gridSMART® at AEP

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PNNL-SA-105365
Agenda and Discussion Goals

- Opening Comments and Introductions
- Review of the IVVC System in Owasso, OK
- AEP VVO Technology Plan
- Alternate Evaluation Method – Bump Test
- Other gridSMART Activities
  - Communications and Network Architecture
  - AMI
  - Rural Applications
  - Sensors
  - Distribution Automation
- Questions
- Adjourn
AEP System Overview

- 5.3 Million customers
- 11 States
- 39,000 MW Generation

AEP Service Territory

- 39,000 miles Transmission
- 220,000 miles Distribution
- 6,000 Distribution Circuits
- 3,200 D Transformer Windings
# gridSMART® Modernization Activity Summary

<table>
<thead>
<tr>
<th>Projects</th>
<th>Smart Meters</th>
<th>DACR Circuits</th>
<th>VVO Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEP Ohio - Phase I</td>
<td>132,020</td>
<td>70</td>
<td>17</td>
</tr>
<tr>
<td>AEP Ohio - Phase II</td>
<td>900,000</td>
<td>250</td>
<td>50-80</td>
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<td>AEP Texas</td>
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<tr>
<td>PSO- Phase I</td>
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<tr>
<td>PSO Phase II</td>
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<td>I&amp;M</td>
<td>9,850</td>
<td>9 complete + 25 proposed</td>
<td>9</td>
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<tr>
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<tr>
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<td>3 complete + 3 planned</td>
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<tr>
<td>SWEPCO</td>
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<td>16 complete + 3 proposed</td>
<td>N/A</td>
</tr>
</tbody>
</table>

*Data is approximate/estimated*

*Distribution Automation Circuit Reconfiguration (DACR)*

*Volt VAR Optimization (VVO)*
PSO gridSMART – System Overview
Goals of IVVC Operation:

- Flatten and lower voltage profile
- Better control VARs
- Reduce demand and energy consumption
- Maintain ANSI Voltages
- Interoperable with DACR

[Similar to CAN3-C235-83 (R2000)]

– Nominal 120 VAC – Range A (Normal Operation)

- Service Voltage 114 V – 126 V
  - Voltage at which utility delivers power to home

- Utilization Voltage 110 V – 126 V
  - Voltage at which equipment uses power
  - Optimum voltage for most motors rated at 115 v
  - Incandescent Lamps rated at 120 v
IVVC Day On vs Day Off
VAR Control

Owasso Total kW, kVar, kVA
(>) Sat Aug 24 2013 00:00:00 - Tue Aug 27 2013 00:00:00 (<=)

Date/Time
Reading

- Owasso Total kW/RTU Owasso 109th Min: 30198 Max: 87819 L
- Owasso Total kVar/RTU Owasso 109th Min: -1900 Max: 8854 L
- Owasso Total kVar/RTU Owasso 109th [Fri Aug 23 2013] Min: -1900 Max: 16556 L
- Owasso System TotalkVA/RTU Owasso 10 Min: 30516 Max: 87839 L
Major System Components Include

- 3 distribution substations with 3-LTC’s and two (2) non-LTC transformer with bus regulators
  - LTCs using Beckwith control and bus regulators using Cooper Power CLB6 Control
  - Breakers using SEL351S Relays
  - Breakers using S&C Intellinode modules
- 13 distribution feeders on a 13.2 kV base system (2 external ties)
- 43 S&C IntelliRupter DACR Switches and 21 Intellinodes on breakers and transformers
- 47 S&C IntelliCap Plus Series Capacitor Controls
- 50+ End of Line (EOL) voltage sensors 9 field distribution voltage regulator banks using Cooper Power CLB6 Control
- L&G Series IV IWR Radio (serial not IP)
  - Separate Radio network from the metering portion of the project.
- SCADA Integration
DIFFERENT REGULATION TOPOLOGIES AFFECT THE REGULATION ZONE

(A) Regulation with LTC
All the station circuits and phases are regulated to the same tap. The lowest point on any phase on any feeder limits the voltage reduction.

(B) Station Bus Regulation
Each phase of all feeders is regulated to the same tap. The lowest point on each phase limits the voltage reduction for that phase on all feeders.

(C) Feeder Regulation
Each phase of each feeder is regulated independently. The lowest point on each phase of each feeder limits the voltage reduction for that phase on that feeder.
Experience with three vendors:
(alphabetical order)

- Cooper Yukon VVO
- GE VVO
- Utilidata AdaptiVolt™ VVO
IVVC Performance In Multiple States
Integrated Volt VAR Control (IVVC)
AEP’s gridSMART Projects
Performance Evaluations

- AEP has installed and evaluated different IVVC systems, in different areas, on different feeders with different load dynamics and electrical topologies.
- We have seen varying results from these system studies, as is expected.
- It is not correct to directly compare the operation of the various systems due to many factors including:
  - Load composition
  - Electrical System topologies including regulators, capacitors, conductors, stations
  - Class of customers and the overall load mix
  - Data resolution used in the study
- What is the take away then?
  - IVVC works and does achieve savings to the end use customer.
  - All systems have room for improvements.
  - Example: do they achieve operation within limits, pf control, increase or decrease the operation of devices versus no IVVC?

- Volt Var Optimization technology works as expected
  - Testing validates that ~2-4% energy and demand reduction is achievable.
AEP asked PNNL to evaluate the effectiveness of the Yukon IVVC system as an independent third party.

2013: Day-on / day-off evaluation of effectiveness of IVVC system
- Formal kick-off meeting to confirm operating methodologies, setpoints, data collection
- Highly favorable results – significant energy savings
- Power factor controlled on average more closely to unity compared to default settings

2014: Follow-up Study
- New method of evaluation – “bump test” – compared to day-on / day-off method
- Savings evaluated based on energy consumption recorded at the customer meter
  - Behind-the-meter savings verified
  - Results broken out by customer class
Binned data plotted vs time of day

- Raw real power demand of a single feeder vs time of day
  - Each small dot is an individual MW measurement
  - Thick solid lines are the average of the two bins
- To remove confounding effect of correlation of power demand with ambient temperature, apply temperature correction process
  - Fit polynomial to real power demand vs ambient temperature
  - Apply correction factor to shift demand to median temperature
  - Perform independently at each time of day
Binned, temperature-corrected power demand
Voltage regulation

- End-of-line voltage set points consistently reached
- Significant voltage reductions achieved of 3.5-6.5V

Example end of line voltages

EOL Voltage setpoints:
- Peak hours of 7:00 AM to 7:00 PM
  - 117.25V lower limit, 126V upper limit
- Off Peak hours 7:00 PM to 7:00 AM
  - 116.5V lower limit, 126V upper limit
Reduction in energy consumption

- Plots show per-phase energy reduction for each of the 13 feeders
  - Left: total MWh/day
  - Right: %

- System-wide totals (weekday):
  - 4.5±0.3% per day
  - 56.0±3.0MWh per day
Day-on / day-off VVC analysis protocol requires 90 days of day-on day-off data collection, large amounts of data (150 million data points), and complex temperature correction.

**Goal:** develop a simpler method of benchmarking a VVC system that could be done in a shorter period of time.
Bump test motivation

- When the IVVC system is turned off, the voltage rises abruptly.
- As the voltage rises, the power demand also rises abruptly.
- The size of the response at that single point may be indicative of the instantaneous power demand reduction of the VVC system.
Data from customer meters

- Energy reduction behind the customer meters
  - Warrants more study
  - Large percentage of total energy reduction is behind the customer meter

- Residential customers showed the strongest CVR response, commercial intermediate, and industrial customers showed a weaker CVR response
Conclusions

- Overall reductions in energy consumption were significant.
- Power factors at the feeder level were improved by the Yukon IVVC system.
- Bump test percentage energy reductions match day-on/day-off study well.
  - Day-on/day-off study requires 150 million data points and 90 days of data.
  - Bump test calculation requires 2,500-30,000 data points and 7-14 days of data.
  - Promising enough to warrant further study.
- Energy savings verified to be substantially behind the customer meter.
- Residential customers showed the strongest CVR response, with commercial, intermediate, and industrial the weakest CVR response.
Other gridSMART Activities

- AMI/AMR
- TOU Rates
- Demand Respond
- Batteries, CES
- Rural Applications
- Distribution Automation
  - Using many different technologies around the system
  - Integrating to SCADA systems
  - Developing standards for installations
  - Ensuring integration with manual, UF and UV load shedding
- Communications and Network Architecture – Mr. Brandon Fugate
Rocky Junction
Remote application

IRs
Take Out Box
Regulators
Remote Access

Improve Reliability
Government Wells
Remote application
Safety and Resources

- Remote Location
- Improvement in Reliability needed
- Safety for Employees
- Funding Levels
Communicating Fault Sensor
Capacitor Bank Monitoring
Communications

- **Wide Area Networks** (Backhaul)
  - Routers connected via transport system
    - Fiber, Microwave, Lease-line(MPLS), Cellular

- **Local Area Networks** (Local)
  - Ethernet Switches, Relays, Converters, HMI

- **Neighborhood Area Network** (Field Communicating Devices)
  - Distribution Switches, Capacitor Banks, Voltage Regulators, Sensors
Network Architecture

**Back Office**
- TSCADA
  - Corp
- DSCADA
  - VVO
- DACR
  - TSCADA Network Firewall

**Station**
- Transmission RTU
  - Distribution Breakers
  - Distribution Cap Banks
  - Bus Tie Breakers
  - Transformer LS Breaker
- Distribution RTU
  - Intellinodes
  - LTC’s
  - Bus Regulators
- Station Router
  - Trans. NonCIP
- Station Router
  - D Network
- Station Router
  - Field Network

**Field**
- Line Devices
  - Reclosers
  - Line Regulators
  - Capacitors
  - Line Metering Devices
NAN RF Propagation of Owasso Area DA\VVO
Communication (CGR)
Communication (Antennas)
Communication (Take-Out Box)
Regulator Station Install
Communications Regulator Control
Thank you.

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