GRID MODERNIZATION AT AMERICAN ELECTRIC POWER

SOUTHWEST ELECTRIC DISTRIBUTION EXCHANGE
General Session: Design
2019 Conference
Fort Worth, Texas
May 2, 2019

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Discussion Topics

- American Electric Power (AEP)
  - Company Overview
- Grid Modernization Efforts
- Technology Currently Being Deployed
- VVO Systems
- Urban vs Rural areas
- Challenges to implementation and lessons learned
- Questions
AEP purchased Sempra Renewables LLC and its 724 MW or wind and battery assets. (April 2019)
INVESTING IN DISTRIBUTION
<table>
<thead>
<tr>
<th>Company</th>
<th>Smart Meters</th>
<th>DACR Circuits</th>
<th>VVO Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEP Ohio</td>
<td>703,997</td>
<td>90</td>
<td>41</td>
</tr>
<tr>
<td>AEP Texas</td>
<td>1,077,119</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>Public Service Company of Oklahoma</td>
<td>575,564</td>
<td>45</td>
<td>52</td>
</tr>
<tr>
<td>Indiana Michigan Power Company</td>
<td>15,364</td>
<td>36</td>
<td>49</td>
</tr>
<tr>
<td>Kentucky Power Company</td>
<td>N/A</td>
<td>24</td>
<td>27</td>
</tr>
<tr>
<td>Appalachian Power Company</td>
<td>196,113</td>
<td>46</td>
<td>3</td>
</tr>
<tr>
<td>Southwestern Electric Power Company</td>
<td>N/A</td>
<td>34</td>
<td>0</td>
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</tbody>
</table>

Smart Grid plans are continuously evolving. Data is approximate/estimated.
AMI/Smart Meter data through 2018.

Total DACR 302 circuits or ~5% of total 6,560 circuits.
Total VVO 172 circuits or ~3% of total 6,560 circuits.
Grid Modernization Efforts

- AMI/AMR
- TOU Rates
- Demand Respond
- Batteries, CES
- Distributed Generation – utility and customer owned
- Microgrid
- Communicating Fault Circuit Indicators (cFCIs)
- VVO/IVVC
- 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
- Distribution and Transmission SCADA Network
- Communications and Network Architecture
- Breaker replacement
- Relay Upgrades
Robust Distribution Capital Expenditure Opportunities

<table>
<thead>
<tr>
<th></th>
<th>Distribution Transformers</th>
<th>Circuit Breakers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life Expectancy (years)</td>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>Current Quantity over Life Expectancy</td>
<td>923</td>
<td>993</td>
</tr>
<tr>
<td>Quantity that will exceed Life Expectancy in next ten years</td>
<td>514</td>
<td>977</td>
</tr>
<tr>
<td>Total Renewal Opportunity over ten years</td>
<td>1,437</td>
<td>1,970</td>
</tr>
</tbody>
</table>
Examples of Incremental Distribution Investment Opportunities

- Grid Modernization
  - Distribution Supervisory Control and Data Acquisition
  - Smart Circuits

- Distribution Line Re-Conductoring
  - Replace deteriorated small wire
  - Increase capacity to facilitate ties for smart circuits
  - Over 86,000 miles of small wire is in service across the operating companies (age profile at least 40 years)

- Pole Replacement Programs
- Obsolete Station Breaker Replacements
- Capacity/Reliability Projects
- Distribution Station Transformers

**Represents ~ $500M/year of incremental investment opportunity to improve system reliability and modernize the system**
What is being deployed?
Some Other types being used in AEP East

- Remote Access Gateways (RAGs)
- RAG GAPs
- 15 kV, 25 kV and 35 kV IntelliRupters
- S&C IntelliCAP 2000 Capacitor Bank Controls
- Communicating Fault Circuit Indicators (cFCI)
- L&G Radio network in devices and stand alone routers (repeaters) with monitoring
- L&G Street Light Photocell radio
- Voltage Regulators – both station and line – CL6, CL7, Beckwith
- LTCs – DDC Monitoring and Control
- Distributed Energy Resources (DER) (ex DG, solar)
- End of Line Voltage Monitors (EOLs) – new design with a meter
- Integrated Volt VAR Control (IVVC or VVO or CVR)
- New DGM Box - design of a low cost, high accuracy voltage, current, fault current
- Intellinodes
- DRTUs
- B2500 Cabinets, S4X Meter
Equipment You Will See

S&C IntelliRupter

- Fault Interruption
- Distribution Grid Sectionalization
- SCADA control
- Hot Line Protection for DLINE crews
- Increase System Reliability
- Oil Circuit Recloser Replacement
- Fuse Saving application
- Decrease system fault impact
- SCADA visibility on remote stations/feeders
Equipment You Will See

MM3 Intelligent Grid Sensor - cFCl

• Fault Detection
• Feeder fault troubleshooting
• Instantaneous load current on demand
• Conductor Temperature
• SCADA visibility on remote stations and feeders
• Non-SCADA OCR trip detection via loss-of-field
• Communications Mesh support
S&C IntelliCAP 2000

- SCADA Control of distribution CAPs
- Yukon Feeder Automation (CVR-PSO)
- CAP Bank Exercise via Yukon (SWEPCO)
- Wi-Fi option increases field operator safety
- Better multi-season control
- Gives system operators control of voltage support
Equipment You Will See

Eaton CL-6B / CL-7 Regulator Control

- SCADA Control of distribution REGs
- Yukon Feeder Automation (CVR-PSO)
- Better multi-season control
- Gives system operators control of voltage support
- Offers control of reverse power regulation
- Remote Engineering Access
DGM Box
Distribution Grid Monitor
Equipment Installation
Equipment Installation
IntelliRupter, Capacitor Bank

Including Siemens Switch
Neutral and VAR Sensor
VVO / CVR / DACR Data Flows

Diagram showing data flows involving various devices and systems such as AREEVA T-SCADA, D-SCADA, POA D-SCADA, TRANSMISSION OPERATIONS, DISTRIBUTION OPERATIONS, POA VIEWER, YUKON ADMIN, YUKON DATABASE SERVER, and YUKON COMM SERVER, connected through ethernet and serial interfaces.
Information passed from T SCADA Network to D SCADA Network by programming static routes in the substation router for each device.
Smart Circuits Architecture

Volt VAR Control System

Mesh Master

- Mesh Network
- Reclosers or Switches
- Line Regulators
- Line Capacitors
- Line Voltage Monitors

DMS

- Fiber or Mesh
- Breaker Control
- Transmission RTU
- EIA-485
- Cat 5
Radio Systems

L&G 900 MHZ
Cellular – Public and Private
AMI
  L&G
  SSN
Speednet
Fiber

Device Numbers – We have standards established.
  SCADA, Field view, DNP address, D and T Networks
Leave existing numbers on locations until new equipment is commissioned.

Standard for AEP West
Will match in Small world/Field view, POA, AREVA, SCADA/RPA
VOLT-VAR Optimization (VVO)
ANSI Standard C 84.1 – 1995 “Electrical Power Systems and Equipment – Voltage Ratings” [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
Goals of VVO Operation:

- Flatten and lower voltage profile
- Better control VARs
- Reduce demand and energy consumption
- Maintain ANSI Voltages
- Interoperable with DACR
VVO Performance In Multiple States

VVO achieves a 3% energy reduction on average
• **Used by AEP**
  - Utilidata AdaptiVolt – IN, MI, OH, KY
  - Cooper / Eaton Yukon – OK, WV
  - GE D 400 – OH (Not considered for new deployments)
  - GE POA – (Will be tested when available)

• **Not used by AEP**
  - Dominion / DVI Edge (Requires AMI)
  - S&C IntelliTeam VV (Model Based)
.....Rural and Urban System (not current totals)

<table>
<thead>
<tr>
<th>Number Circuit WO/SCADA (est)</th>
<th>Percent Total</th>
<th>Number Circuit W/SCADA (est)</th>
<th>Percent Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2175</td>
<td>34.3%</td>
<td>4163</td>
<td>65.7%</td>
</tr>
</tbody>
</table>

*May not be complete SCADA in existing locations.

Grid of the Future

<table>
<thead>
<tr>
<th>AEP</th>
<th>Urban, Suburban, Rural</th>
<th>Circuit Count</th>
<th>Total Miles</th>
<th>Customers</th>
<th>% Circuits</th>
<th>% Miles</th>
<th>% Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban (&gt;150 customer/mile)</td>
<td>68</td>
<td>228</td>
<td>51,076</td>
<td>1.1%</td>
<td>0.1%</td>
<td>1.0%</td>
<td></td>
</tr>
<tr>
<td>Suburban</td>
<td>1,331</td>
<td>22,860</td>
<td>1,586,622</td>
<td>20.7%</td>
<td>10.3%</td>
<td>29.7%</td>
<td></td>
</tr>
<tr>
<td>Rural (&lt;50 customers/mile)</td>
<td>5,041</td>
<td>199,140</td>
<td>3,695,873</td>
<td>78.3%</td>
<td>89.6%</td>
<td>69.3%</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6,441</td>
<td>222,229</td>
<td>5,333,572</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Implementation Challenges

- Scope and size of deployments are difficult to manage with multiple technologies
- Difficult to develop and retain SMEs
- Large, old systems requiring large scopes to upgrade
  - Communication in stations, old breakers, relays, RTUs
- SCADA Systems
  - Two systems today – POA and AREVA
- Commissioning of systems – time consuming for field and dispatch centers
- Firmware and software management
  - How to test
  - When to adopt
- Training and sharing of knowledge on systems and operations
- Data management
  - Collection of locations, programming, hardware, firmware
  - Device moves, deletions and additions create additional complexity
- Second Day Support
  - Roles and responsibilities
  - SGCC, NOC
  - Operations Company Support
Implementation Challenges

- Must develop a wide range of skills and knowledge including networks, security, communications, protection and controls, station, relaying, operations.
- Communications is the key
  - For the systems to work together
  - For the groups to work together
- Must be aware of
  - Under voltage
  - Under frequency
  - Manual trip
  - Hot Line Tagging (HLT) (field or DDC)
  - Loading Limits
- Vendors become partners. They are good at their systems not always on the systems as the integrate overall into the utility system.
  - Dallas Service Center
- System Phasing
- Difficulty in getting the final pieces completed.
Implementation Challenges

- Could benefit from better initial studies for placement and voltage regulation
- Impacts may point to needs for additional stations and feeders in urban areas
- Needs for better scheduling and better processes to keep the projects moving forward
- Develop and utilize standards as much as possible.
Implementation Challenges

Big key is communications. These projects take continued group effort. No one person has the ability or capacity to do it alone. It takes collaboration from almost every level and group inside the utility.
Comments/Questions
Thank you.