Volt / VAR Optimization – Several Case Studies

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IEEE Advancing Technology for Humanity

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

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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!

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Who Wins with CVR and VVO?

The Utility Companies

End use customers – Residential, rural, commercial and industrial

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

Regional Technical Forum

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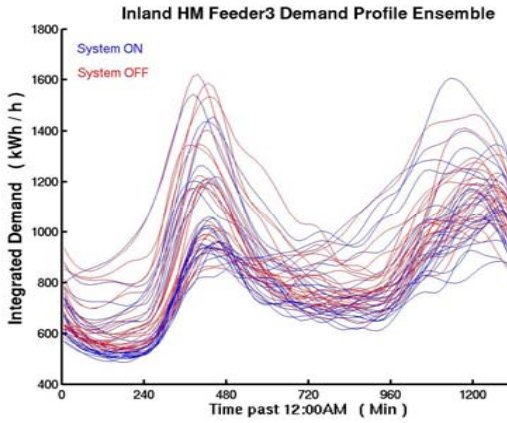
Assumptions and Models

- 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



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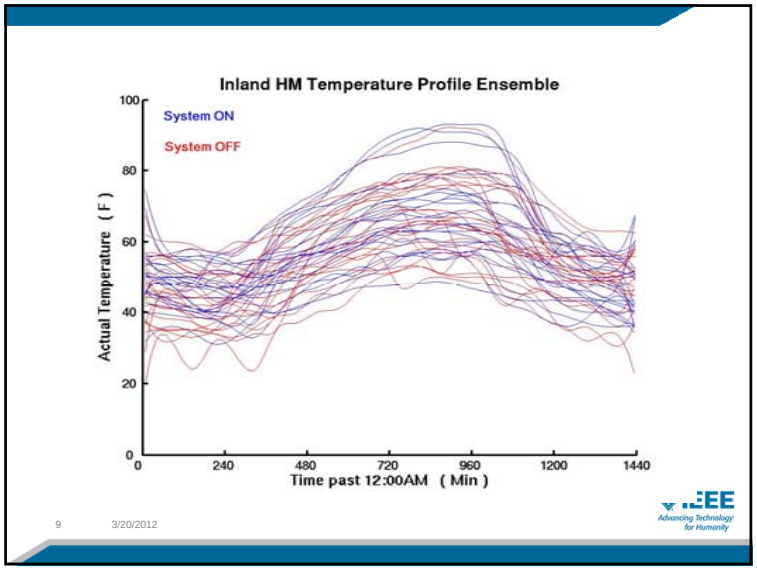
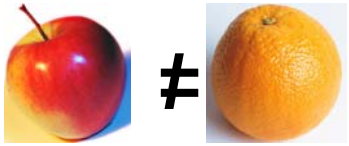


Benefits of the Time Series Analysis Approach

- Feeder acts as it 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

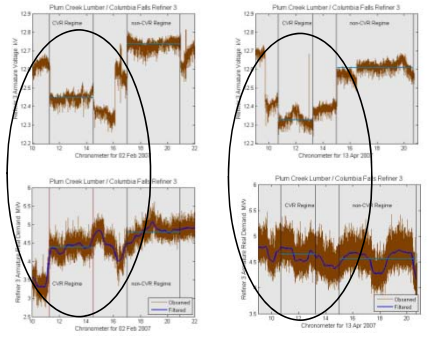
Refiner 3 - Test 1 Refiner 3 - Test 2

Voltage

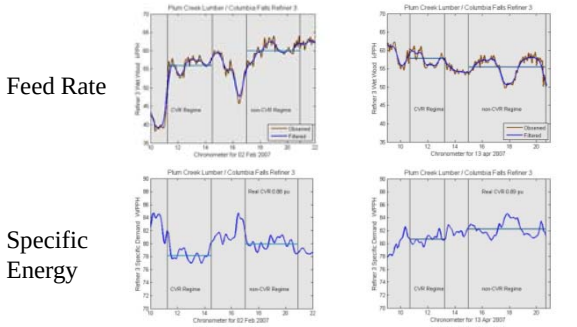
Voltage ↓ Demand ↓

Demand

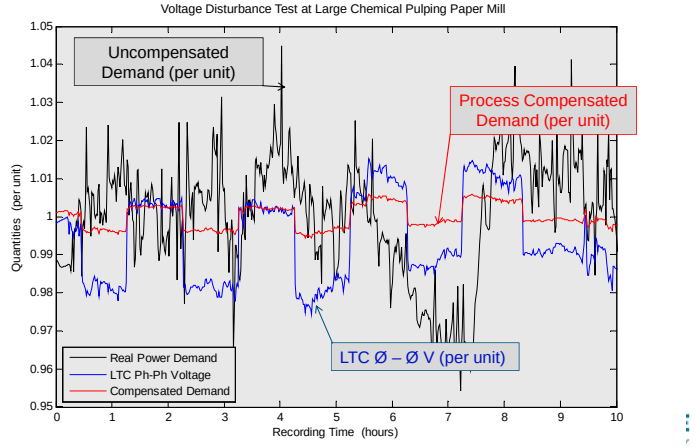
Voltage ↓ Demand ↑



With Process Info



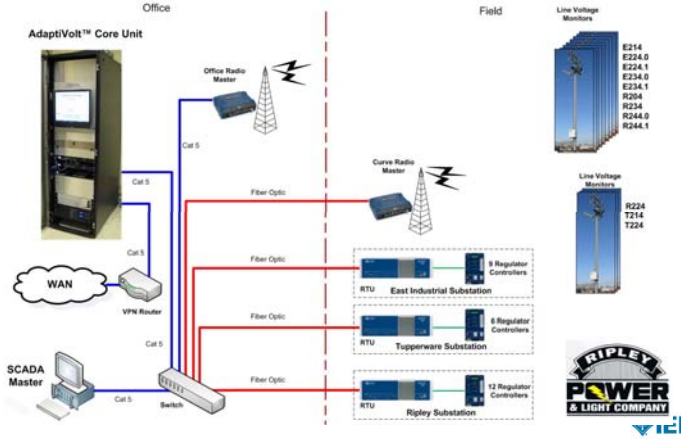
Example of Process Compensation



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



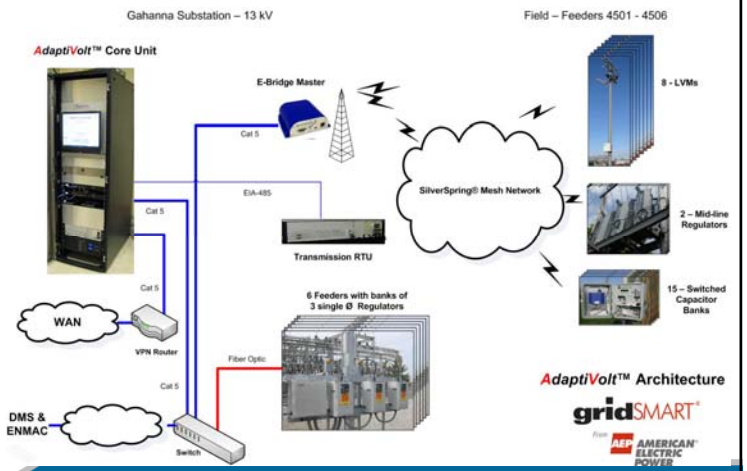
Ripley Results at High Level

- 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

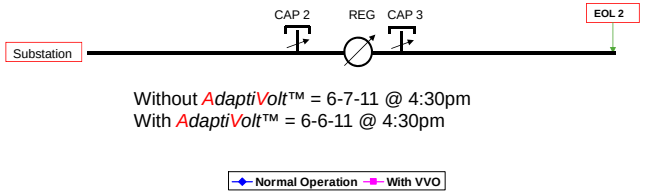
GridSmart® VVO Pilot

- 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

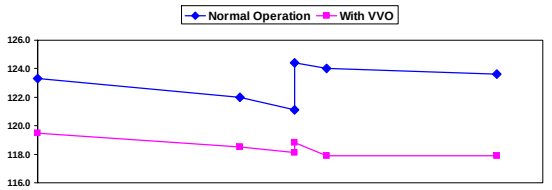
AEP Gahanna Architecture



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



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



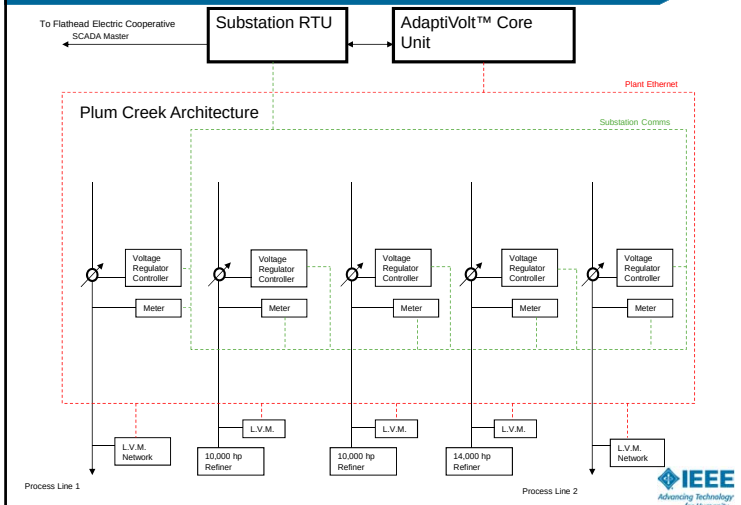
AEP Gahanna Results

- 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)

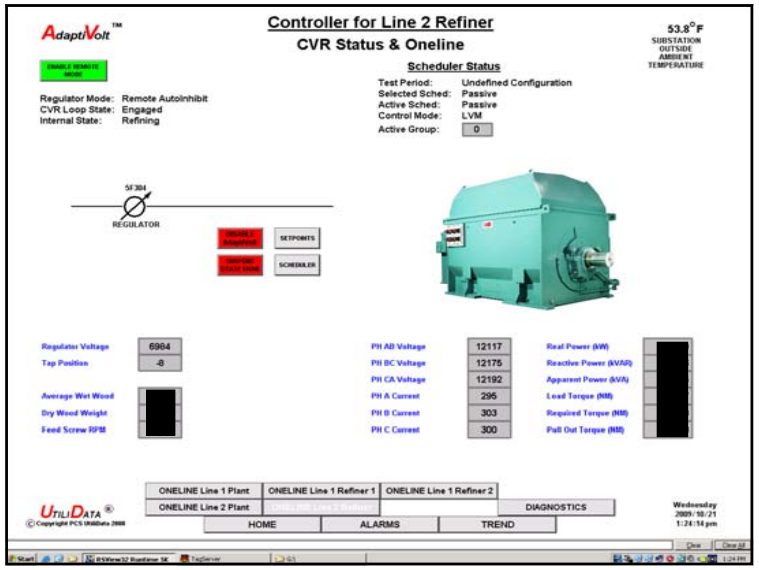
- 40 MW load Medium Density Fiberboard facility located in Columbia Falls, MT
- Thermo-mechanical pulping process
- Plum Creek is the largest private landowner in the US
- Project sponsored by BPA and Flathead Electric cooperative
- Operational in September, 2008

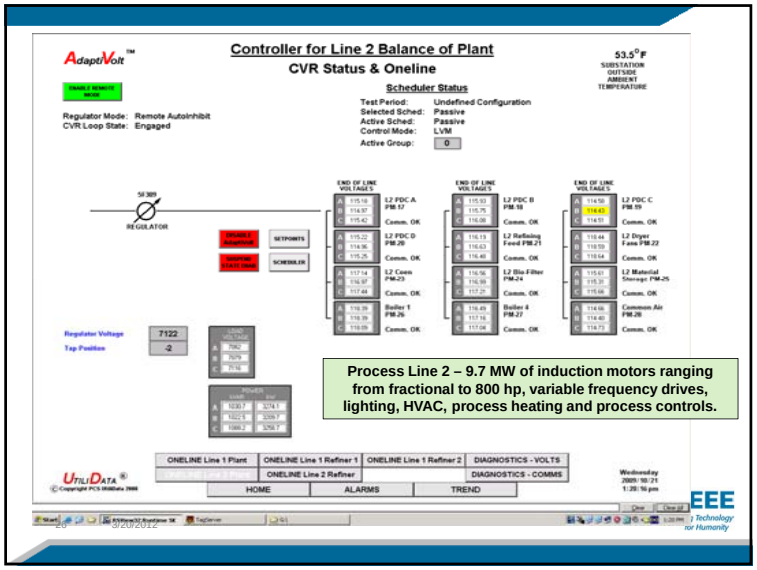


VARMINT & VIPER

- VARiable
- Moment
- INTegrator
- Protects large motors
  - Synchronous
  - Induction

- Voltage
- Integrating
- Probability
- Estimating
- Regulator
- Provides close voltage control without excessive regulator operations





Overall Results

Plum Creek

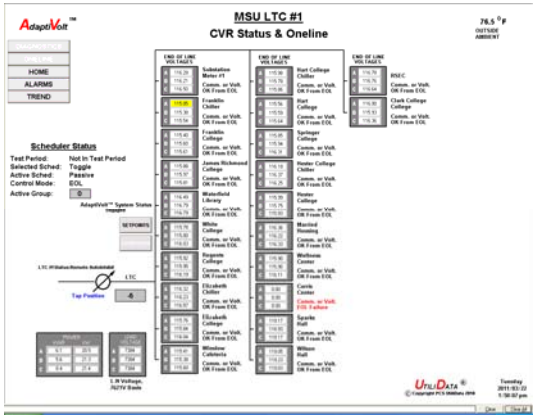
Overall Demand Reduction – 3.72%

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

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

MSU Graphics Display



Results for MURRAY STATE UNIVERSITY

- 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 in in our daily life.
- Now being used widely in system protecion, power monitoring and is being considered for short-term load forcasting.

One Area where DSP Changed our Lives?

DSP VVO Paradigm is Somewhat Analogous to:

or maybe

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