Volt/VAR Optimization – Several Case Studies

Prepared by:
Thomas Wilson, Principle, DA Solutions
on behalf of
UtiliDATA
(509) 385-1194
wilson.dasolutions@comcast.net

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VVO in the Pacific Northwest

- VVO and CVR typically results in a 3% average demand reduction for utilities
- Northwest Power and Conservation Council has assigned a value of 400 aMW available using V/VO in the Pacific Northwest through 2025
- Enough savings to power 317,391 average American homes each year

Benefits of VVO in Other Regions

- VVO and CVR provides an average demand reduction of 3% for utilities
- Reduce TVA peak approximately 1004 MW
- Reduce regional energy consumption 5,220 GWh per year
- Almost equivalent to 1 Browns Ferry BWR unit
- Enough savings to power 522,000 average American homes each year

Who Wins with CVR and VVO?

End use customers – Residential, rural, commercial and industrial

The Utility Companies

Regional Transmission and Generation
Measurement & Verification

- How do we know...
  - That we have reduced energy consumption and demand
  - That CVR or VVO is the cause?
- How do we measure it?

Protocol #1
- Washington State University
- University of Waterloo
- Bonneville Power Administration
- Regional Technical Forum
- Approved in April 2004

Assumptions and Models

- Linear model for demand and energy consumption:
  - Linear dependence on delivered voltage
  - Asymmetric linear dependence on ambient temperature
  - Stochastic customer behavior, average & random components
- Time Series approach
  - Improved analysis based on robust regression methods
  - Analysis of demand profile ensembles

Methodology

- Compare demand on a uniform basis
  - operation on alternate days
  - exposure to same environment
- Exploit prior knowledge of the demand processes and the resulting signals, such as:
  - daily periodicity
  - utilization devices efficiency vs. voltage
  - customer demand behavior
- Demand processes are locally linear
- Apply results only within bounds of observations

Inland HM Feeder3 Demand Profile Ensemble
Benefits of the Time Series Analysis Approach

- Feeder acts as its own control or baseline Feeder
- No constraints on regression methods or models
- No implied constraints on probability density of random data
- Estimates of demand profiles require no extrapolation
- Estimates bounded by observations
- Estimation of performance can be based on limited survey measurements

Measurement and Verification Protocol for Industrial Processes

Must use Process Compensation to avoid comparing

And to assure comparison of

Without Process Info

Refiner 3 - Test 1

Refiner 3 - Test 2

Voltage

Demand

Voltage

Demand
With Process Info

Refiner 3 - Test 1
Feed Rate
Specific Energy

Refiner 3 - Test 2

Example of Process Compensation

Voltage Disturbance Test at Large Chemical Pulping Paper Mill

Recording Time (hours)
Quantities (per unit)

Ripley Power and Light

- Demand Reduction VVO Pilot sponsored by TVA and EPRI “Green Circuits” program
  - AdaptiVolt™ deployed as a central system
  - 3 substations
  - 9 feeders, each feeder has 3 single-phase regulators
  - Licensed RF telemetry system
- August 4, 2009 – Commenced project
- March 3, 2010 – Project commissioned

Ripley Architecture
Ripley Results at High Level

- M&V testing indicates:
  - Energy reduction range of 1.3% to 5.4% across all feeders
  - 5.96 GWh per year energy savings
  - Demand reduction up to 3.4% or 1.64 MW
- Opportunities for further improvements identified

GridSmart® VVO Pilot

- GridSmart® pilot project in Gahanna, Ohio
  - 1 of the 13.2 kV feeders had a 3Φ regulator and 5 had banks of 3 single Φ regulators – now 6 do!
  - Fifteen (15) - field located switched capacitor banks
  - 2 feeders have mid-line regulators
  - Field communications using Silver Spring Networks, substation communications using fiber optic
  - EPRI “Green Circuits”
- AdaptiVolt™ system live December, 2010

AEP Gahanna Architecture

AEP Ohio: Gahanna – 4505 (13 KV) Voltage Profile

Without AdaptiVolt™ = 6-7-11 @ 4:30pm
With AdaptiVolt™ = 6-6-11 @ 4:30pm

Normal Operation
With VVO
AEP Gahanna Results
- Used “Protocol #1 for Automated CVR”
- Average Energy Reduction was > 3%
- Station Peak Demand Reduction > 3% (higher than Energy Reduction %)
- Approximately 1/3 reduction in tap operations with no significant change in capacitor switching operations (approximately 1 operation every other day).

Operational results better than expected.

Plum Creek Timber (IVO)
- 40 MW load Medium Density Fiberboard facility located in Columbia Falls, MT
- Thermo-mechanical pulping process
- Plum Creek is the largest private landowner in the US
- Project sponsored by BPA and Flathead Electric cooperative
- Operational in September, 2008

VARMIN & VIPER
- VARiable
- Moment
- INTEGRator
- Protects large motors
  - Synchronous
  - Induction
- Voltage
- Integrating
- Probability
- Estimating
- Regulator
- Provides close voltage control without excessive regulator operations
Process Line 2 – 9.7 MW of induction motors ranging from fractional to 800 hp, variable frequency drives, lighting, HVAC, process heating and process controls.

Energy savings at full production – 9,063,800 kWh/year!

Overall Demand Reduction – 3.72%

Murray State University

- Demand Reduction Pilot sponsored by TVA
- AdaptiVolt™ on isolated college campus served by 2 on-Load Tap Changing transformers
- 4 Feeders
- Uses 22 power monitors that were installed for their new EMS system
Results for Demand Reduction Pilot sponsored by TVA
- AdaptiVolt™ on isolated college campus served by LTC
- Uses 22 power monitors that were installed for their new EMS system
Final M & V testing Results:
- 4.38% peak reduction
- 4.82% energy conservation
- 27.5% mean reactive reduction

Challenges in VVO Solutions
- Load model accuracy
  - Understanding of Load Reaction to differing voltage levels
- Physical model accuracy
- Some evidence of tap change frequency increase
- Communications reliability
- Compute power required for large systems

DSP is a Relatively New Technology
- DSP roots are in the 1960’s and ‘70’s with the advent of available digital computers
- DSP is now ubiquitous. We use it in our daily lives.
- Now being used widely in system protection, power monitoring and is being considered for short-term load forecasting.
One Area where DSP Changed our Lives?

DSP VVO Paradigm is Somewhat Analogous to:

or maybe

and

Potential Advantages of DSP based VVO

- Load model and physical model accuracy is removed as a limit on VVO performance
- Significant tap changer life improvements
- Better overall performance
  - Capacitor and tap changer operation detection
  - Better CVR and demand reduction performance
- Much lower compute power costs leading to more economic and cost effective VVO

Discussion