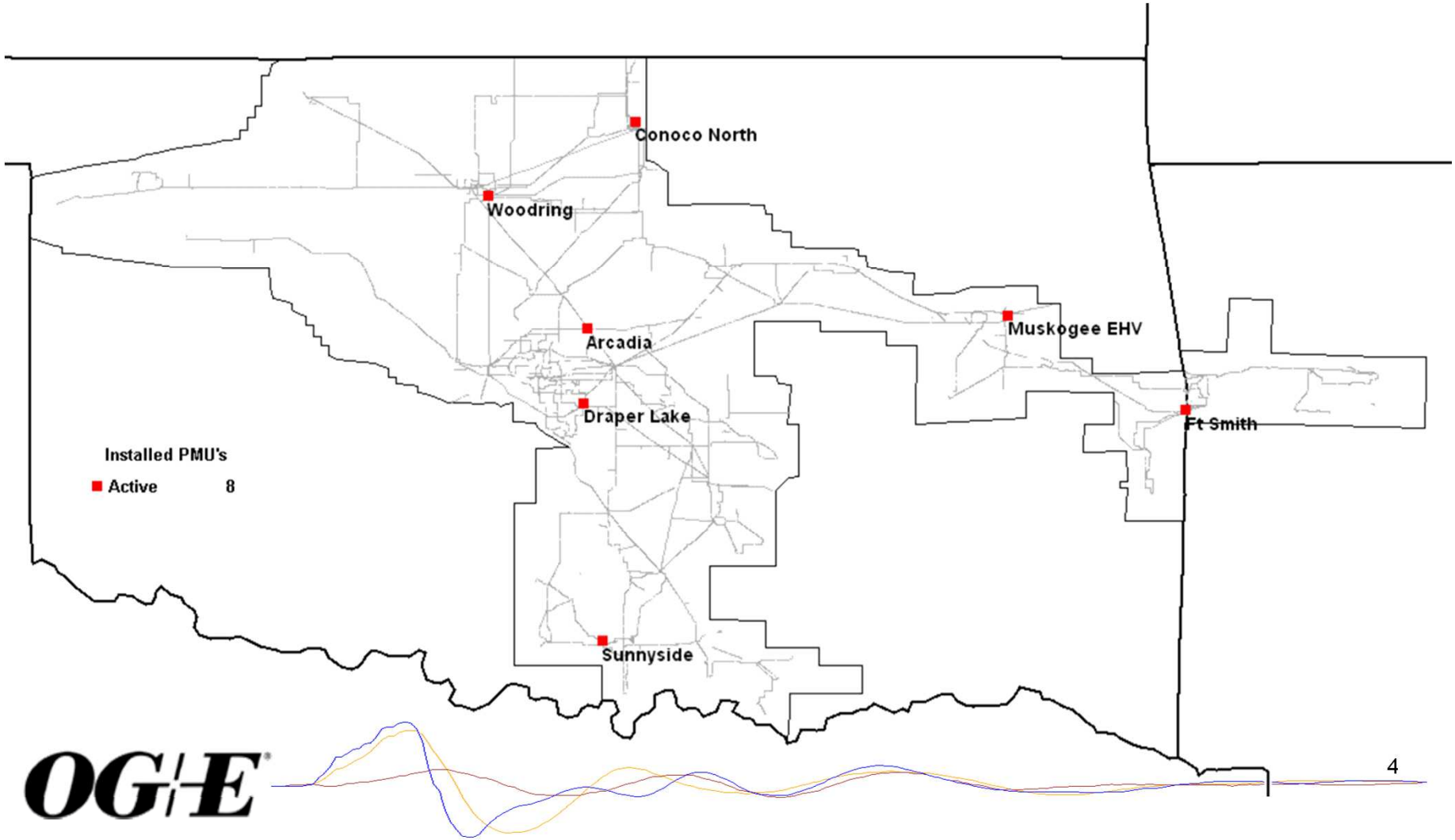
Outline

- History of Current Setup
- Use of OpenPDC
- Applications of SynchroPhasor Technology
- Future Plans

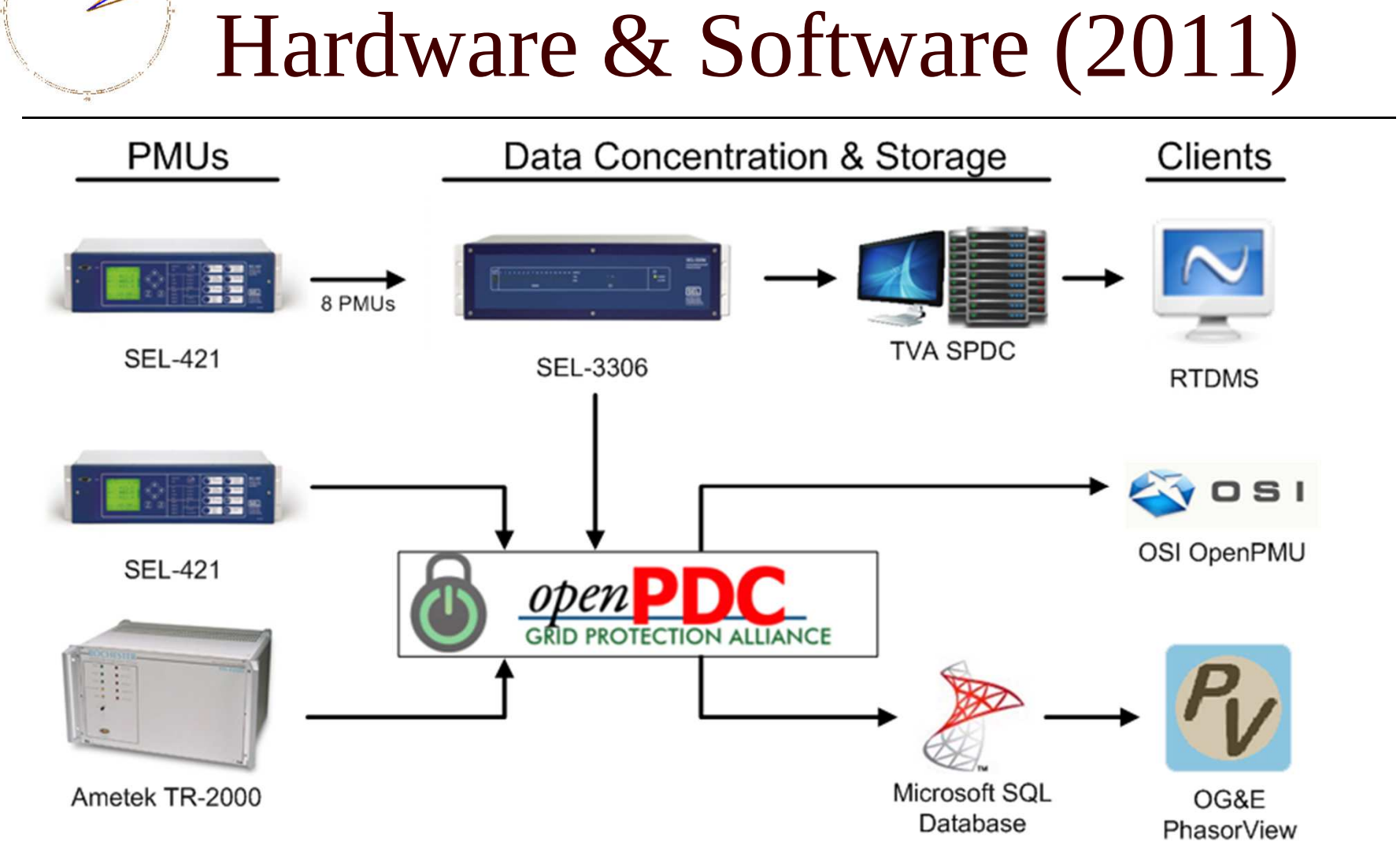
Hardware & Software (2009)



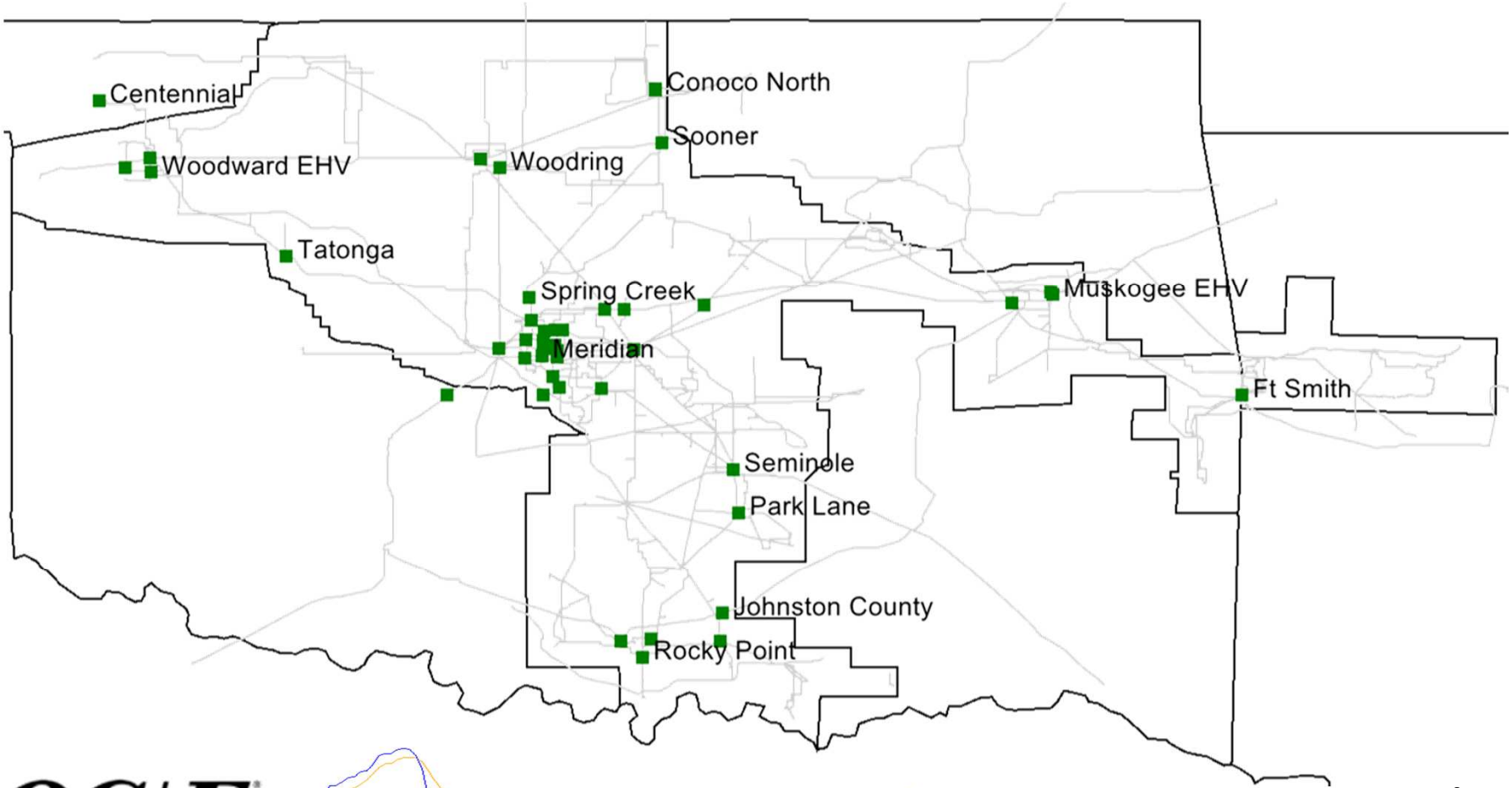
PMU Locations 2009



Hardware & Software (2011)

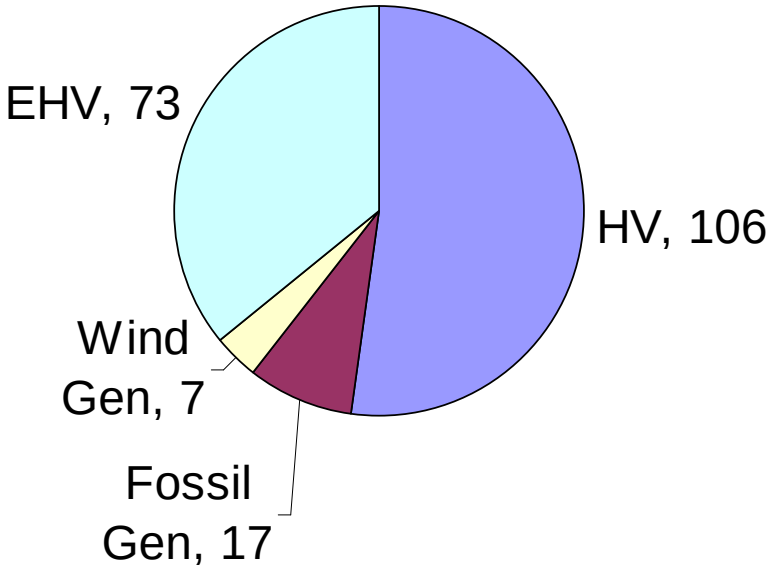


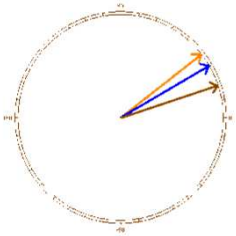
PMU Locations (2011)



PMU Coverage Stats

- 100% of EHV System
  - 53 Line Terminals, 20 Autotransformers
- 100% of Wind Farms
  - 1000MW, 7 Plants
- 90% of Fossil Generation
  - 6200MW, 17 Units
- 31% of HV System
  - 106 Line Terminals





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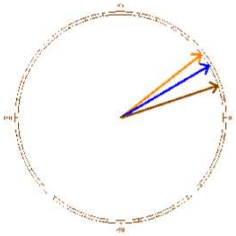


Action Adapter

- Inherit TimeSeriesFramework.Adapters. ActionAdapterBase
- Override Start()
- Override Stop()
- Override PublishFrame(IFrame frame, int index)
- Optional AdapterCommand Attribute
  - PauseSQLImport
  - ResumeSQLImport

Action Adapter

- Start() – Instances Queue Management and SQL Import
- End() – Saves partial results of Queue and stops SQL Import
- PublichFrame() – Add frame to the Queue

Queue Management

- EnQueue() – Converts Frame to Terminal Measurements and adds to the queue.
- DeQueue() – Returns up to 2 seconds of data from the beginning of the queue.
- Responsible for Switching between in-memory storage and on-disk storage.

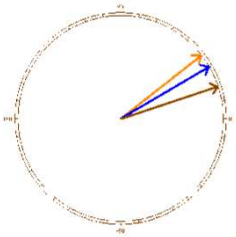
SQL Import

- Reads data from the queue every second.
- Compresses Data
- Inserts into SQL via Stored Procedure
  - SQL 2008 allows table parameters to be passed to stored procedures from .NET

Data Requirements

- Currently archiving 17GB per day (138 Terminals)
- 8TB of Data archived since Jan 2009.
- New compression algorithm reduced this requirement to 6.4GB per day.

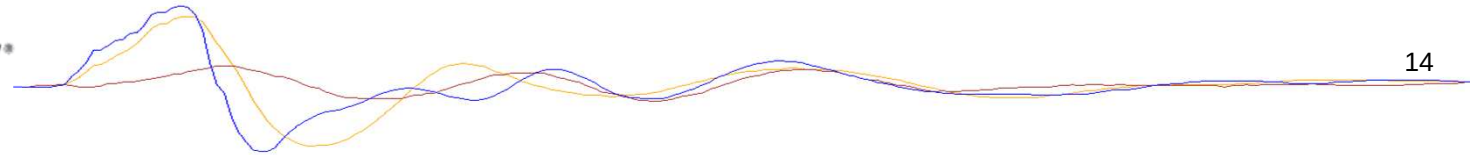
- OGE is currently not planning to retire any data. Give it time and 1TB will be as small as floppies are today.

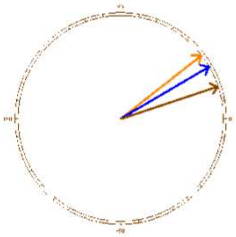


Compression (Lossless)

Method	Compression	Compress Speed	Decompression Speed
QuickLZ	38.10%	6.5MB/sec	56.7MB/sec
LZMA	53.10%	184KB/sec	5.76MB/sec
OGE's	56.90%	644MB/sec	792MB/sec

OGE





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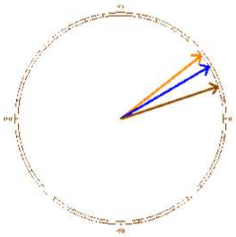
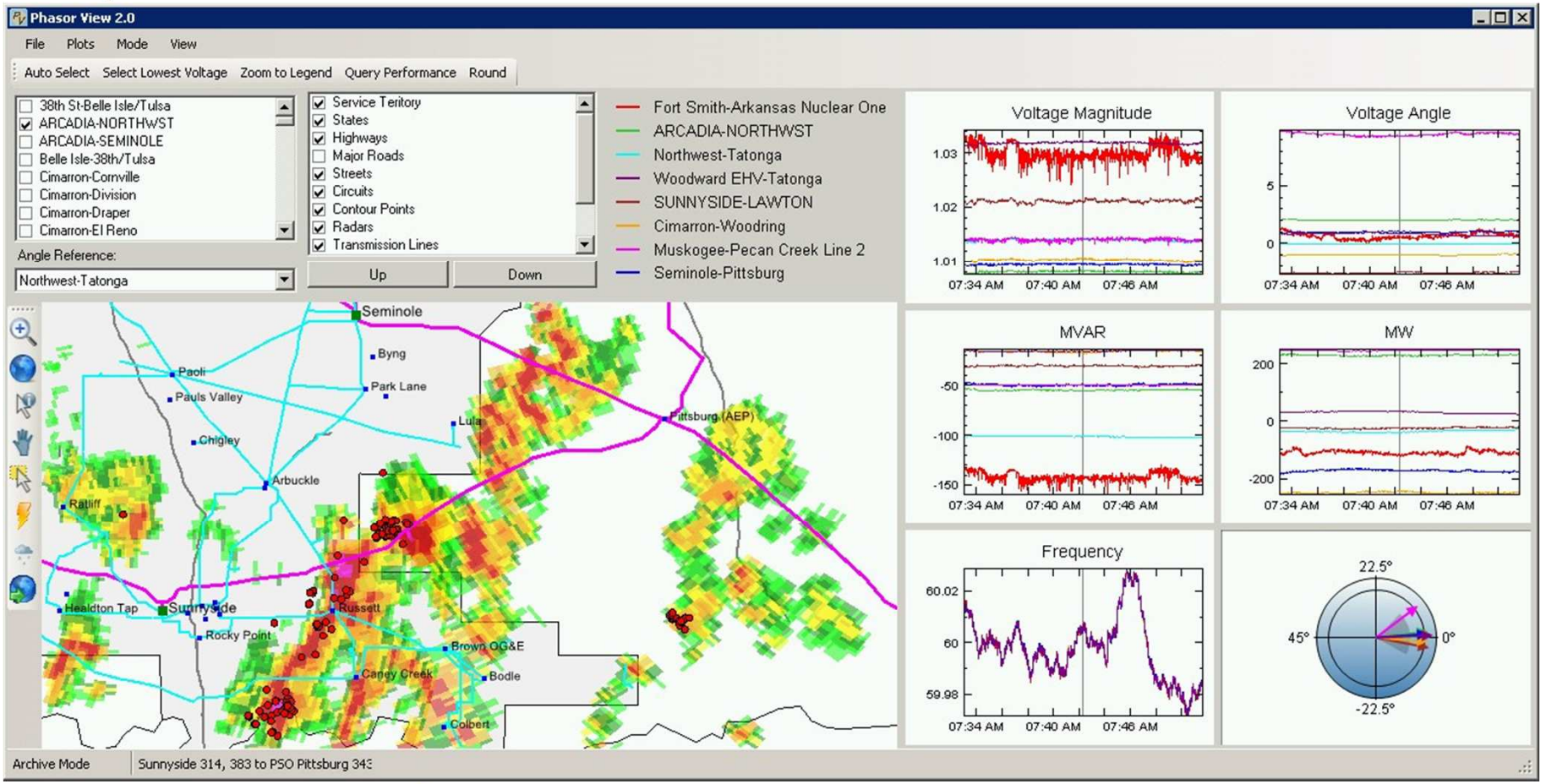


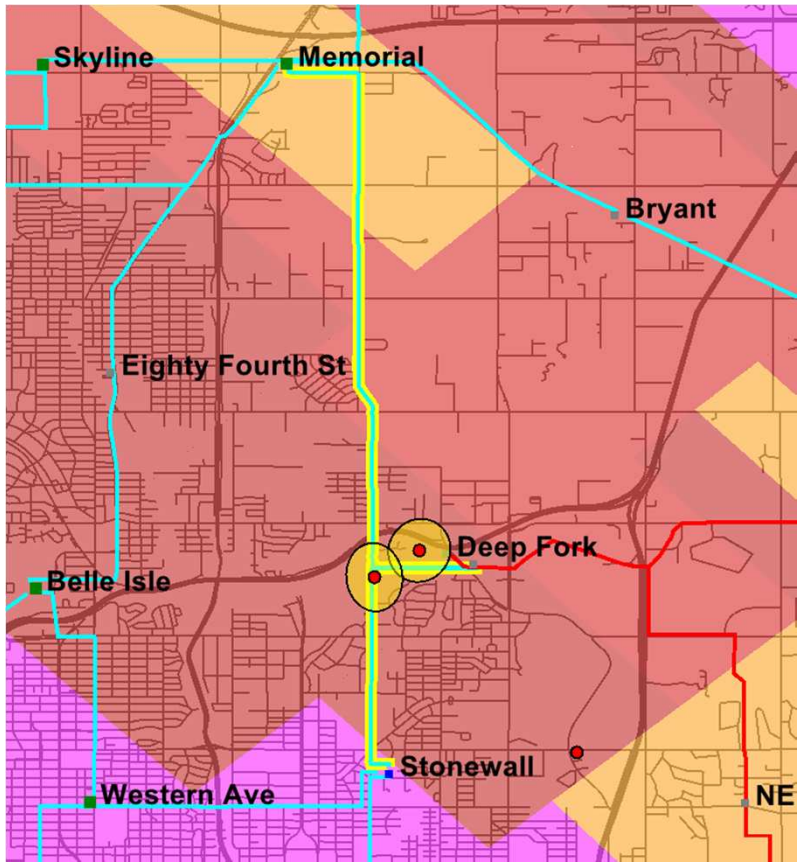
Applications

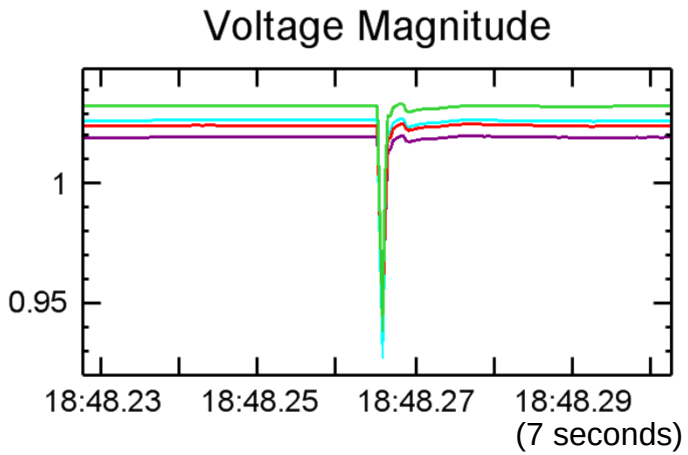
- Situational Awareness
- Disturbance/Misoperation Analysis
- State Estimator Enhancement
- Stability Assessment
- Proactively Find Equipment Problems
- Voltage Recovery Assessment (reactive reserves)
- Wind Farm Integration/Monitoring

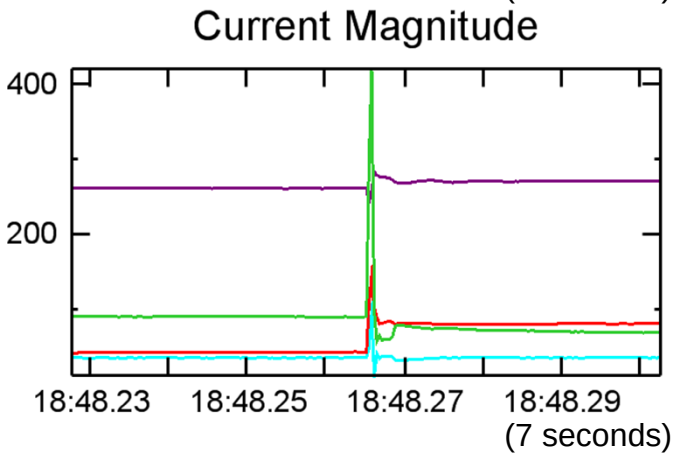
Situational Awareness - PhasorView



Disturbance/Misoperation Analysis with PhasorView

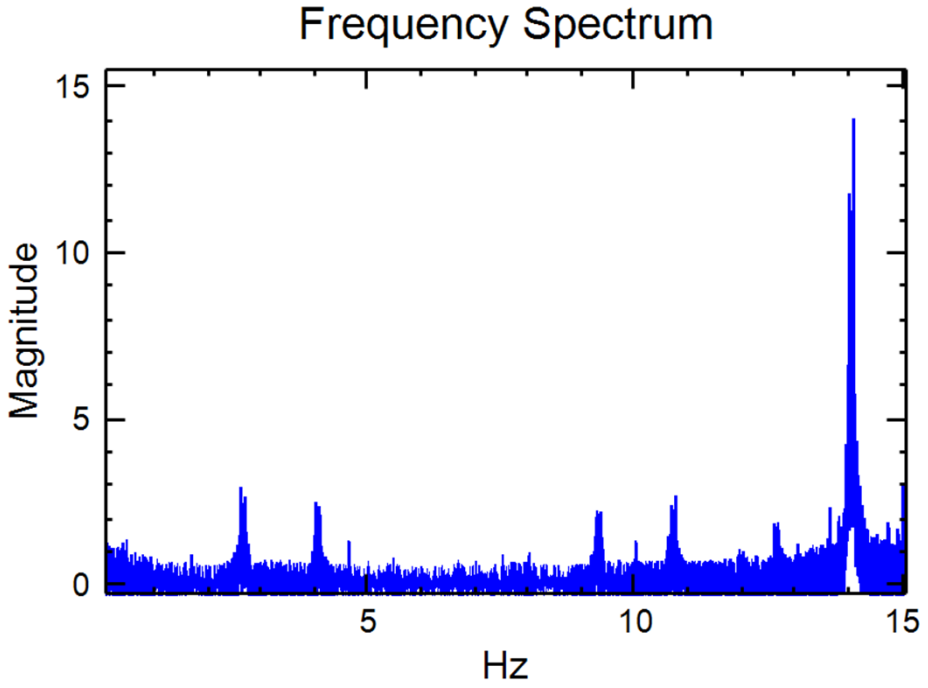






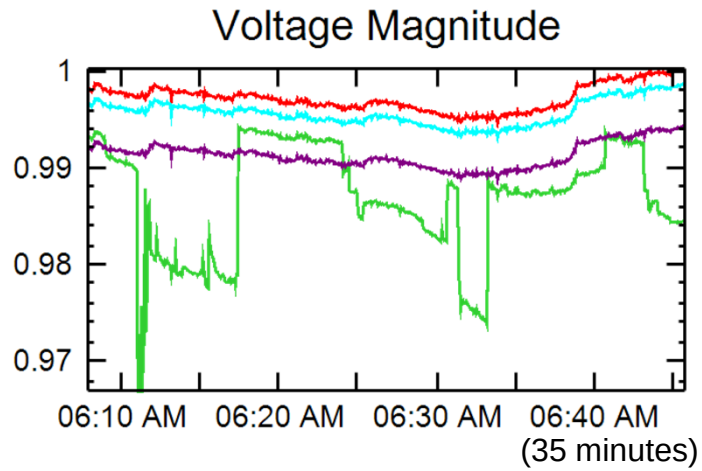
Stability Assessment - FFT

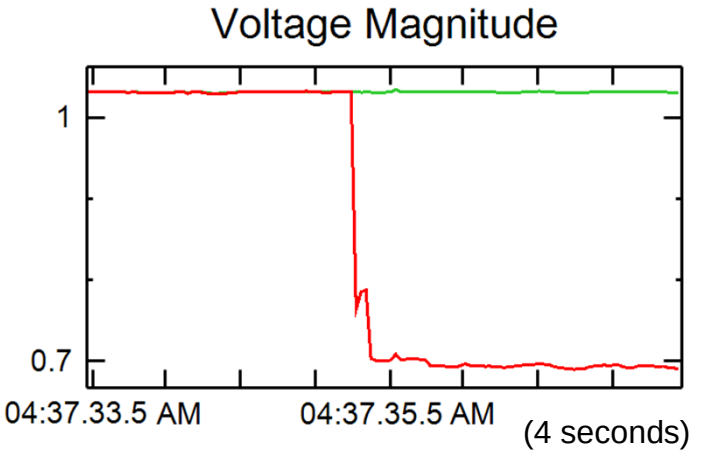
- FFT algorithm used to detect oscillations
- Sends email or text message when the oscillations reach an objectionable level
- This wind farm PMU shows many undesirable components, the worst at 14Hz



Discovery of Failing Equipment

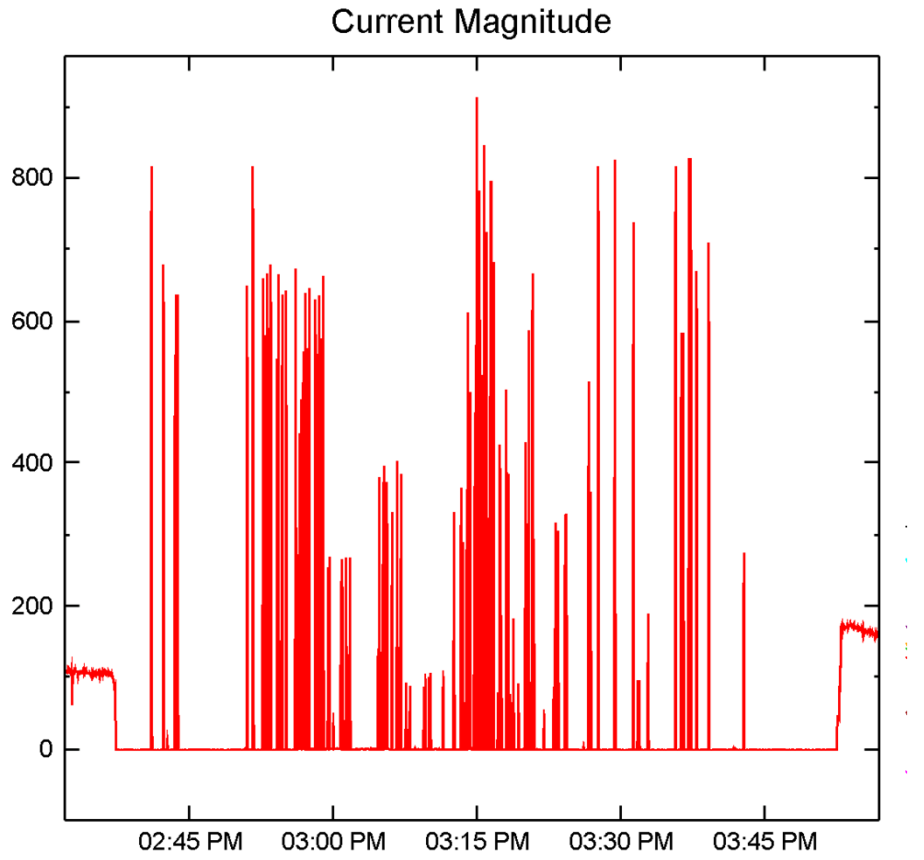
- Discovered many loose connections in the potential circuits at fuses or terminal blocks
- This has caused misoperations in the past (relays get confused)
- Proactively finding these helps prevent future outages and misoperations





Strange Overcurrent Event

- 8/18/2011 – 345kV line from Sunnyside to Lawton went dead.
- 260 high current event were experienced.
- Both forward and reverse faults.
- Relay Testing.



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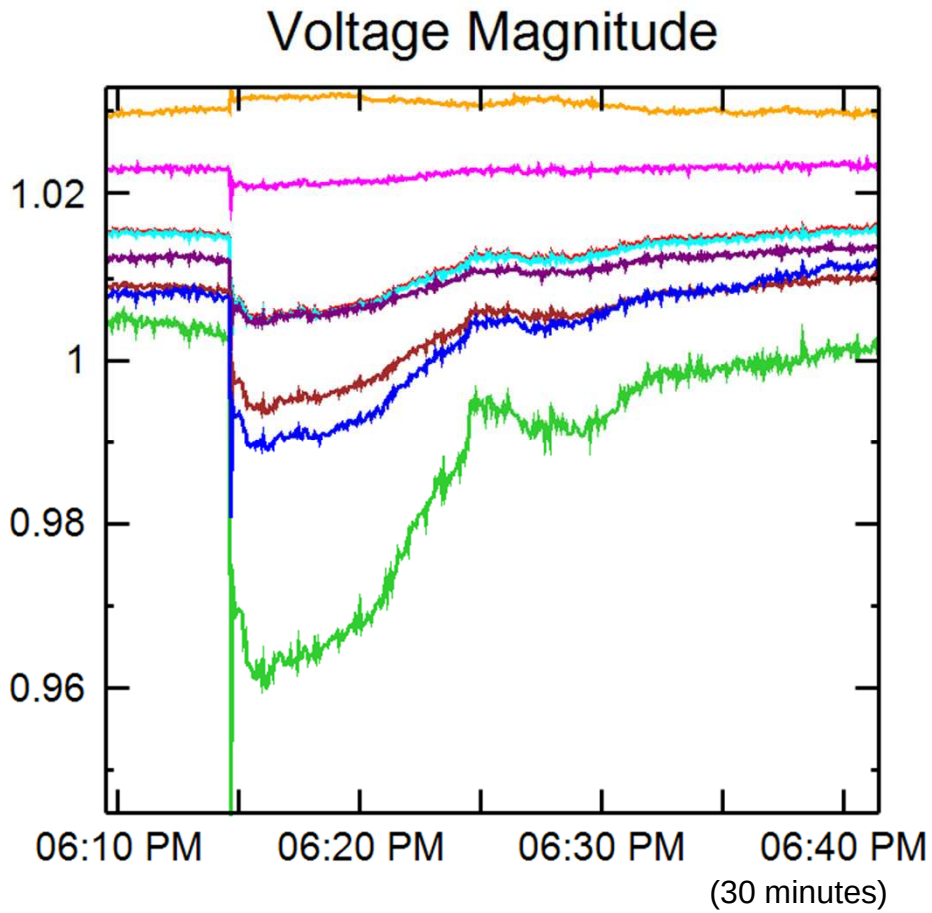
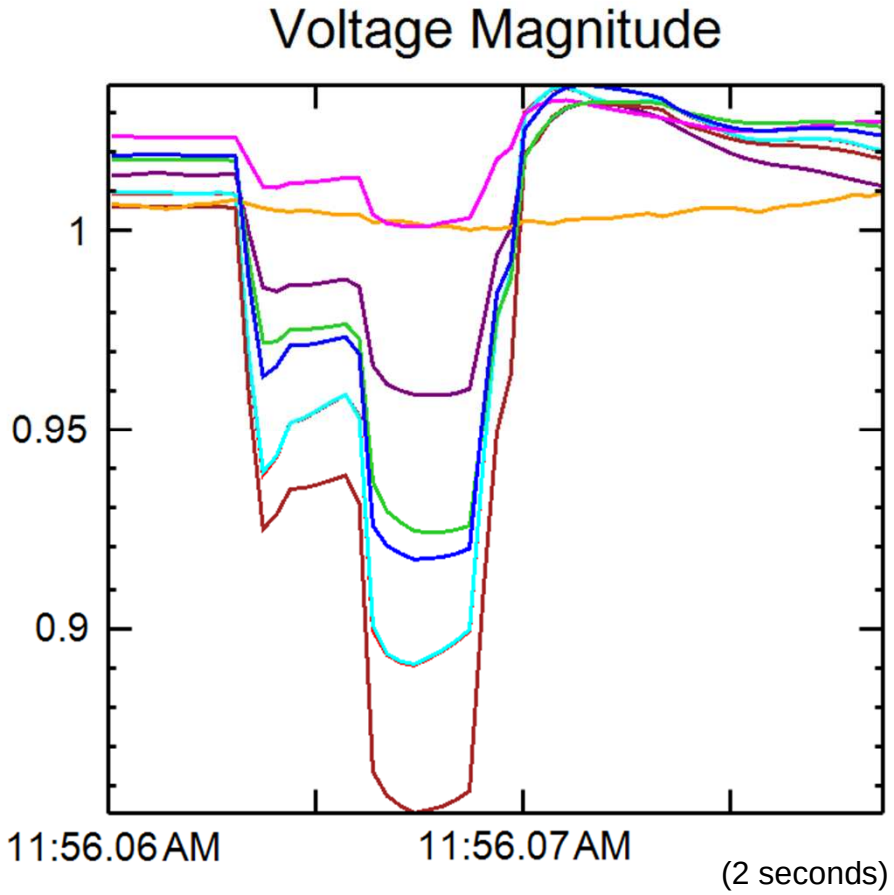
Voltage Recovery Assessment

- 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



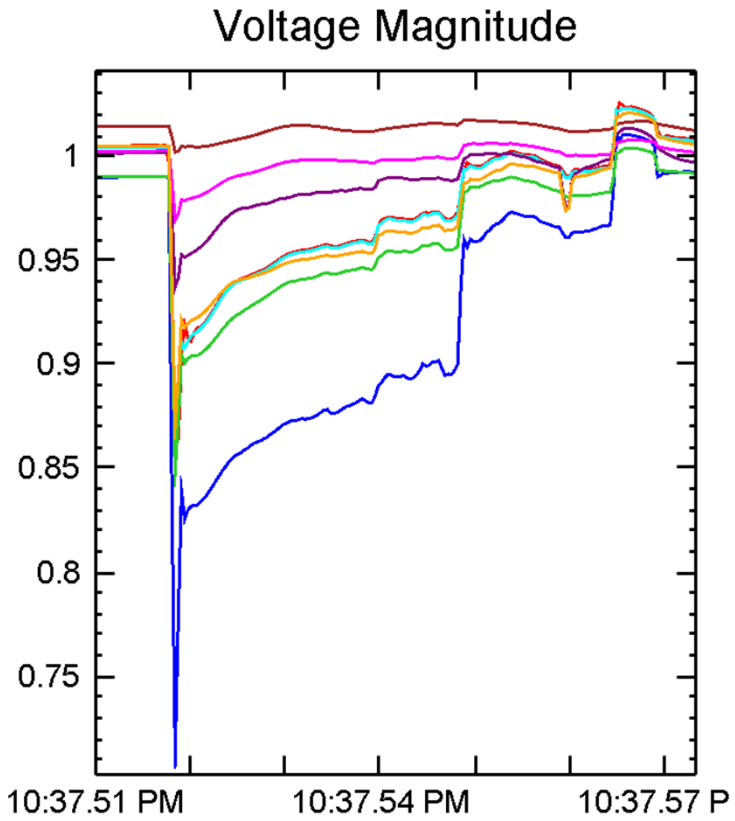
Voltage Depression during a fault

- 1/28/2009 - Fault in Oklahoma City can be seen on the entire EHV system
- Voltage pull downs are much worse when line communications (carrier) is turned off



Importance of Breaker Failure Relaying

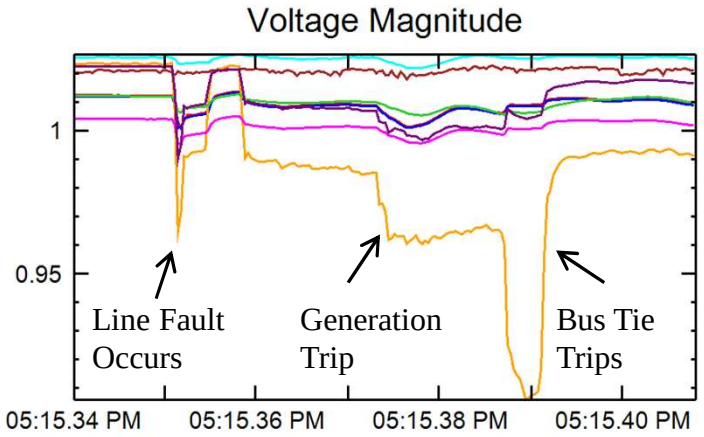
- 4/26/09 – Hollywood PCB 185 failed to trip for a fault on the Wilkinson line.
- Breaker Failure relaying not installed on PCB 185.
- Took about 5 seconds to clear the fault remotely
- Luckily nothing burned down and no generators tripped – this is the kind of thing that leads to blackouts

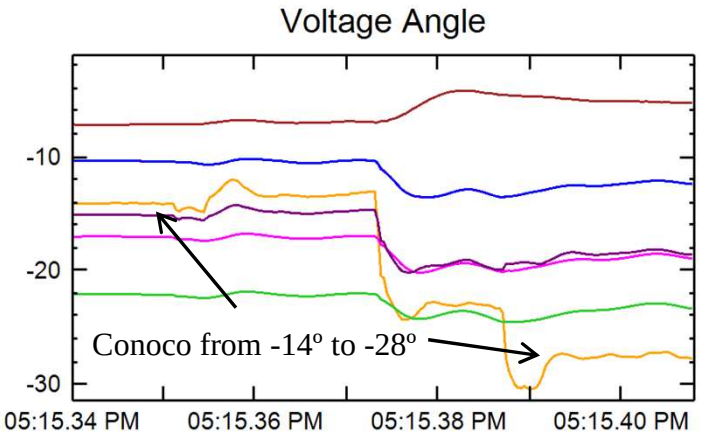


(6 seconds)

Another Five Second Event

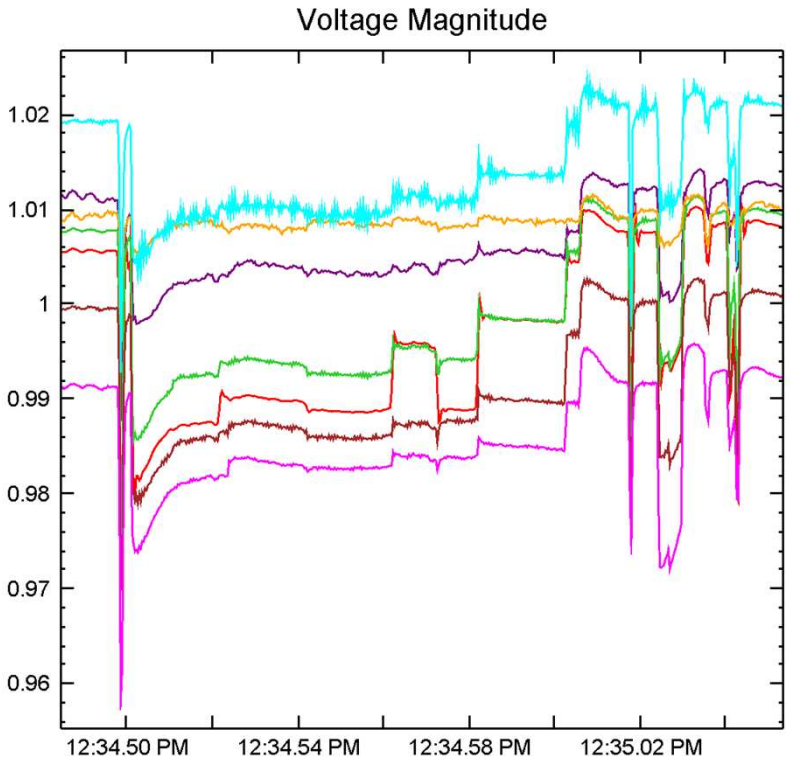
- 8/10/2009 – Fault on the 138kV Sooner-Cow Creek/Stillwater Line
- Sooner fails to operate due to a relay wiring problem
- Results in Sooner Unit 1 trip and 400MVA bus tie transformer trip
- 138kV Conoco North voltage angle changes from -14 degrees prior to event to -28 degrees after, which indicates system stress





Ten Second Fault Event

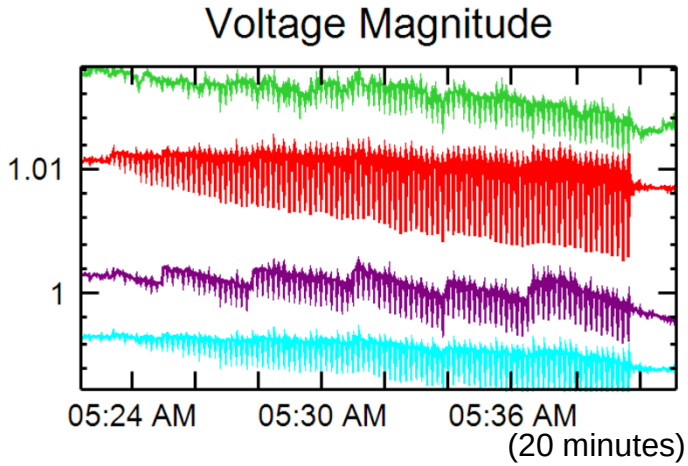
- 3/6/2011 – Fault on the 138kV HLS-Bristow/Rock Creek line caused by a trackhoe contact
- Relay failed to detect a Ground Fault (problem with polarizing CT circuit)
- Took 19 breakers to remotely clear fault.
- Finally cleared when the fault went phase to phase
- 32,000 Customers effected
- 2hr 17min restore time
- 4.1 Million CMI

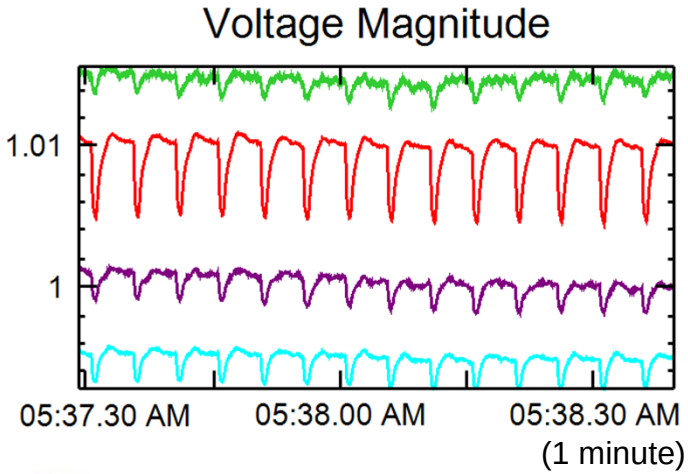


(16 seconds)

Stability Assessment - Redbud Oscillations (Solved)

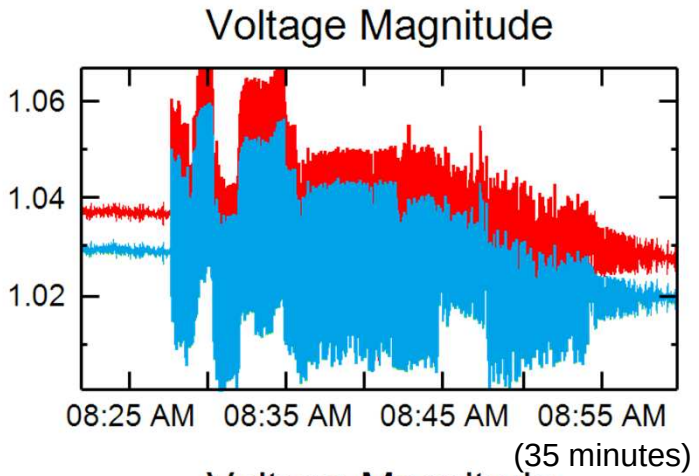
- Discovered voltage oscillations on EHV system (0.2Hz)
- Signal is most pronounced on the MVAR plot
- Suspected a generation problem
- Determined to be a problem with Redbud Unit 4 when in VAR control mode
- VAR control mode used during unit startup, oscillations stop when operator switches to voltage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

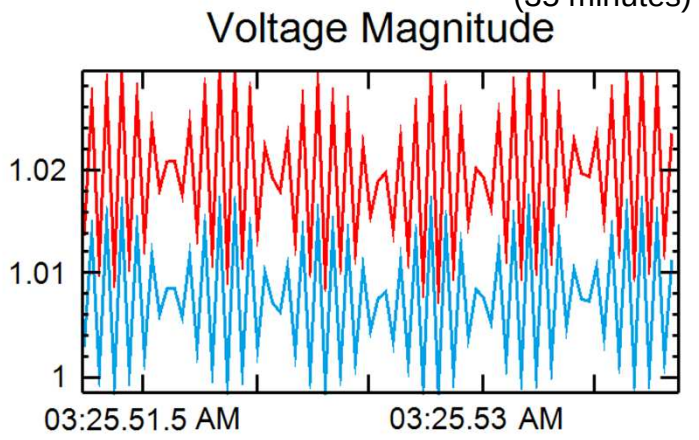




Wind Farm Oscillations

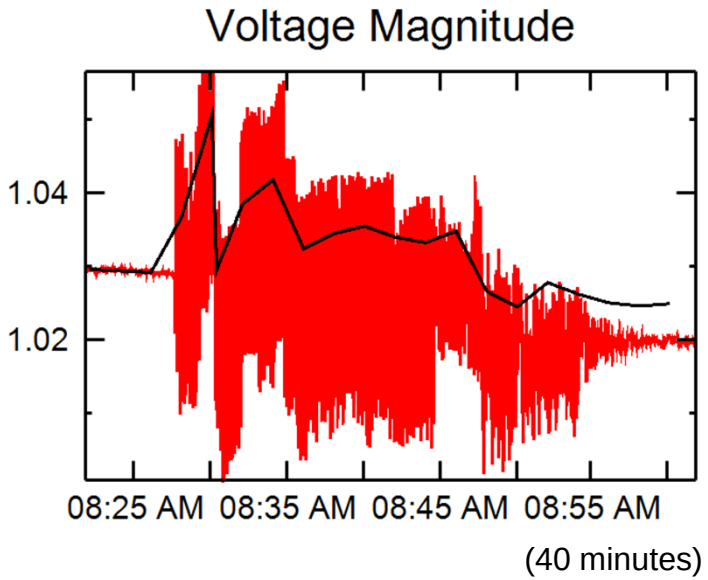
- Only during high winds
- FFT analysis shows 13-14Hz
- Voltage fluctuations as high as 5%
- Interaction between wind farms?
- Switching performed to electrically isolate the wind farms
- Determined it is a problem at different wind farms with the same turbine model
- The only solution is to curtail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





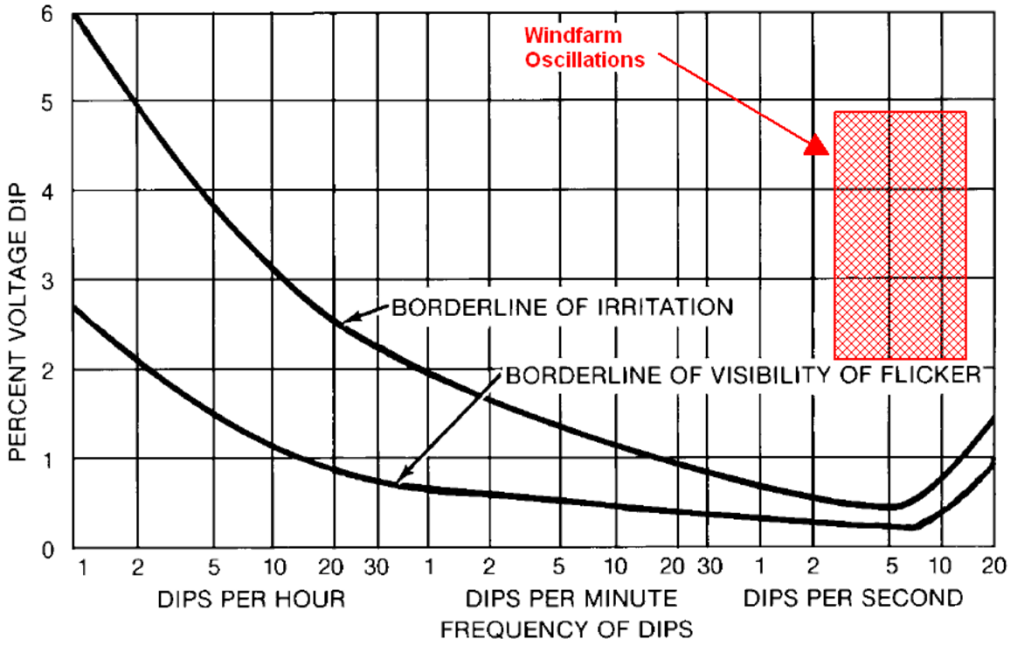
SCADA vs Synchrophasors

- Black trace shows the voltage magnitude reported by SCADA
- Red trace shows the synchrophasor data
- The oscillations are obviously undetectable with SCADA



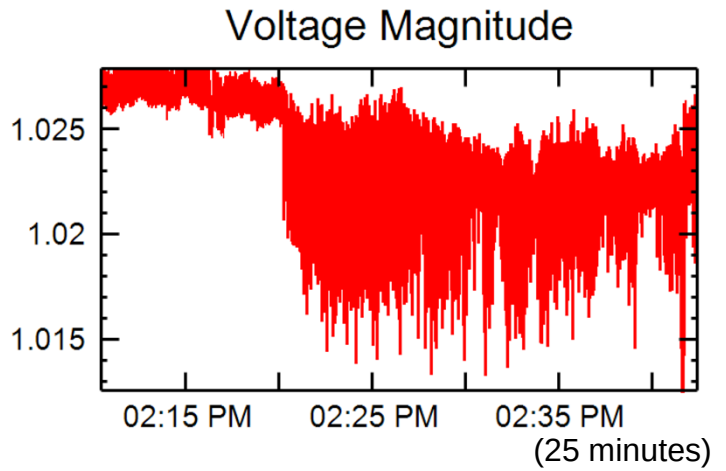
Customer Impact

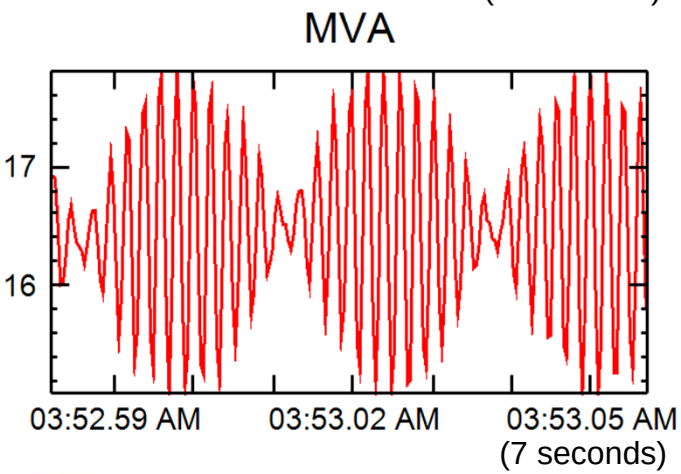
- Using IEEE 141, the oscillations were well into the objectionable flicker zone
- Called the Woodward service center to ask if they could see the lights flickering
- They confirmed visible flicker and noted numerous customer complaints
- We are currently working with the manufacturer to resolve the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



Monitoring Power Quality

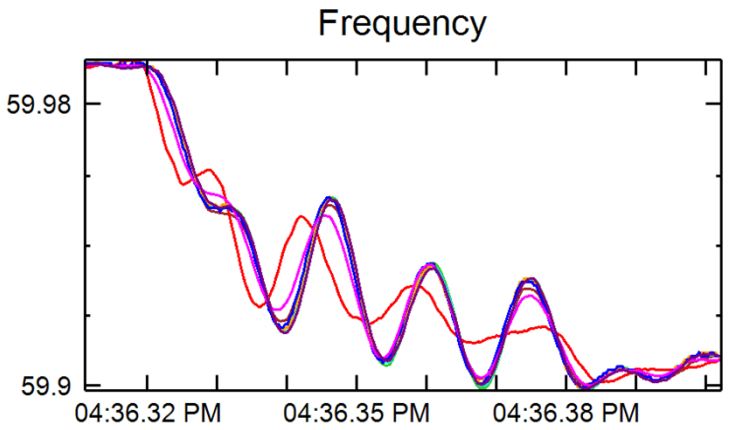
- It has been observed that large loads inject noise onto the system
- Large refineries and arc furnaces are the worst offenders
- Synchrophasors allow for real time power quality monitoring



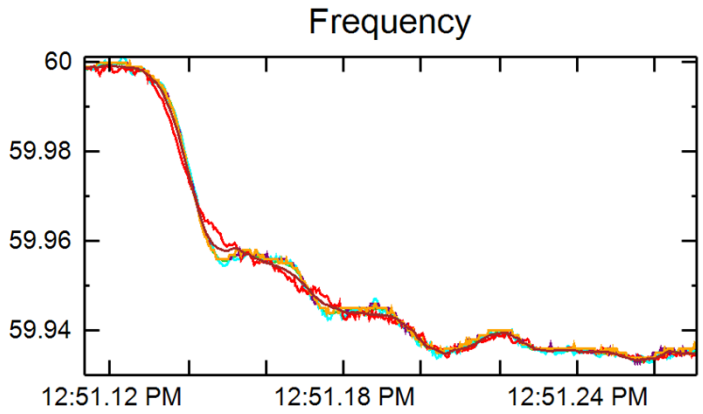


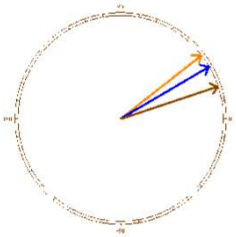
Generation Trips

- 4/27/2011 - Browns Ferry Nuclear Plant Trip (Tornado)



- 8/23/2011 – Generation Trip in Washington DC (Earthquake)





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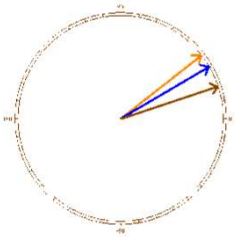

Future Plans

- Continue to bring new PMUs online!
- PhasorView Enhancements
  - Adjust line widths in the GIS to reflect loading on the lines.
  - Have arrows that show the change in the VAR flow so a fault location can be quickly identified.
  - Use the relay digital data to generate operation reports.