Synchrophasors at

Austin White P.E.
Oklahoma Gas & Electric Company
IEEE PES GM 2016
Outline

- OG&E Background
- Synchrophasor Applications
- Example Events
- Synchrophasor Based Protection
- Renewables Integration
PMU Deployment 2008-2015

PMUs Online

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

356 PMUs Total
Simplified Architecture

- **SIEGate**
  - 9 PDCs (SEL-3373)
  - 300+ PMUs (SEL-421)

- **openPDC**
  - GRID PROTECTION ALLIANCE

- **openHistorian**
  - GRID PROTECTION ALLIANCE

- **OG&E PhasorView**

- **Microsoft SQL Database**
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!

Voltage Magnitude

(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

Voltage Magnitude

02:20.21.000 PM 02:20.22.500 PM 02:20.24.000 PM
(4 seconds)
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.

Failing analog input

- Cimarron-Driver
- Cimarron-Minco
- Cimarron-Northwest
- Cimarron-Woodring
  - Cimarron-Cornville
  - Cimarron-Division
  - Cimarron-El Reno

(2 weeks)
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
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

PTP Network Tunnel

POTT Scheme utilizing dual PMU server/client channels to transmit and receive KEY

Transmission Line
No Traditional Comm Channel (carrier, fiber)
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)

- Blue line: June 27 (Highest)
- Red line: July 6 (Cloudy)
- Green line: June 17 (Lowest)
Comparing Days (Synchrophasor Data)
Output With Cloud Coverage

KW

Partly Cloudy  Clear Sky  Rainy

10 AM  11 AM  12 PM  1 PM  2 PM  3 PM  4 PM  5 PM  6 PM
Questions?

• Thanks! Feel free to contact me if you have any questions.
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OG&E’s PhasorView