Utility Case Study: Volt/VAR Control at Dominion

Presented to EUCI VOLT/VAR OPTIMIZATION CONFERENCE
June 11-12, 2012
Dominion
Leading Energy Provider in Northeast U.S.

Leading provider of energy and energy services in the Midwest, Northeast and Mid-Atlantic regions of the U.S.

- 27,500 MW of electric generation
- 6,300 miles of electric transmission
- 11,000 miles of natural gas transmission, gathering and storage pipeline
- 947 billion cubic feet of natural gas storage operated
- Cove Point LNG Facility
- 2.4 million electric customers in VA and NC
- 1.3 million natural gas customers in OH & WV
- 2.1 million non-regulated retail customers in 15 states (not shown)
Alternative Energy Solutions: Supporting All of the Business Units

- Dominion Virginia Power
  - Electric Transmission
  - Electric Distribution
  - Unregulated Retail

- Dominion Generation
  - Utility Generation
  - Merchant Generation

- Dominion Energy
  - Gas Transmission
  - Gas Distribution
  - Producer Services
  - Appalachian E&P

Dominion Resources Services, Inc. Alternative Energy Solutions Group

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Customer Voltage Based VVO

Program Highlights
• Achieves precise customer voltage control.
• Provides substantial customer savings.
• Requires no change in customer behavior.
• Requires no customer purchases or incentives.
• Benefits all customer classes.
• Justifies investments in distribution and metering infrastructure.
• Integrates with other direct load control programs.

Key Deliverables
• Delivers significant and sustainable energy savings.
• Delivers significant and sustainable demand savings.
• Reduces demand, conserves energy, and reduces impact on the environment.
• Adapts to real-time system changes.
Customer Voltage Based VVO

1 to 6%
2 to 4%
1 to 2%

Dominion Voltage Inc.
Management and Mapping of a Distribution Assets

- Change volume of assets on distribution is significant
- Common to re-configure distribution connectivity
- Significant change in assets for large storm restoration
- GIS tracking of assets does not address electrical connectivity information
- Distribution GIS systems have significant data problems because of volume, age, size, and location
Geospatial Distribution Analysis, Control & Validation

Plan

- AMI Voltage Data
- GPS Location Data
- Circuit Phase & Connectivity

Validate

Manage

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Voltage Management with DMS/SCADA, DA, & AMI

System Installation
Transformer #2
Circuit 410 & 422

Circuit Geography

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The Energy “EPAD”

Three Applications within the Customer Voltage Based VVO:

**Planner** – Studies operating voltages, determines the average expected energy savings for the candidate circuits, and recommends any distribution upgrades required to achieve maximum savings.

**Manager** – Configures CVR and coordinates the operation of Capacitors, Regulators, & LTC’s.

**Validate** – Confirms achievement of expected energy savings through verifiable statistical analysis.
1. Target worst outliers with best fix
2. Fixing the additional points below 116 V would give additional range for CVR.
Integrate Customer Data into the Planning Software

Voltage at Peak Load: Traditional Planning Model Results

No visibility of isolated secondary voltage issues

Customer Voltages Mapped in Planning Software

Customer getting 113-114 V. Wrong meter – to be replaced.

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Improvement in Customer Voltage Quality

FM Data Plot for February 2012 to March 2012

Date

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The objective of the Measurement and Verification phase is to confirm through verifiable statistical analysis that the expected energy savings by circuit was achieved.

The rigorous statistical method incorporates a paired difference test that compares daily/hourly samples of the baseline circuit data (“OFF” condition) to the CVR circuit data (“ON” condition) under matched operating conditions.
Statistical Savings Analysis

Savings Results

- Lifetime Usage (MWh): 458,312
- Lifetime Savings (MWh): 10,356
- Lifetime Savings: 2.26%

- 30 Day Usage (MWh): 14,585
- 30 Day Savings (MWh): 501
- 30 Day Savings: 3.44%
$267,000 in energy savings yielded for 8,760 hours of CVR operations at the single Trabue Tx2

Demonstrated real-time feedback from premise level readings enabled Dominion to continuously execute voltage control to keep all customers in lower 5% band

Trailing 180 day performance yields $292,000 (5,144 MWh) in annualized energy savings
CVR technology is currently deployed in Midlothian, Charlottesville and Northern Virginia for approximately 80,000 customers.
Total CVR benefits increase as the Program is implemented across each circuit. Not just a “one and done”, ensures achieved benefits are sustained & new benefits are added as your grid grows.
In August 2008, Dominion Virginia Power had developed a business case for its AMI solution for its 2.4 million Virginia jurisdictional customers.

*Projections based on data filed in Dominion Virginia Power rate case PUE – 2009-00019.*

*Based on 2008 PJM Southern Region nodal forward price curves.*
Peak Load Distribution Analysis, Control & Validation

Hourly Load Profile

- Ckt 1
- Ckt 2,3
- Ckt 4,5,6
- All Ckts

Slow Voltage Raise

Peak Hour Data Samples

- Water Heater Energy Storage Affect
- Sequential Circuit Voltage Switching
- Return to VVO level with no secondary peaks
- No Customer impact
- DSM VVO

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Extending Measurement to the Utilization Level

**ANSI C84.1 Standard System Voltages**

- **Service Voltage**: The voltage at the point where the electrical system of the supplier and the electrical system of the user are connected.
- **Utilization Voltage**: The voltage at the line terminals of utilization equipment.

- **Range A**: Normal operational voltage range. Occurrence of voltage outside this range should be infrequent.
- **Range B**: Excursions of voltage above and below the Range A limits. While a part of practical operations, these excursions shall be limited in extent, frequency, and duration. Corrective action shall be taken to restore to Range A.
Geospatial Distribution Analysis, Control & Validation

Plan

- AMI Voltage Data
- GPS Location Data
- Circuit Phase & Connectivity

Manage

Validate

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Power Tagging Technologies
Sensors to measure grid device connectivity, voltage and load
Greenlet Technologies

Sensors to measure and control utilization level, voltage, and load

Centralized Application for Energy Service Companies and Utilities: Manages usage of millions of appliances in order to reduce peak power consumption. The software application monitors power, predicts power consumption and power reduction potential, sends notifications to customers prior to peak events, controls power reduction via Greenlet units and Internet communications, verifies actual power reduction and provides the required information for billing to help calculate payback to consumers for "Peak Shaving".

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Microgrid Management

- Viridity offers a unique controller to optimize microgrids.
- The microgrids created by Viridity are planned to minimize importation of electricity while simultaneously maximizing the opportunity to export electricity out of the microgrid.
- At Viridity Energy, we take every resource into account in the formation of the microgrid, including load, generation and distribution infrastructure.
- Often, reliability is the sole factor that is considered in the creation of a microgrid. As the industry has evolved, economics and security have been added as important factors. Our unique VPower engine brings all of these aspects together, allowing for economic, security and reliability to be symbiotic elements of the microgrid.
- Our Microgrid Solutions are designed to allow for evolution. It is our hope and anticipation that our clients will continue to introduce new technologies into their microgrids, and our technology and unique approach factors in that integration.
Extending Measurement to the Utilization Level

VCU Micro Grid

Build Smart Energy Applications

Instrument Energy Control in Micro Grid

Instrument Energy Use in Micro Grid

SCHOOL OF ENGINEERING - WEST
BASEMENT SWITCHGEAR ROOM

NOMENCLATURE

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Amperage Rating</th>
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<tr>
<td>Switchboard Main</td>
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<td>Motor Control Center B</td>
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<td>Panelboard X2B</td>
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<td>Fire Pump</td>
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<td>Automatic Transfer Switch</td>
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Case Study & Demonstration: VCU MicroGrid

Microgrid Demonstration
Engineering Building Distribution Grid:

1. 30 Power Tagging MIMs for Monitoring
2. Controllable Building Voltage Regulators
3. PTT Virtugrid Application System
4. 200 Greenlet DSM Controllers
5. EDGE Distribution Grid Control
6. Viridity Virtual Generation Aggregation
MicroGrid Vision: VCU Results to the Distribution Grid

"Under Construction"

Power Tagging Technologies On Wire Network Operation:
TIM - Distributed MicroGrid Controller - Communicates to VirtuGrid in Substation
WIM - Communication from Distributed Generation/Storage/Load to TIM
Total benefits increase as the Program is implemented across each Microgrid.

Not just a “one and done”, ensures achieved benefits are sustained & new benefits are added as your grid grows.
Summary

✓ Using Geospatial Distribution technology Dominion has developed and demonstrated a measurement based voltage control algorithm which enables a *practical execution of conservation voltage reduction with voltage optimization.*

✓ The Voltage optimization integrates between the existing DMS Software and AMI.

✓ Independent Measurement and Verification module for Voltage Optimization confirms through verifiable statistical analysis demand and energy savings was achieved

✓ The results of the demonstration prove that there are *measurable* reductions in energy usage using voltage optimization with customer voltage measurement also improves voltage service.

✓ *Dominion’s demonstration shows an average of 2.8% reduction in annual energy.*

✓ *Energy savings do not depend on changing customer behavior, additional customer purchases or adoption of in-home technology*

✓ *AMI technology demonstrates a practical and sustainable method of controlling voltage, providing continuous improvement of circuit performance and clear independent measurement of average circuit savings per customer without the inaccuracies of a non-sustainable circuit model.*
Questions & Answers