SynchroPhasor use at OG&E
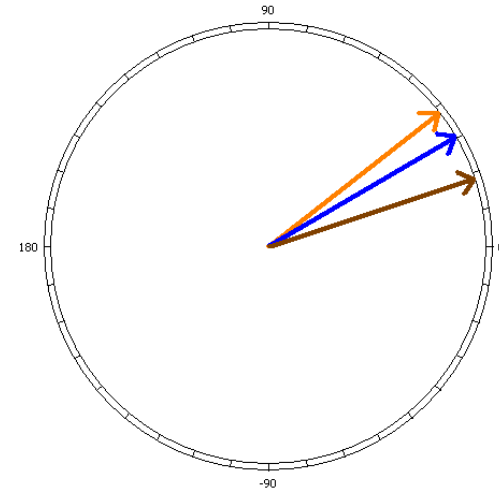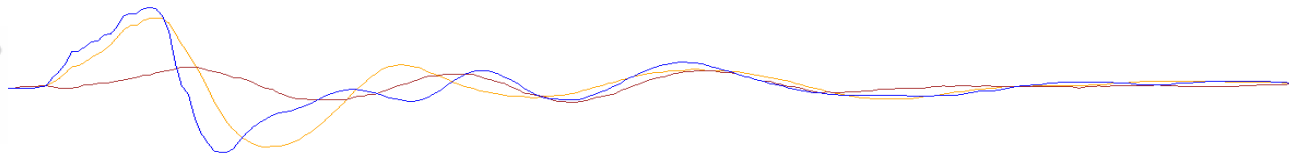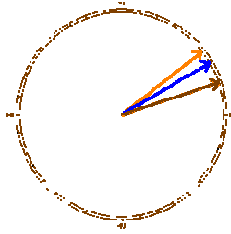
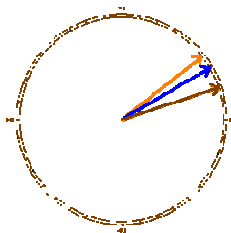Austin D. White P.E.

Steven E. Chisholm
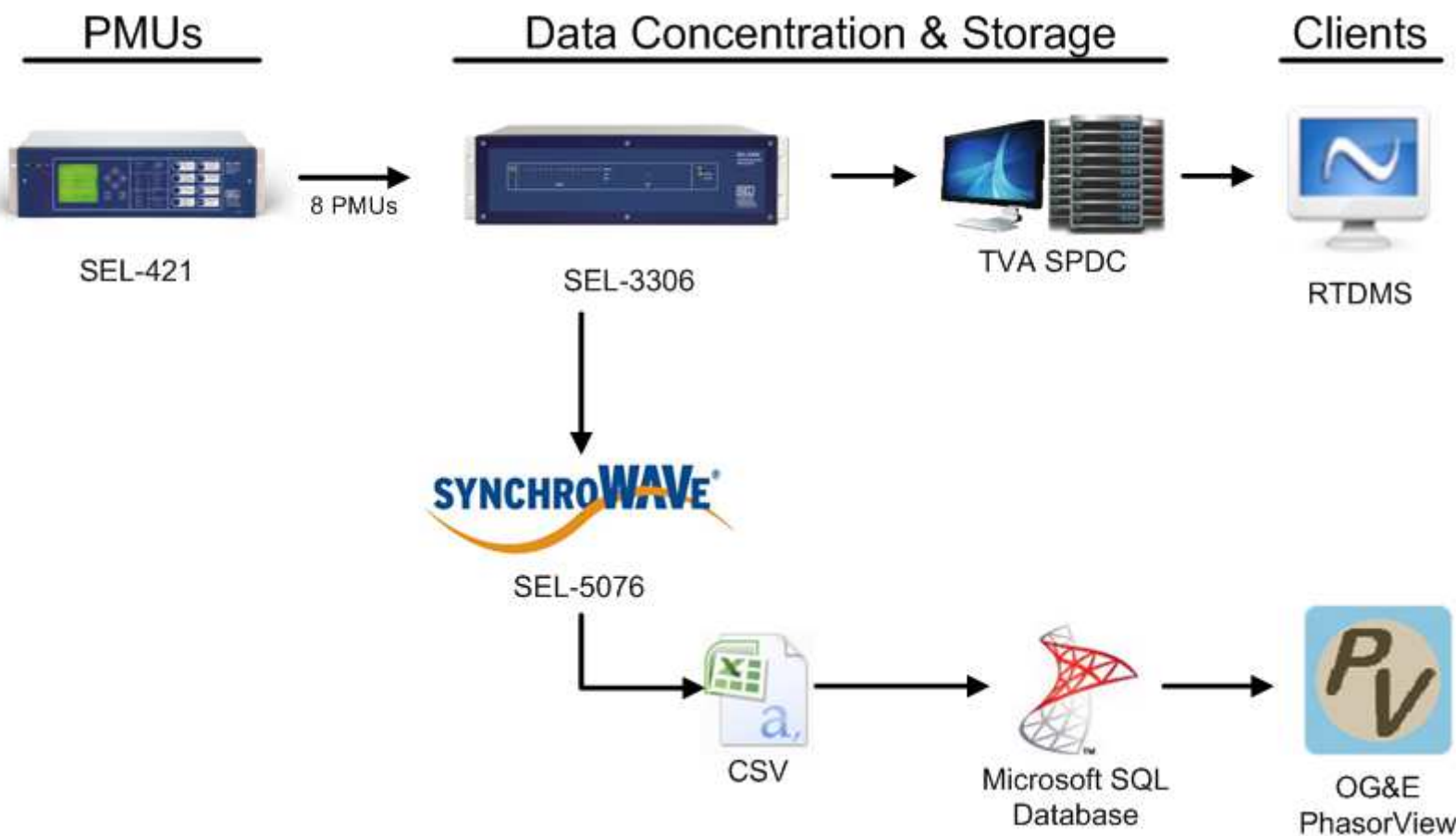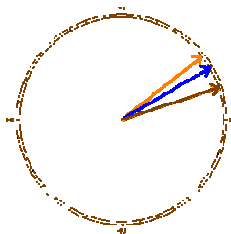
Oklahoma Gas & Electric

Outline

- History of Current Setup

- Use of OpenPDC
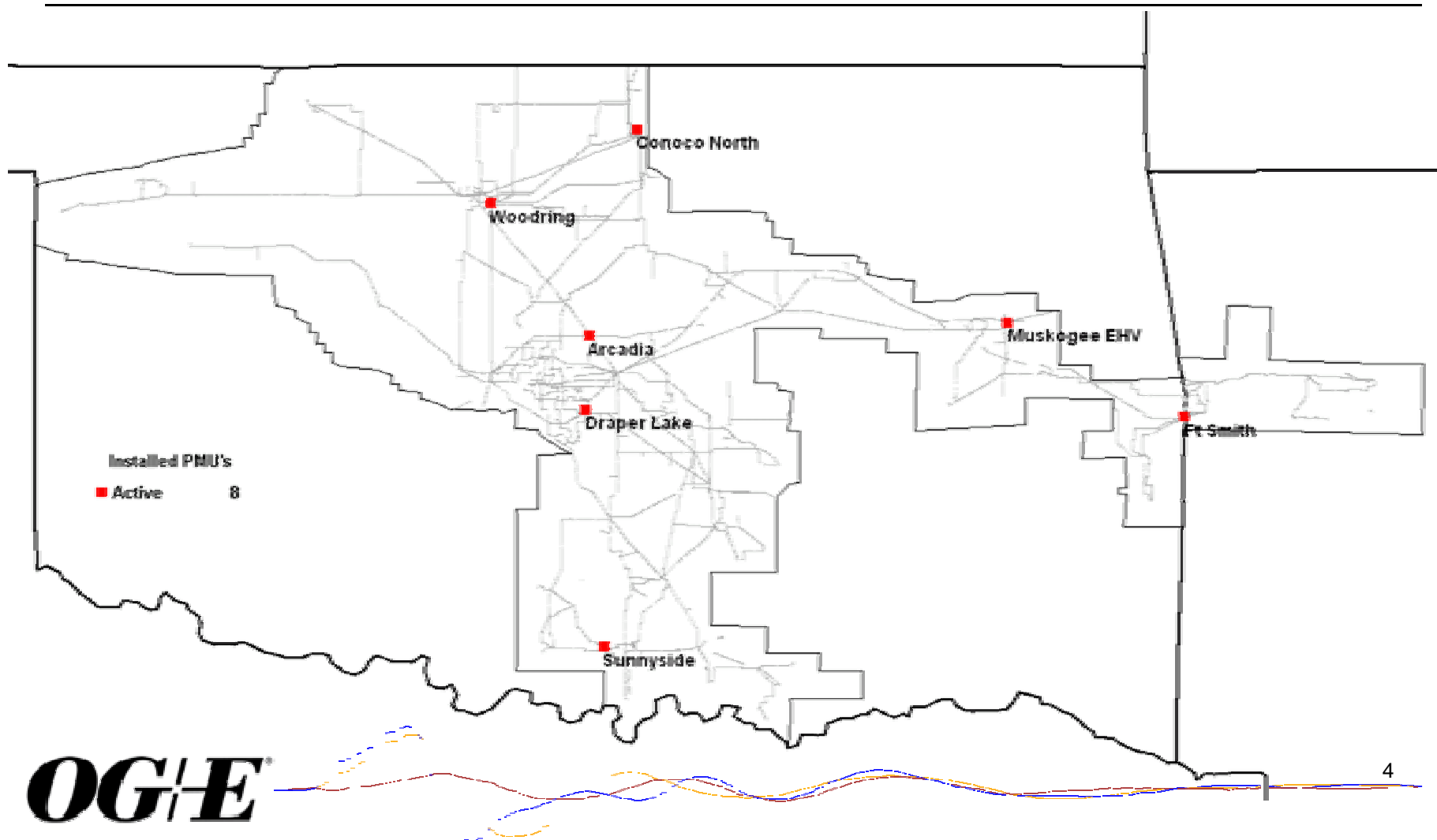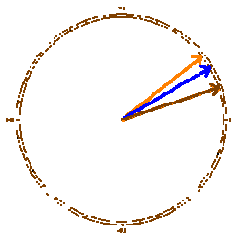
- Applications of SynchroPhasor Technology

- Future Plans

Hardware & Software (2009)

PMU Locations 2009

Installed PMU's
- Active   8

Conoco North

Woodring

Arcadia

Draper Lake

Muskogee EHV

Ft Smith

Sunnyside

OG&E

Hardware & Software (2011)

PMUs — Data Concentration & Storage — Clients

SEL-421 → 8 PMUs → SEL-3306 → TVA SPDC → RTDMS

SEL-421

Ametek TR-2000 → openPDC GRID PROTECTION ALLIANCE → OSI OpenPMU

Microsoft SQL Database → OG&E PhasorView
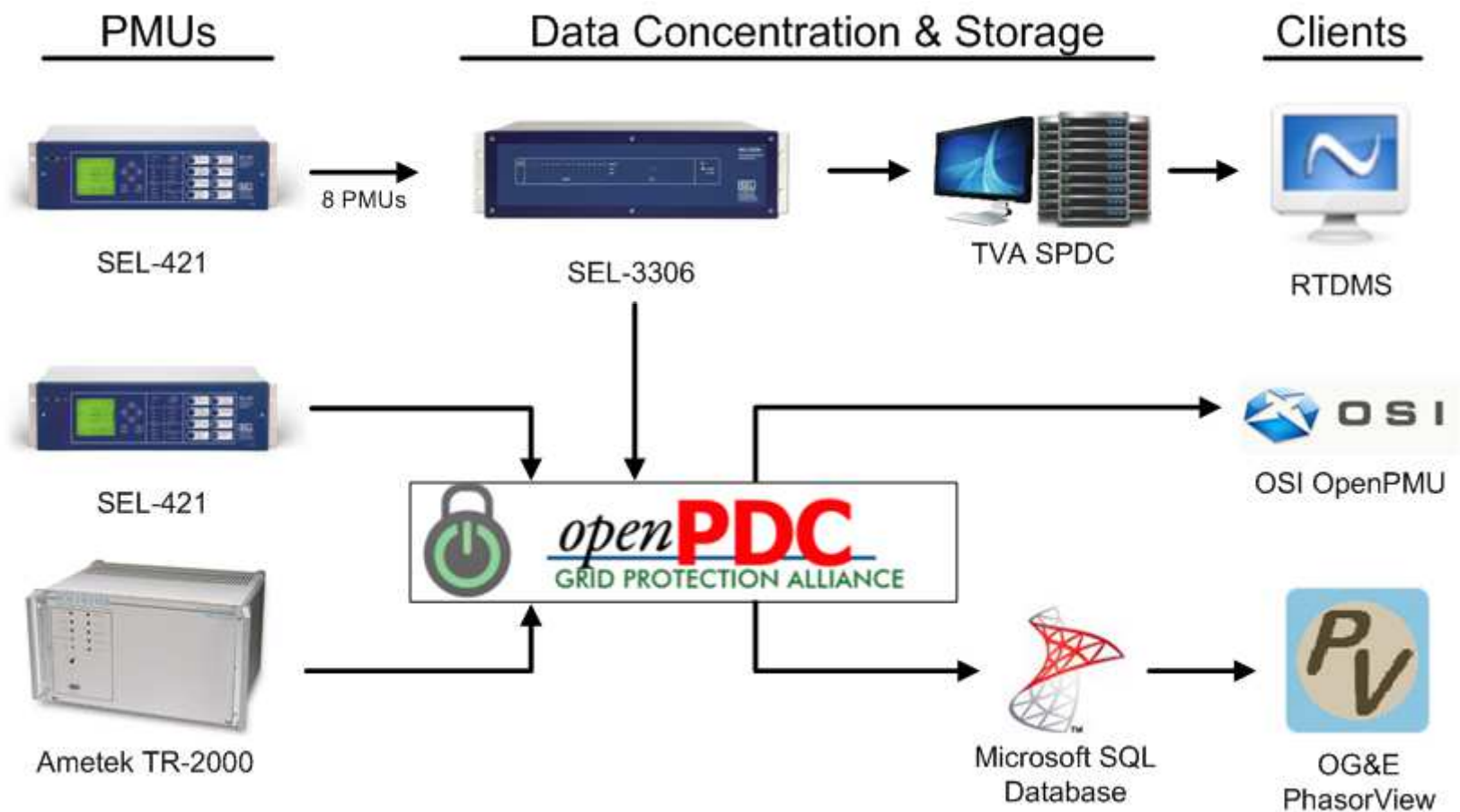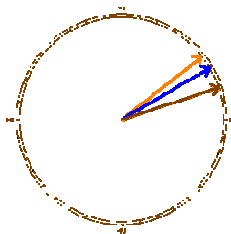
PMU Locations (2011)
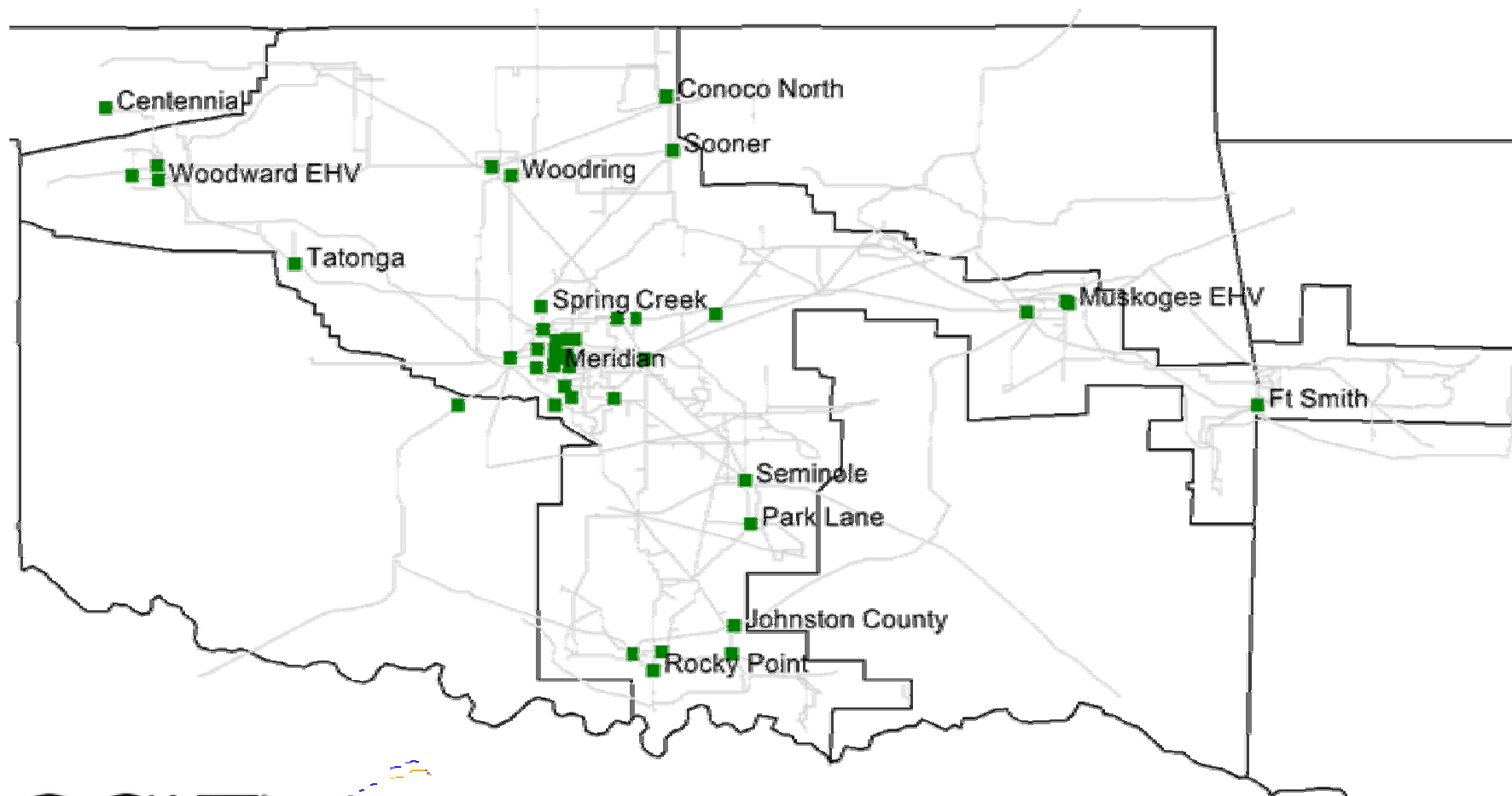
PMU Coverage Stats

- ## 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

EHV, 73

HV, 106

Wind
Gen, 7

Fossil
Gen, 17

Outline

- History of Current Setup

- **Use of OpenPDC**

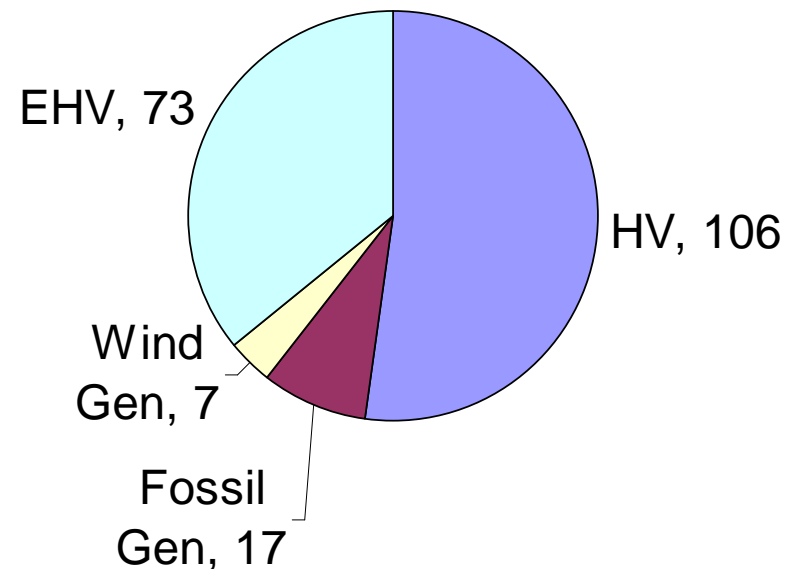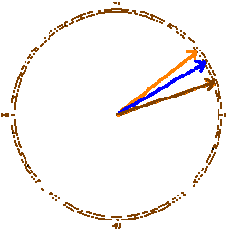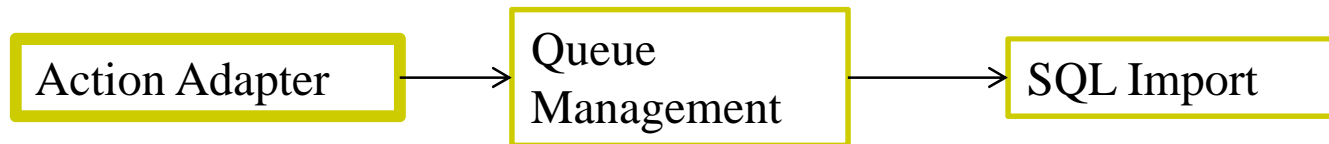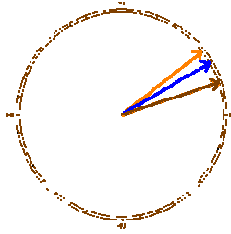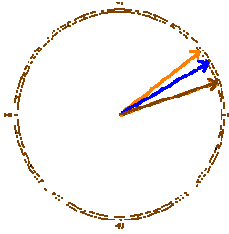- Applications of SynchroPhasor Technology

- Future Plans

Action Adapter

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

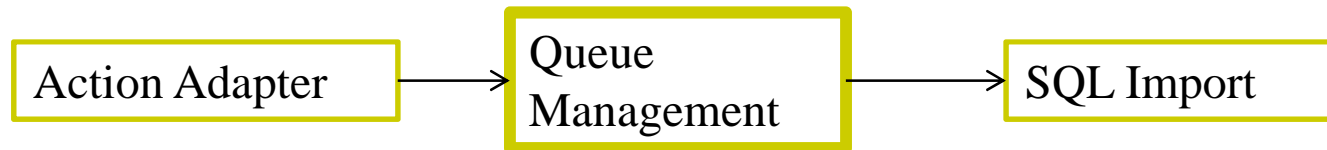# Action Adapter

| Action Adapter | → | Queue Management | → | SQL Import |

- Start() – Instances Queue Management and SQL Import

- End() – Saves partial results of Queue and stops SQL Import

- PublichFrame() – Add frame to the Queue

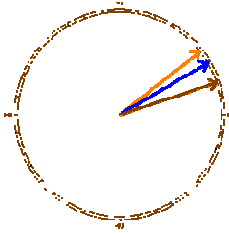# Queue Management

Action Adapter → Queue Management → SQL Import

❑ 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
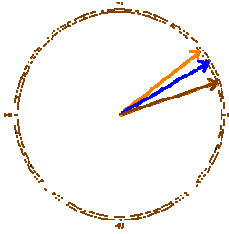
| Action Adapter	→	Queue Management	→	SQL Import

- ❑ 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
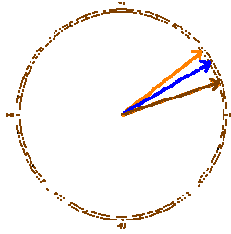
Data Requirements

- 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.
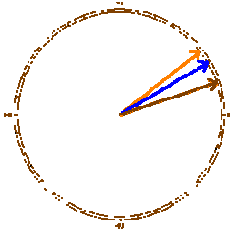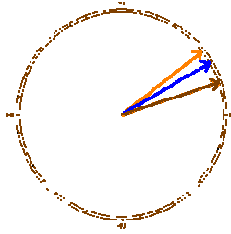
Compression (Lossless)

| 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

Outline

- □ History/Current Setup

- □ Use of OpenPDC

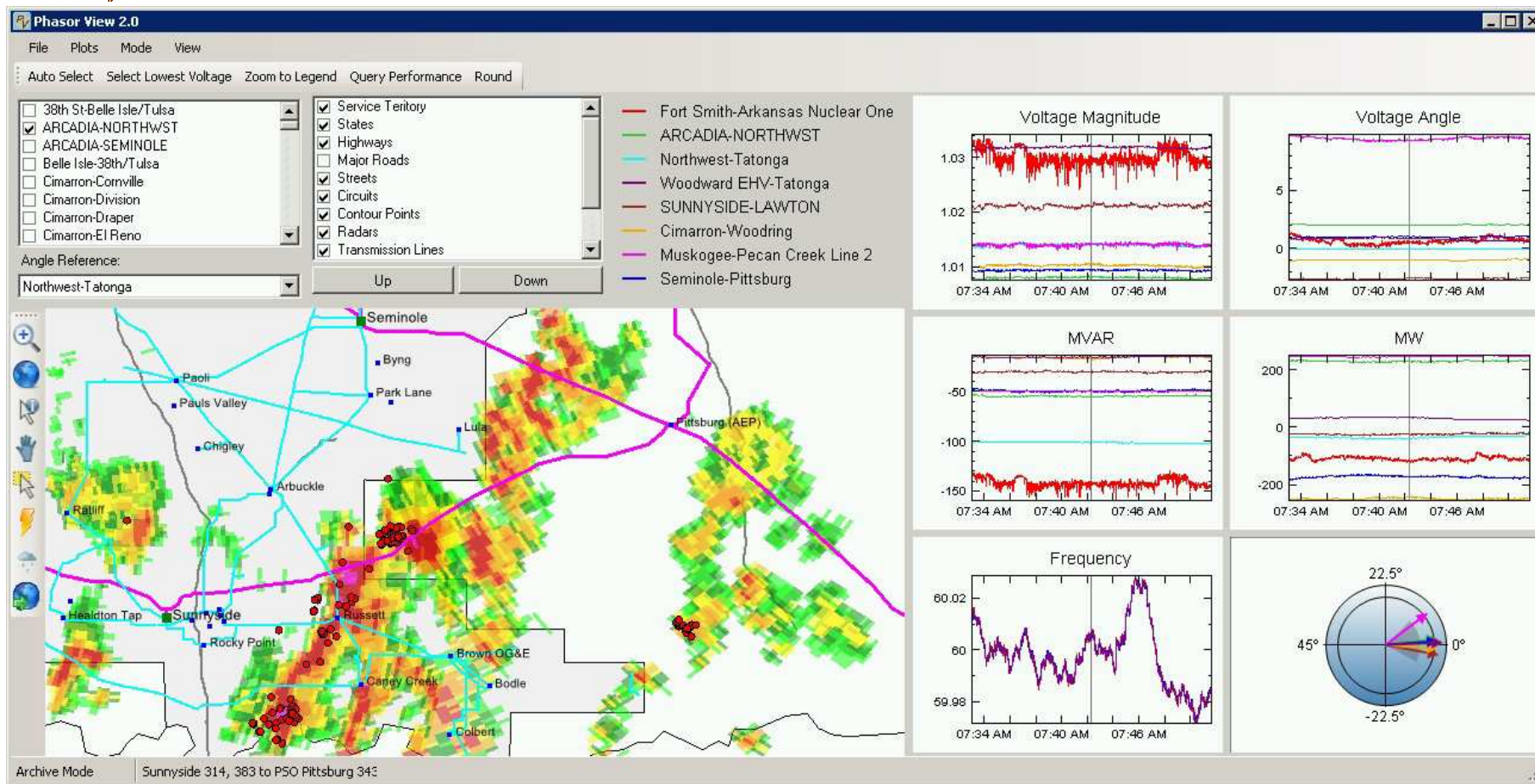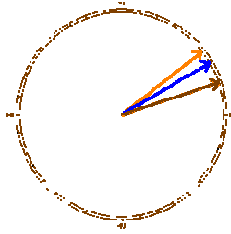- □ **Applications of SynchroPhasor Technology**

- □ Future Plans

Applications

- Situational Awareness

- Disturbance/Misoperation Analysis

- State Estimator Enhancement

- Stability Assessment

- Proactively Find Equipment Problems
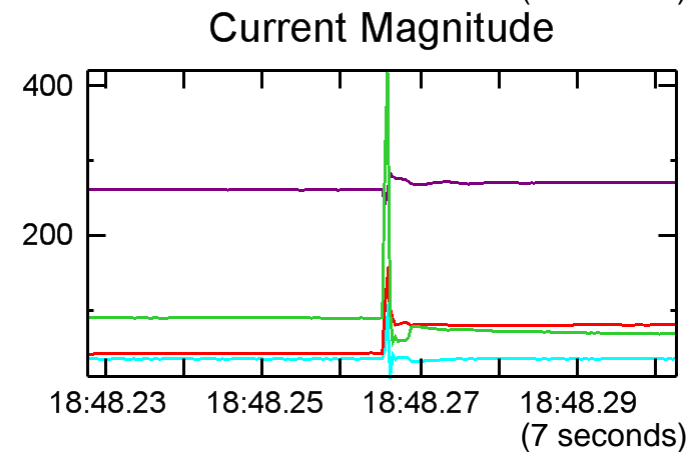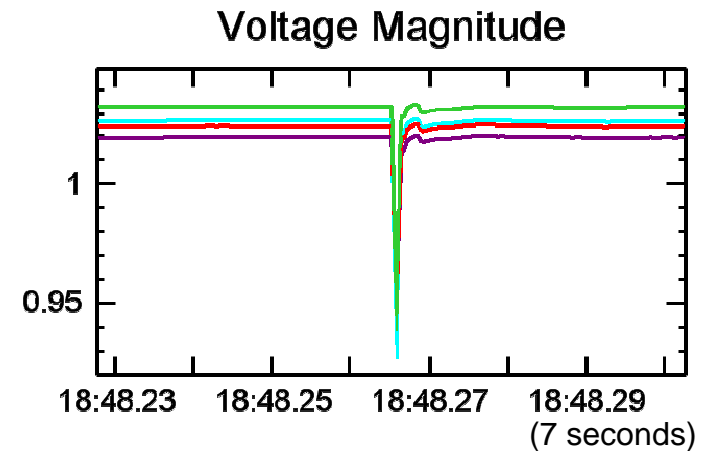
- Voltage Recovery Assessment (reactive reserves)
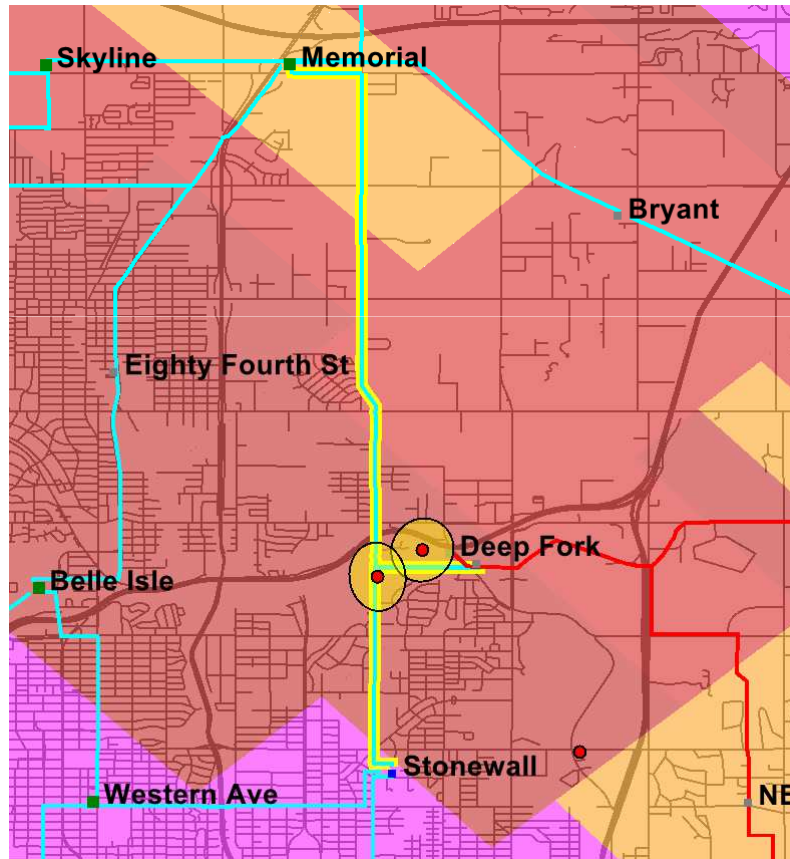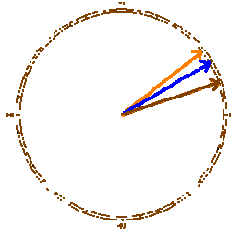
- Wind Farm Integration/Monitoring
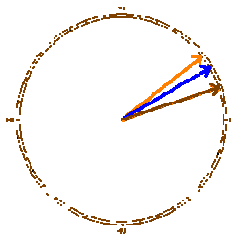
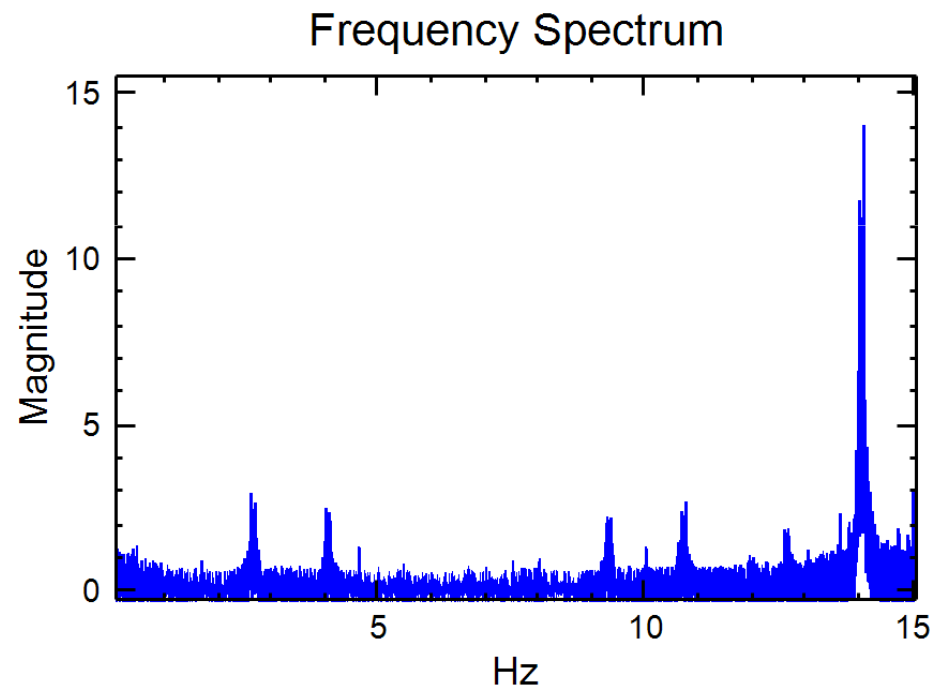# Situational Awareness - PhasorView

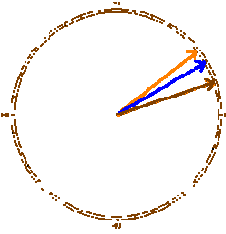# Disturbance/Misoperation Analysis with PhasorView

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

Frequency Spectrum
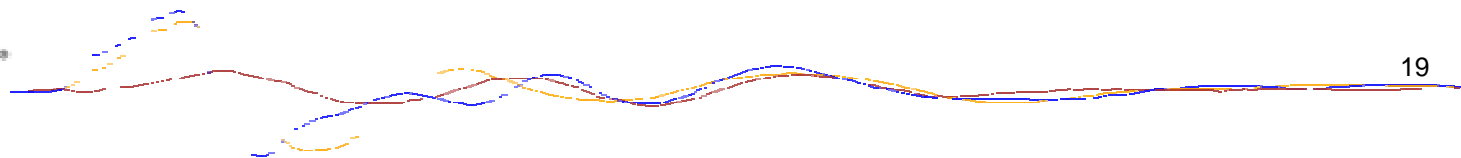
Discovery of Failing Equipment

- 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

Voltage Magnitude

(35 minutes)

Voltage Magnitude

(4 seconds)
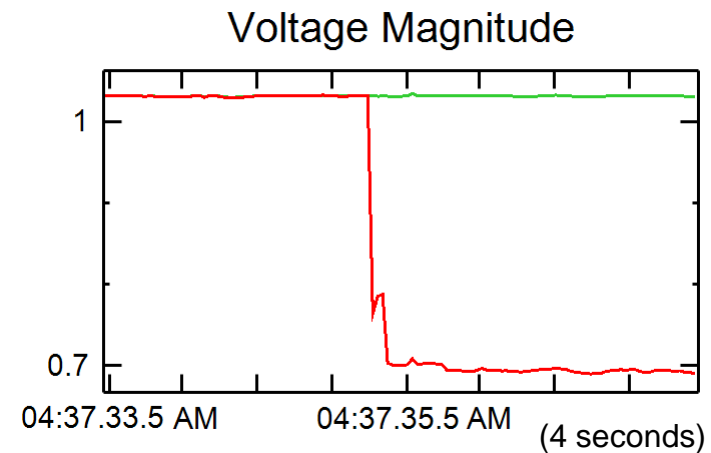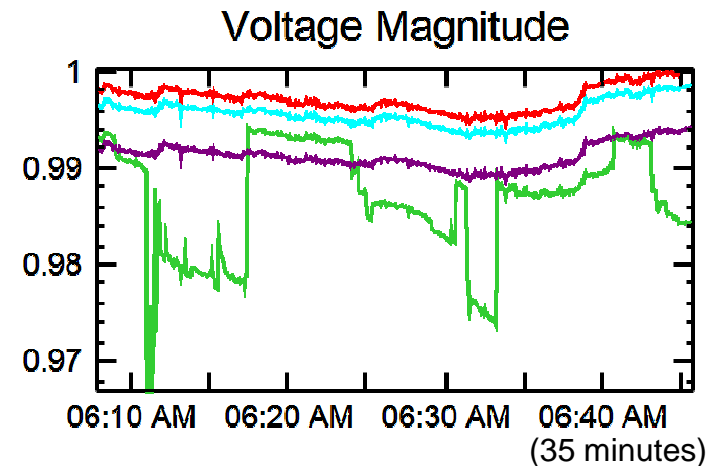
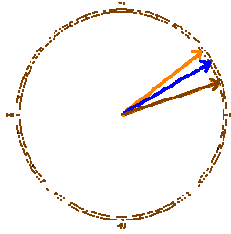# Strange Overcurrent Event

- 8/18/2011 – 345kV line from Sunnyside to Lawton went dead.

- 260 high current event were experienced.

- Both forward and reverse faults.

- Relay Testing.

Current Magnitude

(75 Minutes)
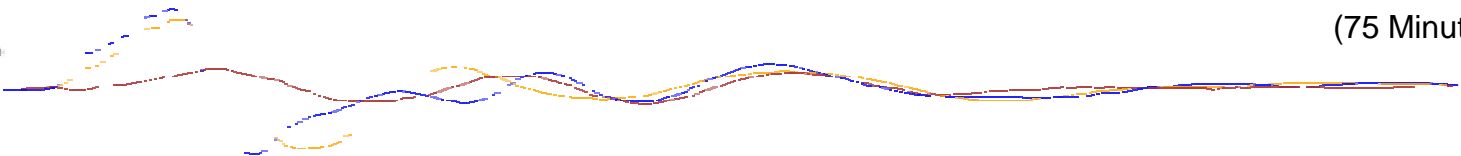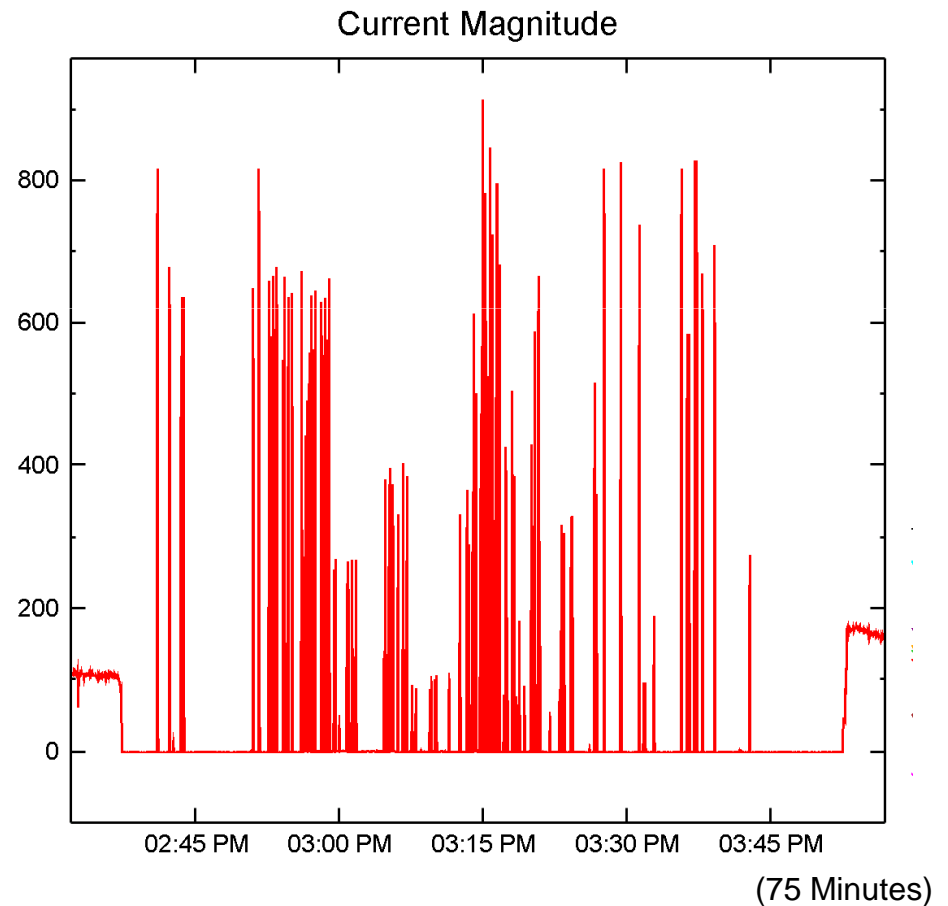
Voltage Recovery Assessment

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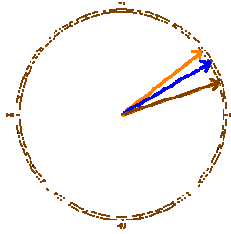
- Caused low voltage in southern Oklahoma, which involved multiple transmission owners

- Loss of generation was over 300 miles away

Voltage Magnitude

(30 minutes)
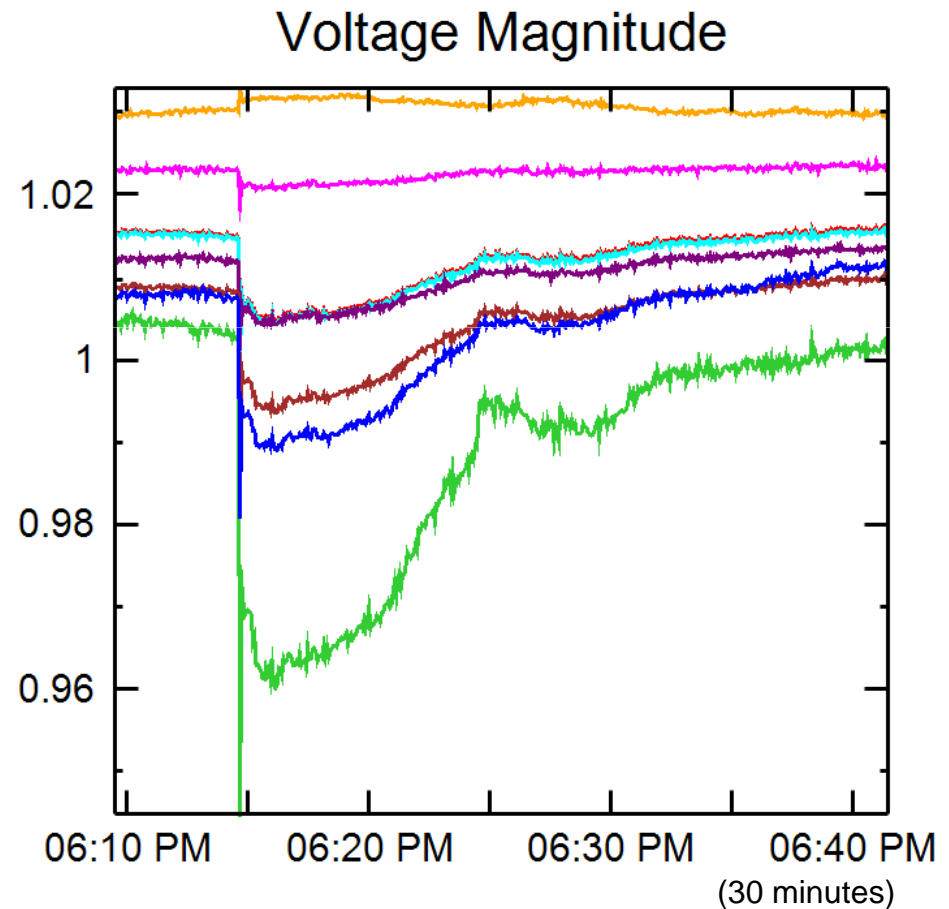
Voltage Depression during a fault

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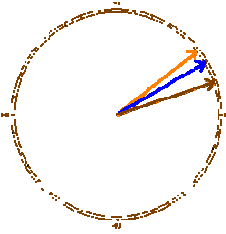
- Voltage pull downs are much worse when line communications (carrier) is turned off

Voltage Magnitude

11:56.06 AM   11:56.07 AM
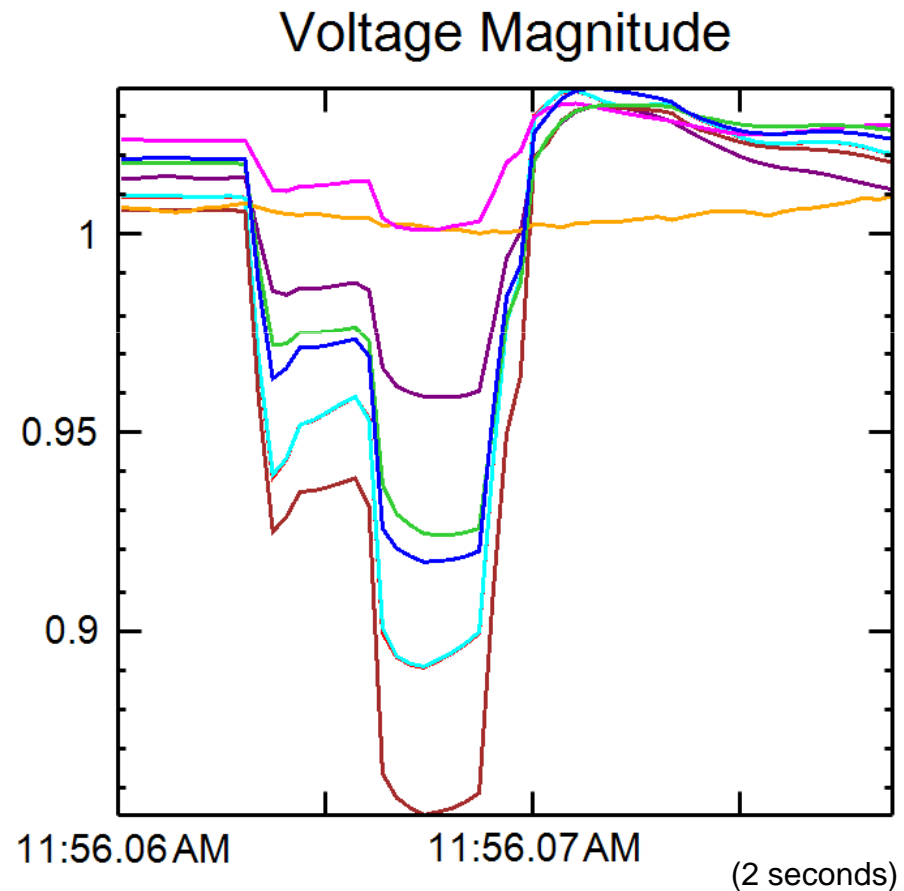
(2 seconds)

Importance of Breaker Failure Relaying

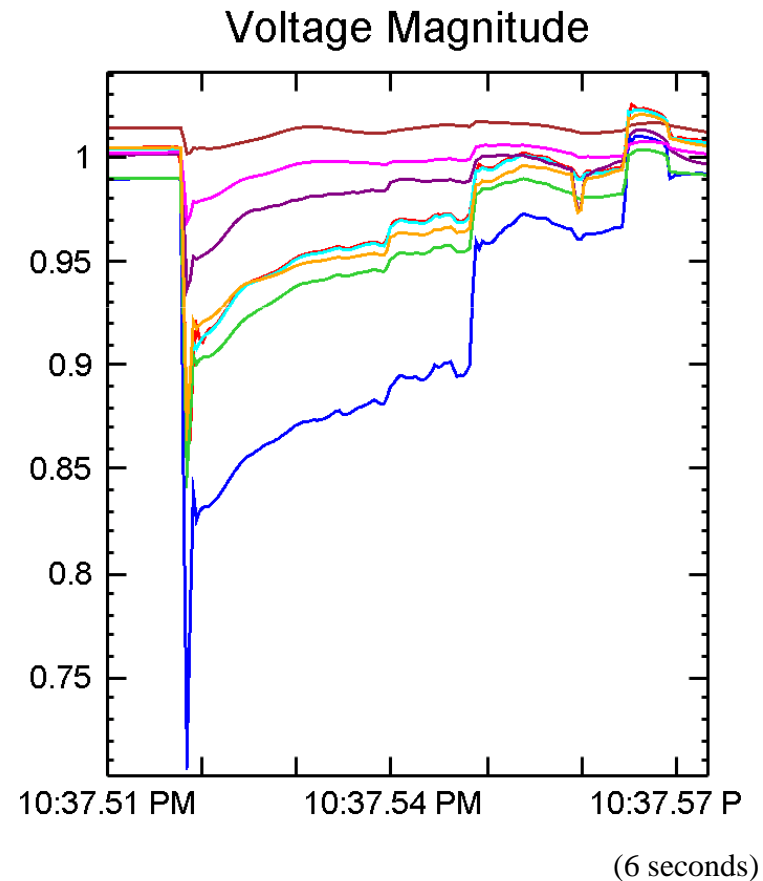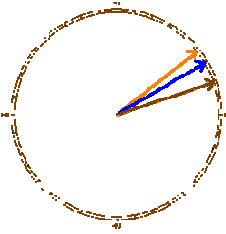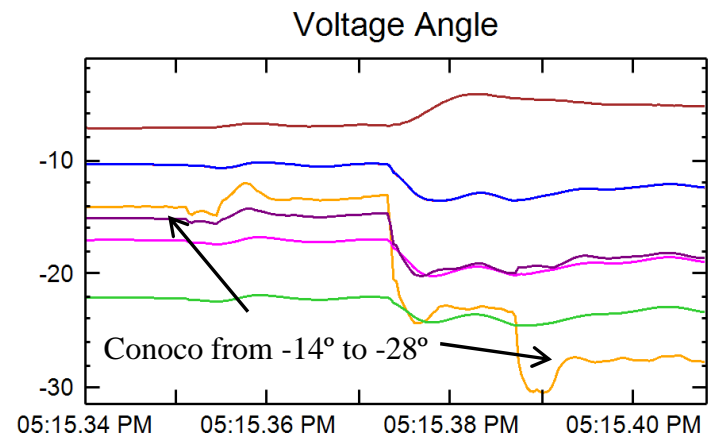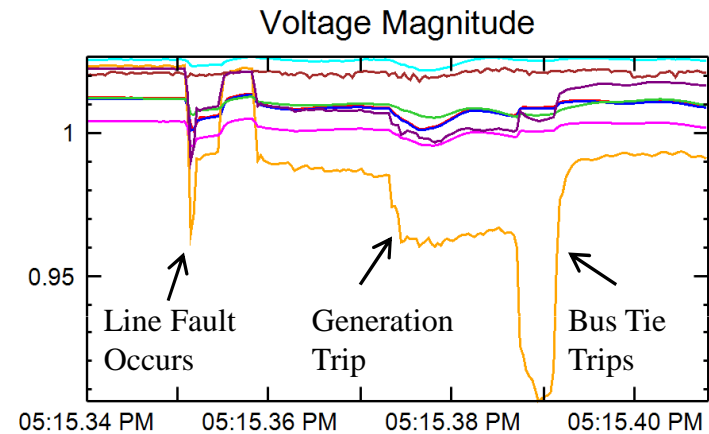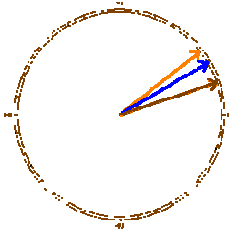- 4/26/09 – Hollywood PCB 185 failed to trip for a fault on the Wilkinson line.

- Breaker Failure relaying not installed on PCB 185.

- Took about <u>5 seconds</u> to clear the fault remotely

- Luckily nothing burned down and no generators tripped – this is the kind of thing that leads to blackouts
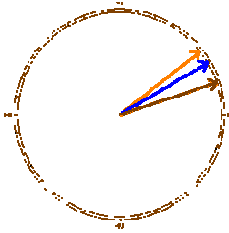
Voltage Magnitude

10:37.51 PM   10:37.54 PM   10:37.57 P

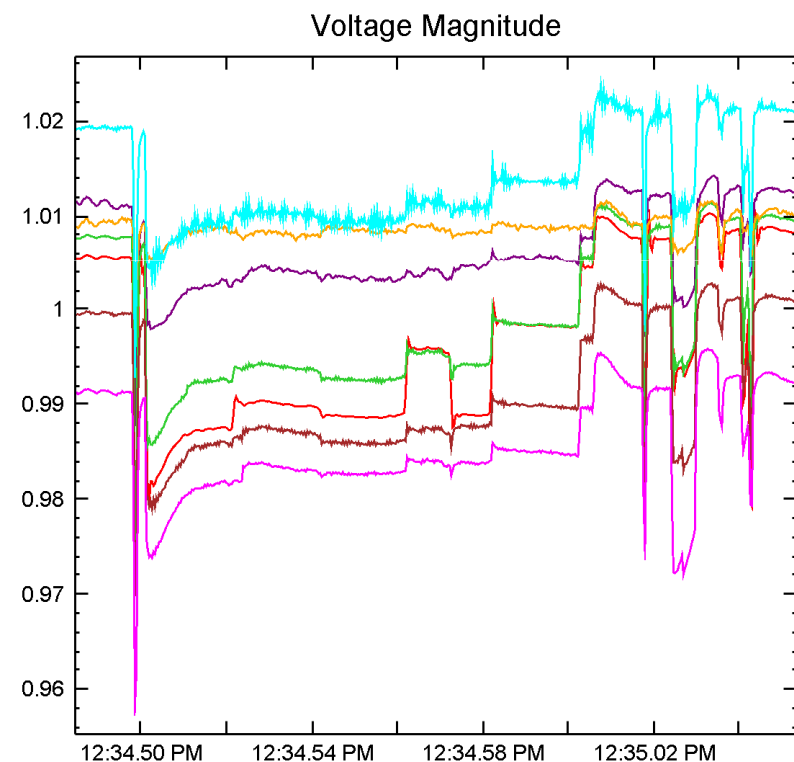(6 seconds)

<u>Another</u> 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
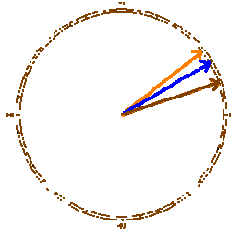
Voltage Magnitude

Line Fault Occurs   Generation Trip   Bus Tie Trips

05:15.34 PM   05:15.36 PM   05:15.38 PM   05:15.40 PM

Voltage Angle

Conoco from -14º to -28º

05:15.34 PM   05:15.36 PM   05:15.38 PM   05:15.40 PM

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
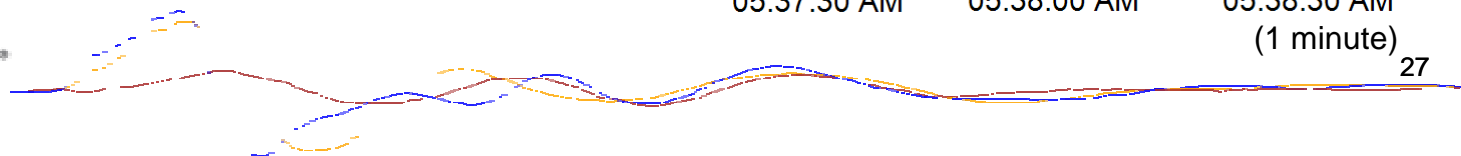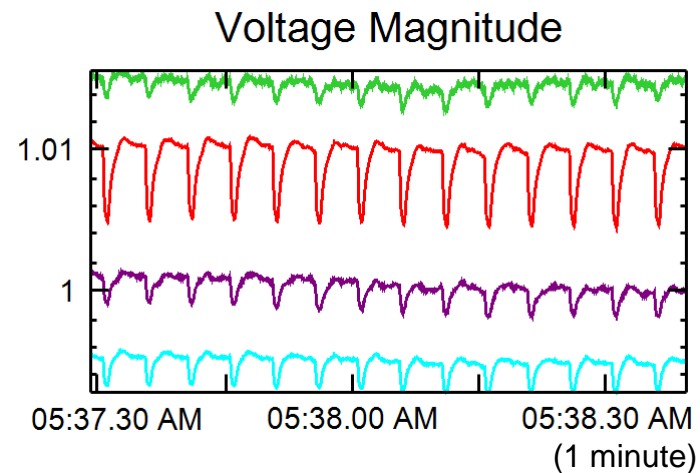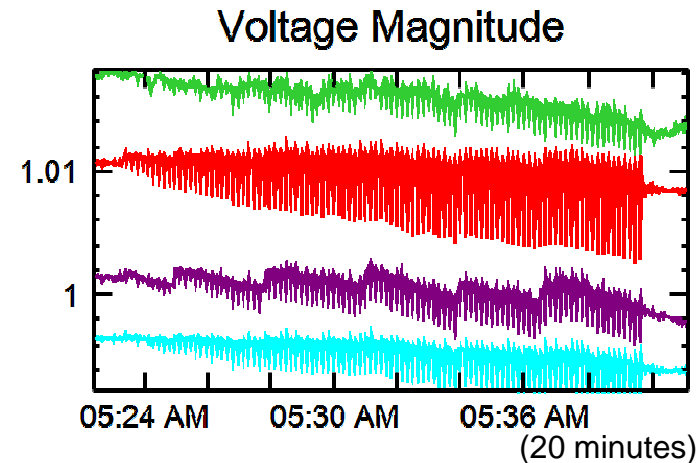- 32,000 Customers effected
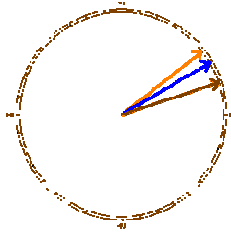- 2hr 17min restore time
- 4.1 Million CMI

Voltage Magnitude

(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

Voltage Magnitude

1.01

1

05:24 AM   05:30 AM   05:36 AM

(20 minutes)

Voltage Magnitude

1.01

1

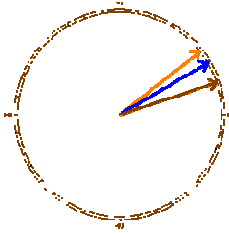05:37.30 AM   05:38.00 AM   05:38.30 AM

(1 minute)

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
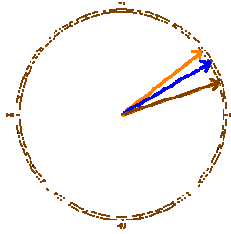- The only solution is to curtail output

Voltage Magnitude

(35 minutes)

**Voltage Magnitude**

(2 seconds)
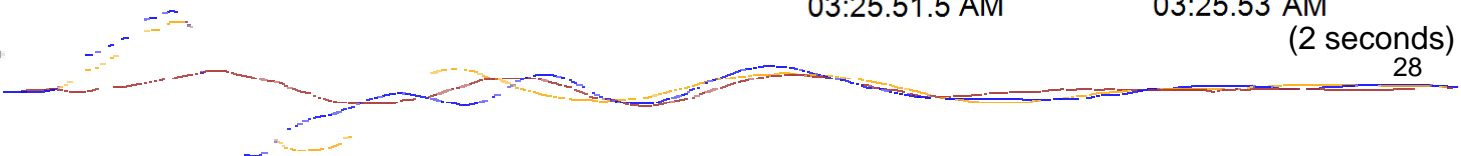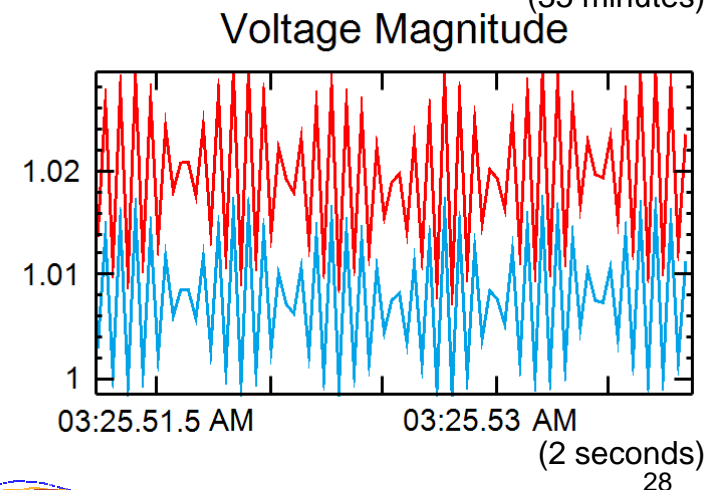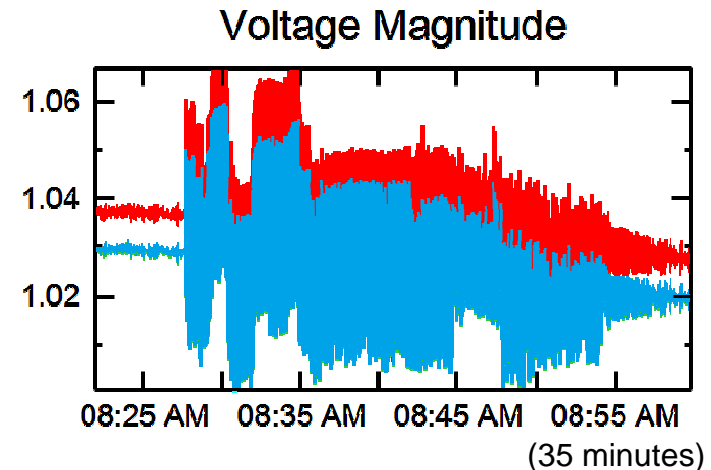
SCADA vs Synchrophasors

- Black trace shows the voltage magnitude reported by SCADA

- Red trace shows the synchrophasor data

- The oscillations are obviously undetectable with SCADA

Voltage Magnitude

1.04

1.02

08:25 AM   08:35 AM   08:45 AM   08:55 AM
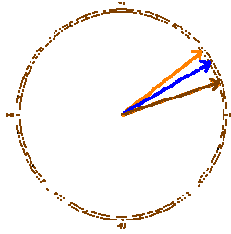
(40 minutes)

OG&E
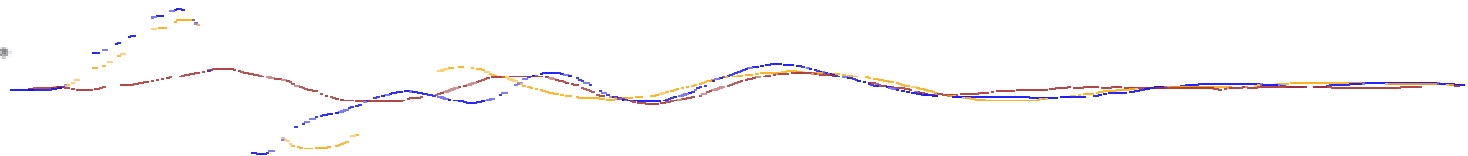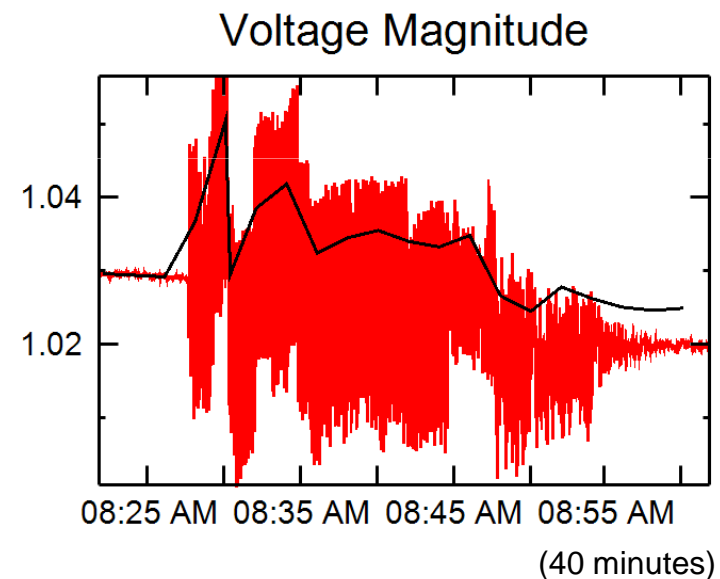
Customer Impact

- 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

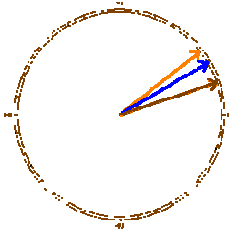- We are currently working with the manufacturer to resolve the issue
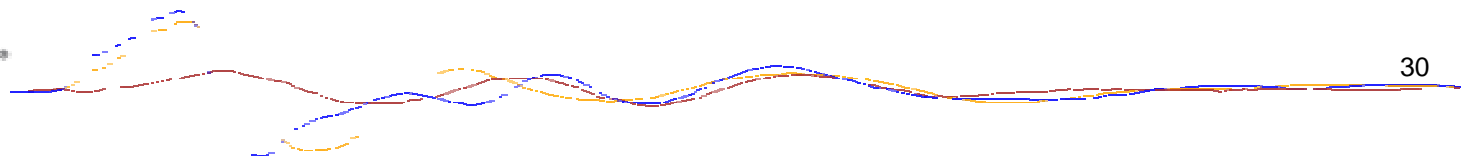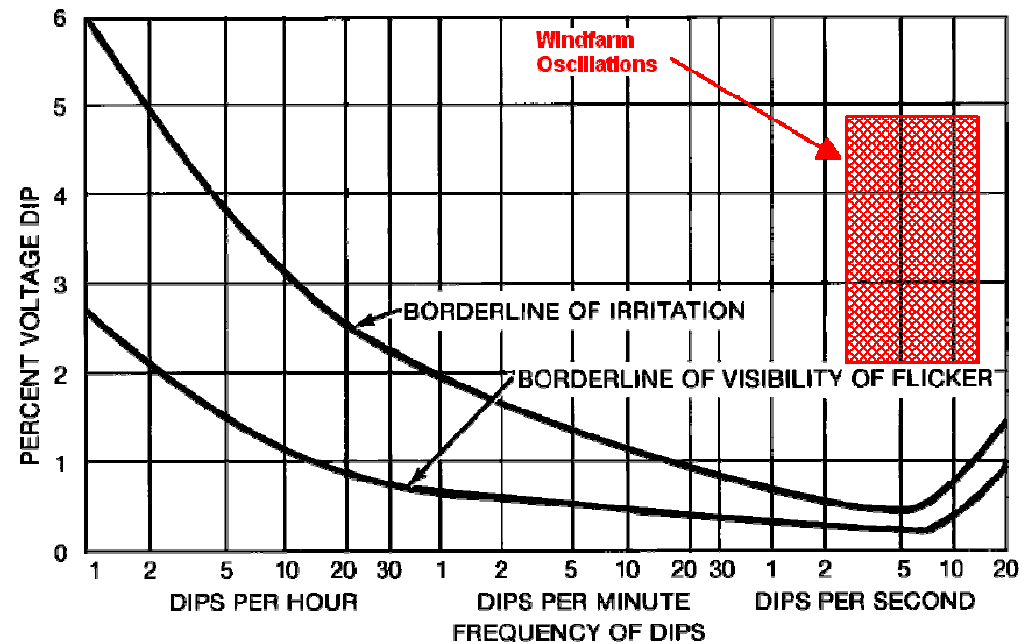
Monitoring Power Quality

- 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
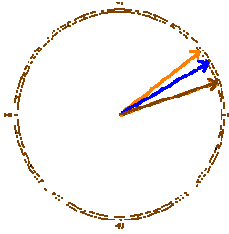
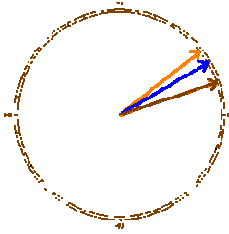**Voltage Magnitude**

(25 minutes)

MVA

(7 seconds)
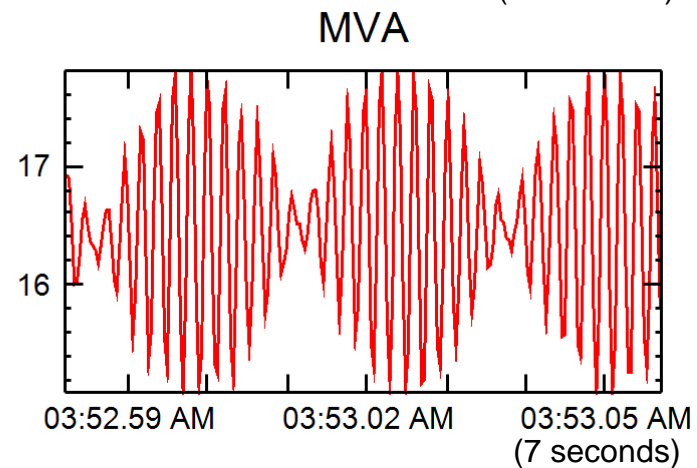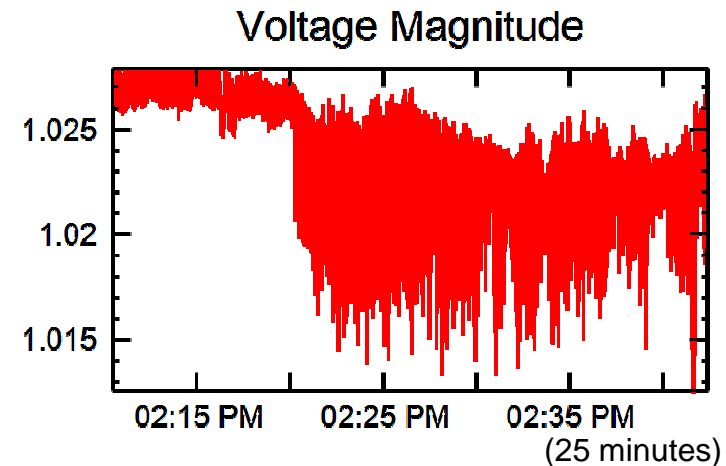
Generation Trips

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

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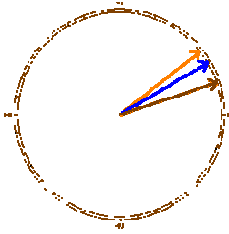 (Earthquake)
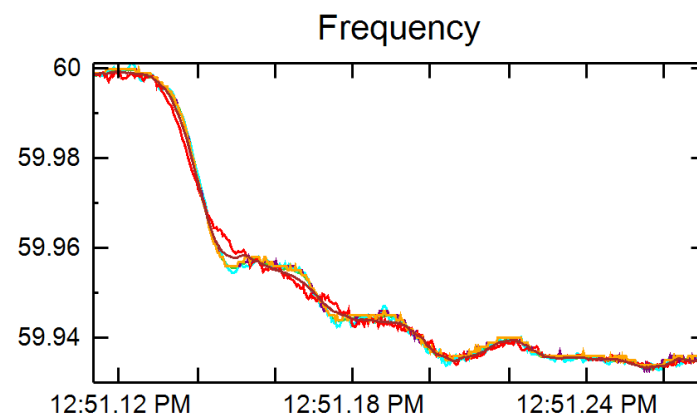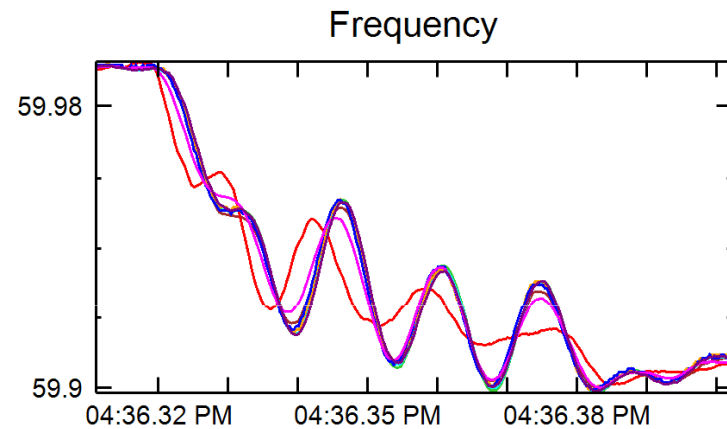
Frequency

Frequency

Outline

- History of Current Setup

- Use of OpenPDC

- Applications of SynchroPhasor Technology

- **Future Plans**

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.

Questions?

- Thanks! Feel free to contact us if you have any questions.
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