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Case Study: How the Commission Used a Smart Grid Program to Identify, Resolve & Prevent Losses

Day 2 – Volt-Var Case Study

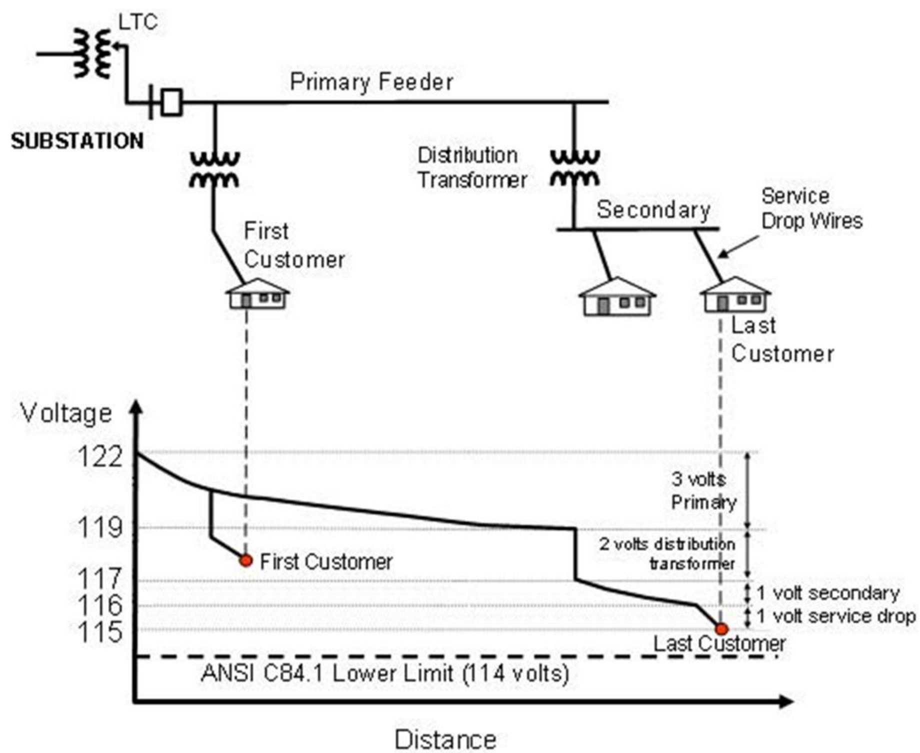
David Cleaver, Public Utilities Commission of Ohio





What is Volt-VAR control?

- Volt-VAR control (VVC) is a fundamental operating requirement of all electric distribution systems
- The prime purpose of VVC is to maintain acceptable voltage at all points along the distribution feeder under all loading conditions.



Volt-VAR Control – Historic Objectives

- Voltage Regulation – Maintaining customer voltage within ANSI limits
- VAR Support – Offsetting need for VARs from Generation & Transmission
- Loss Reduction – Reducing system technical losses
- Capacity – Switched capacitor banks free substation and distribution feeder capacity
- Specific Problem Resolution – Deployment of distribution line voltage regulators often reserved for specific voltage control issues (e.g. long rural feeders)

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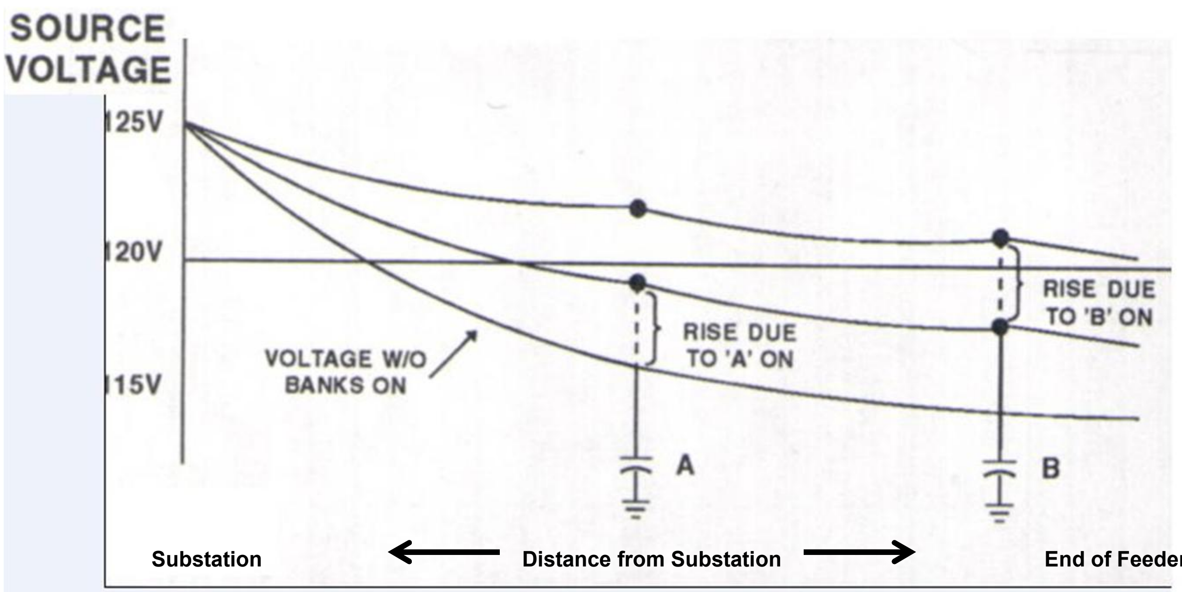
VVC = Voltage Regulation + Reactive Power Compensation

- Use voltage regulators (Vregs) or transformers with load tap changers (LTCs) that automatically raise or lower the voltage in response to changes in load
- Use capacitor banks to supply some of the reactive power that would otherwise be drawn from the supply substations



Volt-VAR Control in a Smart Grid World

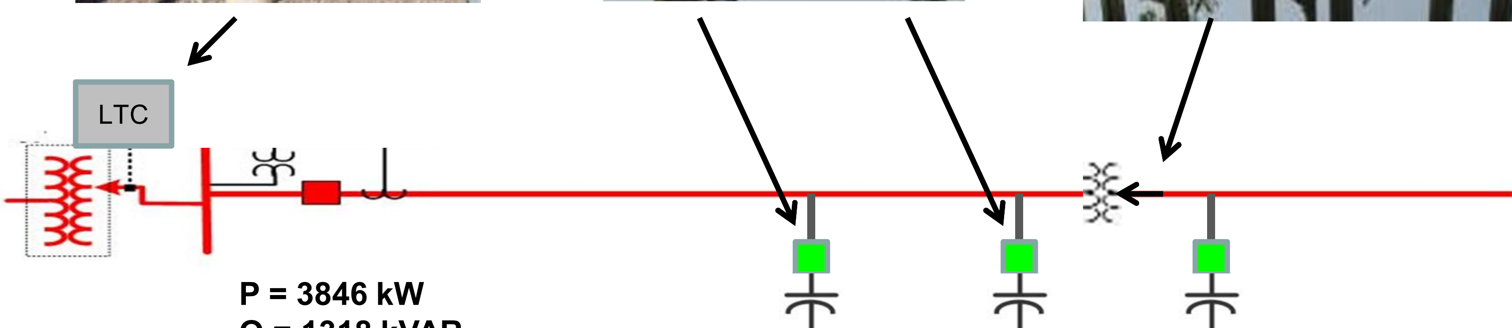
- Expanded objectives for Volt-VAR control include
  - Basic requirement – maintain acceptable voltage
  - Support major “Smart Grid” objectives:
    - Reduce electrical demand and/or accomplish energy conservation through voltage reduction
    - Improve efficiency (reduce technical losses) through voltage optimization
    - Promote a “self healing” grid (VVC plays a role in maintaining voltage after “self healing” has occurred)
    - Enable widespread deployment of distributed generation, renewables, energy storage, and other distributed energy resources (dynamic volt-VAR control)

Basic Volt VAR Control
Field Devices

Substation Load Tap Changer (LTC)

Switched Capacitor Banks

Line Voltage Regulator



P = 3846 kW
Q = 1318 kVAR

PF = .946
Losses = 96 kW

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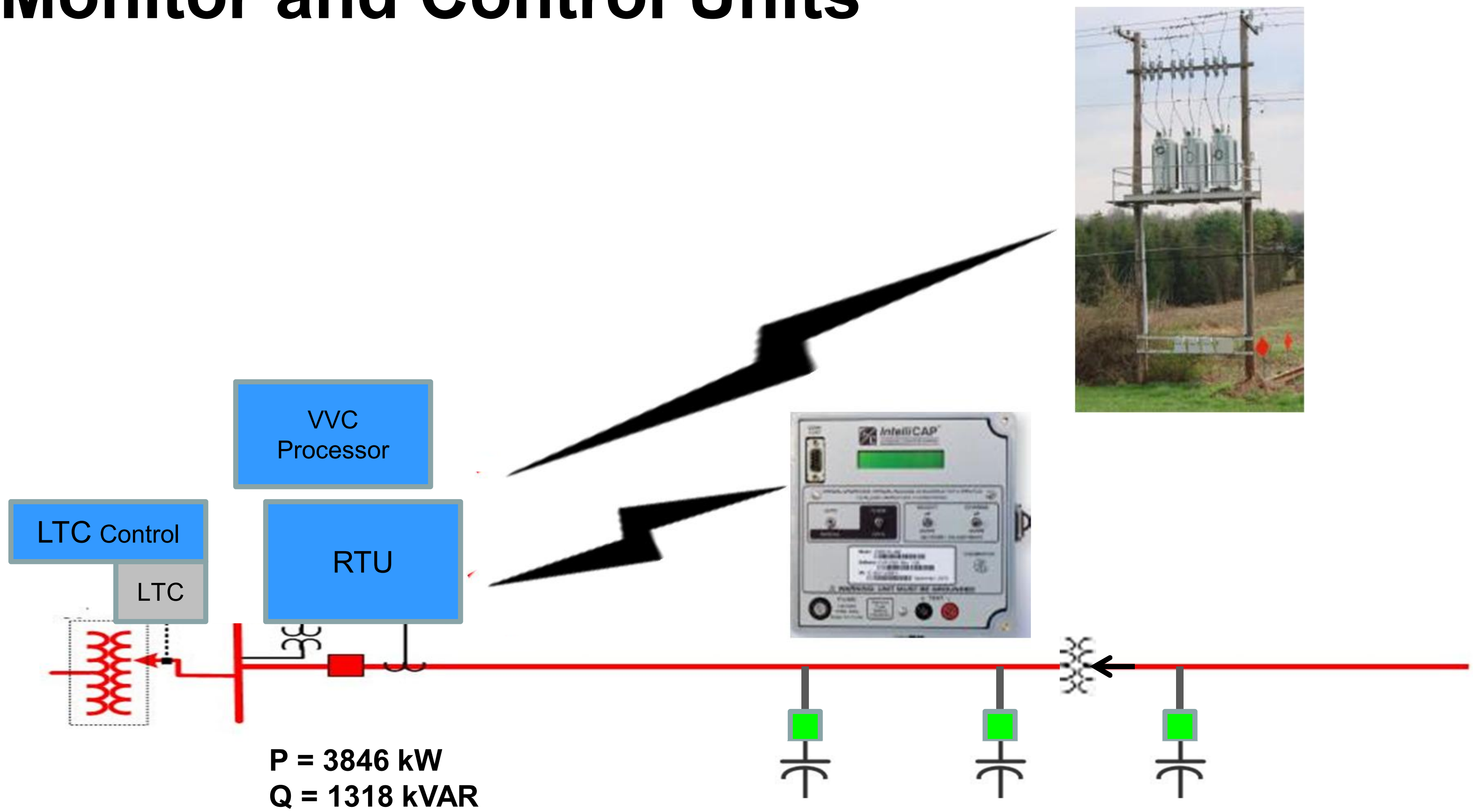
Basic Volt VAR Control
Monitor and Control Units



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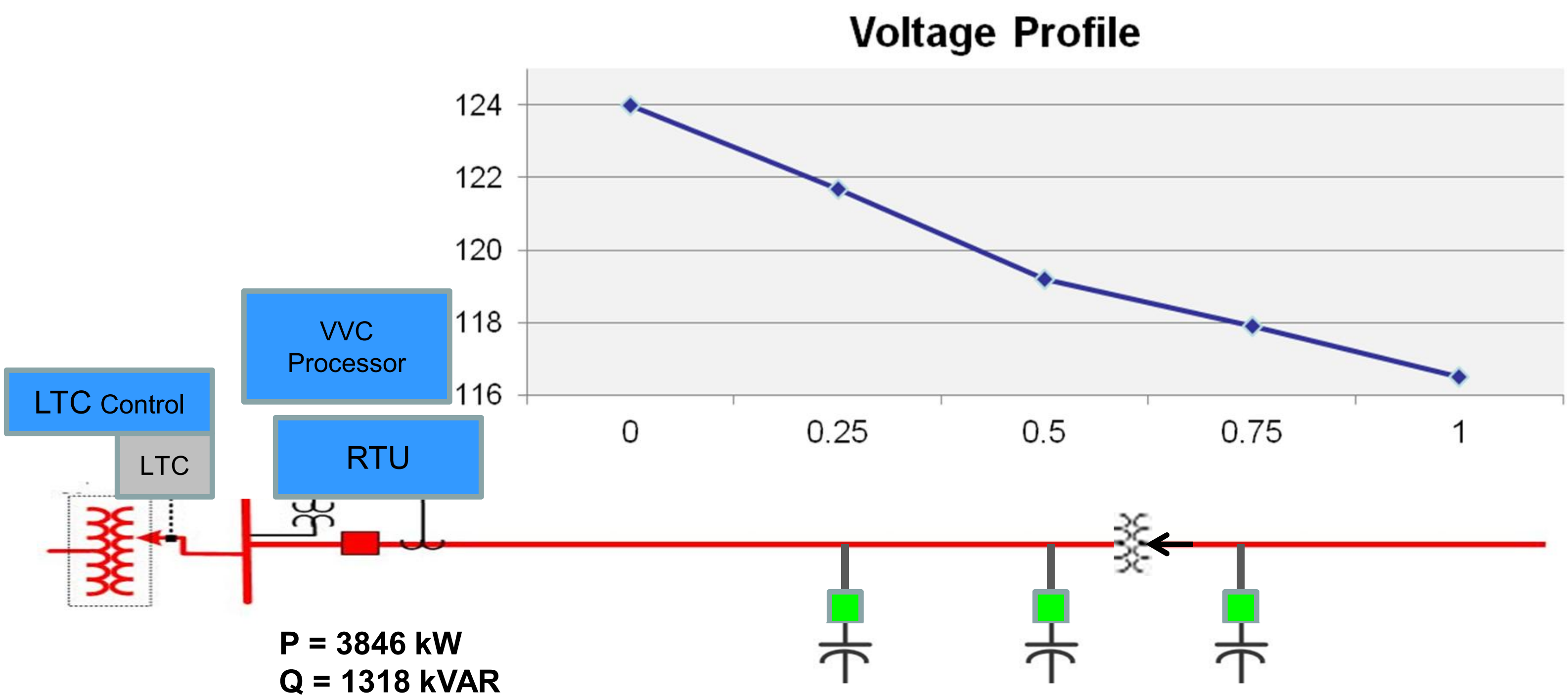
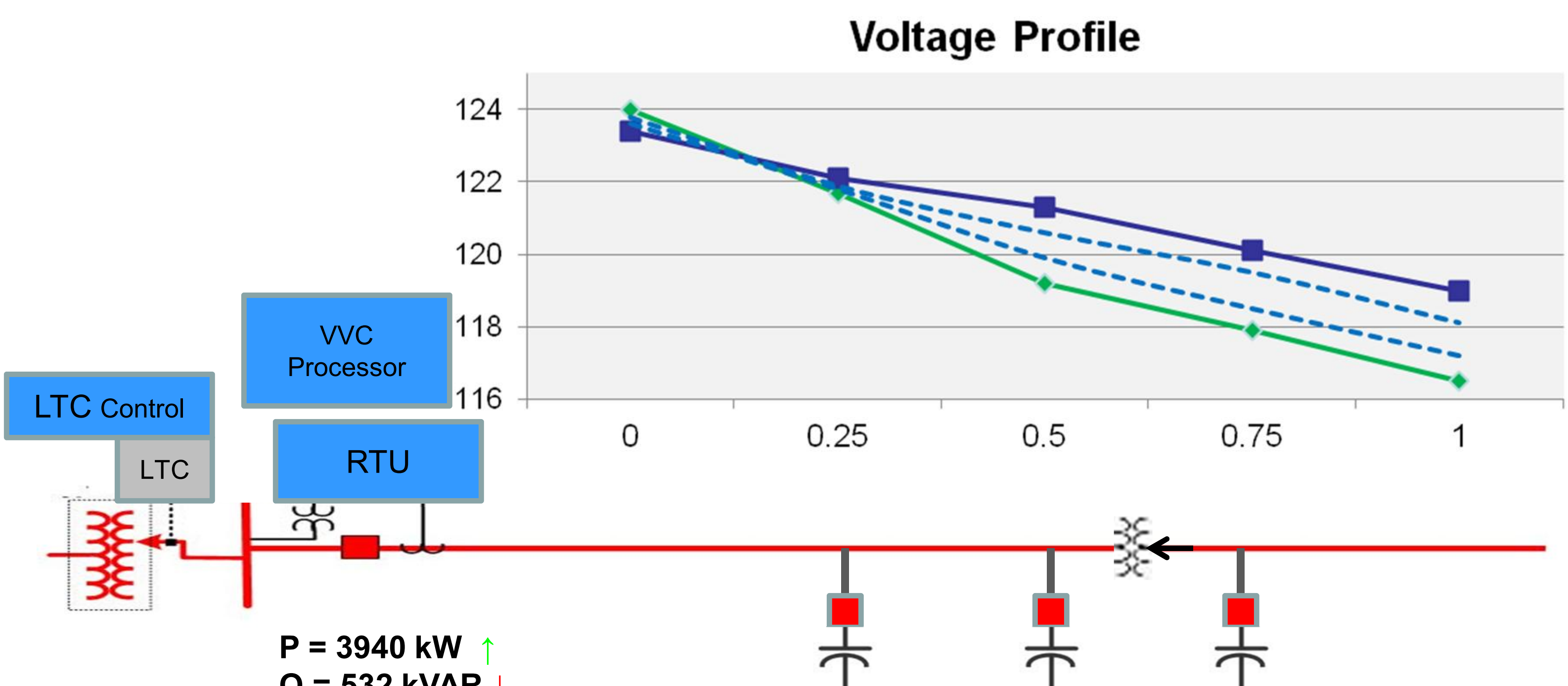
Basic Volt VAR Control
Impact of VVC Field Devices



P = 3846 kW
Q = 1318 kVAR

PF = .946
Losses = 96 kW

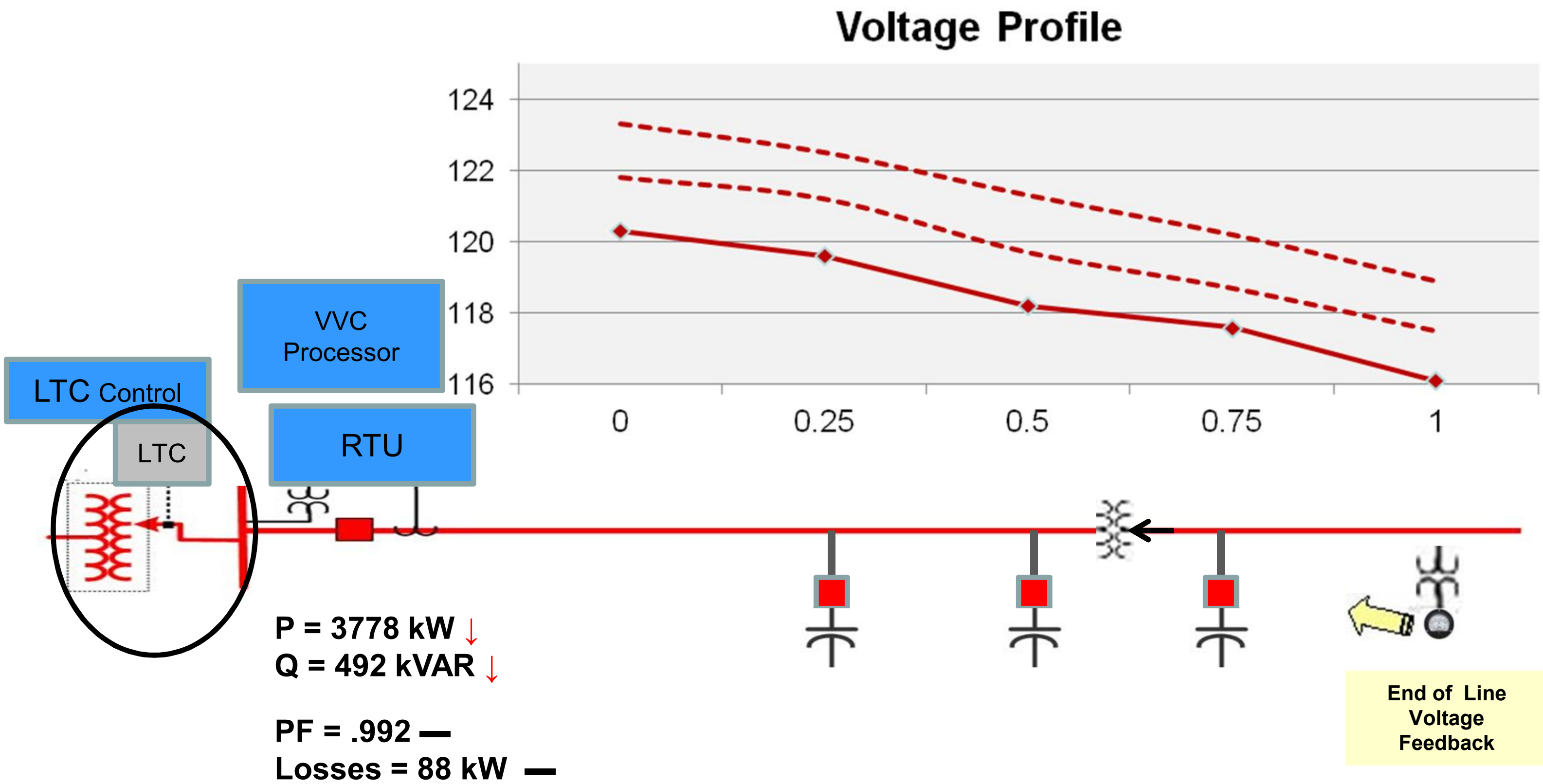
Basic Volt VAR Control
Capacitor Bank Switching



P = 3940 kW ↑
Q = 532 kVAR ↓

PF = .991 ↑
Losses = 88 kW ↓

Basic Volt VAR Control
Impact of VVC Field Devices



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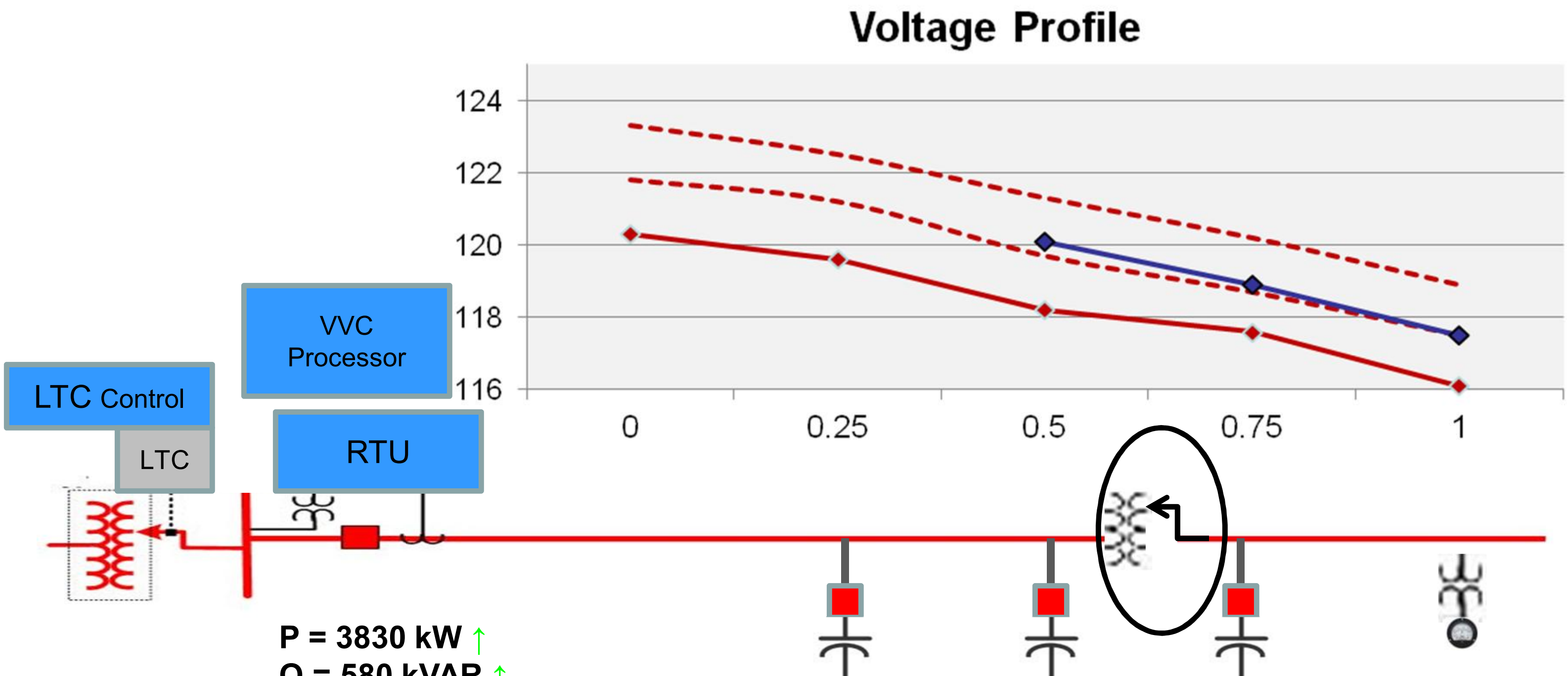
Basic Volt VAR Control
Line Voltage Regulator Control



P = 3830 kW ↑
Q = 580 kVAR ↑

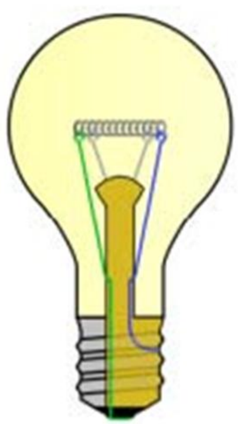
PF = .990 —
Losses = 88 kW —

Maintaining Acceptable Voltage

- Historically, without any ability to monitor delivered voltage in real time, utilities operated at the higher end of the acceptable range. Higher end of the range to provide acceptable voltage (at least cost)
- This ensured that the voltage never dropped out of the acceptable range under normal and emergency conditions
- A published study of over 40,000 distribution transformers across three ICUs over a one year period showed the average delivered voltage at 121 volts

Effect of Reduced Voltage on Loads

- Many electrical devices operate more efficiently (use less power) with reduced voltage



$$P = V^2 \times R$$

"Constant Impedance" Load

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Other Consequences of VVC

- Motors run more efficiently, producing less heat.
- Some reduction in lumen output as voltage is reduced depending on the type of lighting
- For some devices, like water heaters and electric resistive heat that regulate to a temperature, reducing voltage reduces the instantaneous power drawn but it does not reduce overall energy usage; the devices just run longer.
- At lower voltages some loads do draw more current causing an increase in losses, but this loss increase is very small compared to the reduction of demand.

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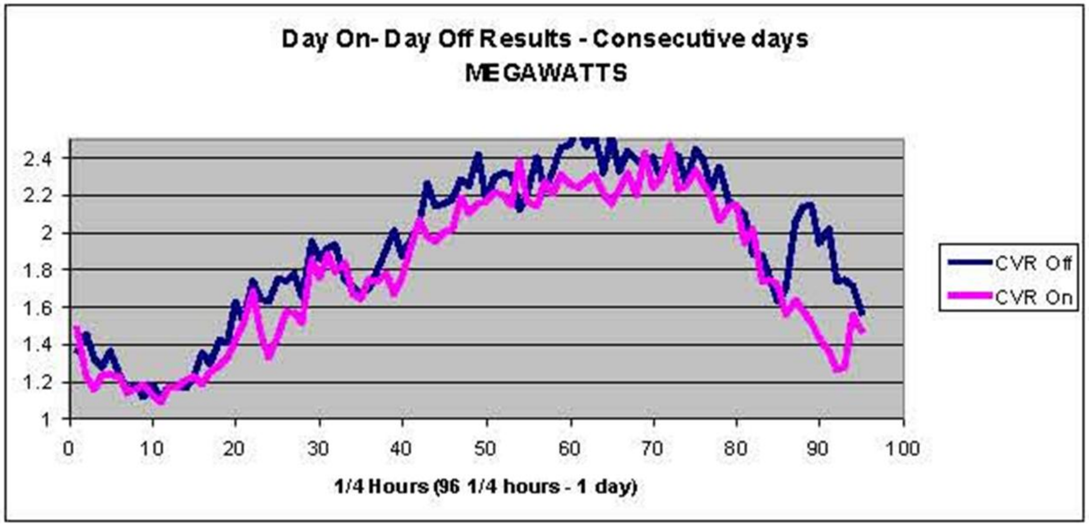
"Measurement and Verification"(M&V) Approaches for Volt-VAR Control

- Run on-line power flow program to determine "what would have happened" without volt-VAR control – then compare with actual measurements
- "Day on/Day off" testing – reduce voltage every other day - compare measurements from VVC "on" day with VVC "off" day using statistical analysis



Improved Understanding of Load to Voltage Sensitivity
Key Research Questions

1. Will voltage reduction work as well for my utility as it has for other utilities?
2. Will the utility have to spend a lot of money on feeder improvements before I can implement VVC?
3. Will the Voltage Reduction benefit last long into the future? Or, will the benefits diminish over time?

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AEP's Volt / Var Control Technology Deployment Smart Grid Pilot Program in Columbus, Ohio

- **AEP Ohio gridSMART Demonstration Project:**
  - GE IVVC Technology on existing infrastructure – 5 Stations (4 -34KV & 7 -13KV Circuits)
  - Adapti-Volt Technology on existing infrastructure – 1 Station (6 – 13KV Circuits)
  - Independent analysis by Battelle of theoretical and measured results

- **Indiana & Michigan Power Co.:**
  - "Low Tech" approach on 9 circuits with re-engineering and minor infrastructure upgrades
  - Evaluating plans for VVC Technology application and infrastructure upgrades on selected circuits in Indiana and Michigan.

- **Public Service Company Oklahoma gridSMART Project:**
  - Applying Cooper VVC and infrastructure upgrades on 11 circuits in Owasso

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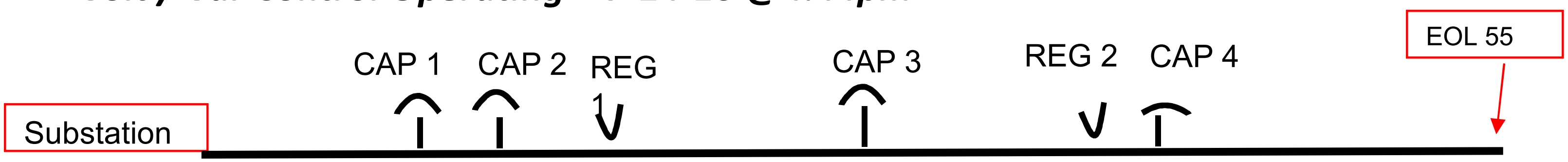
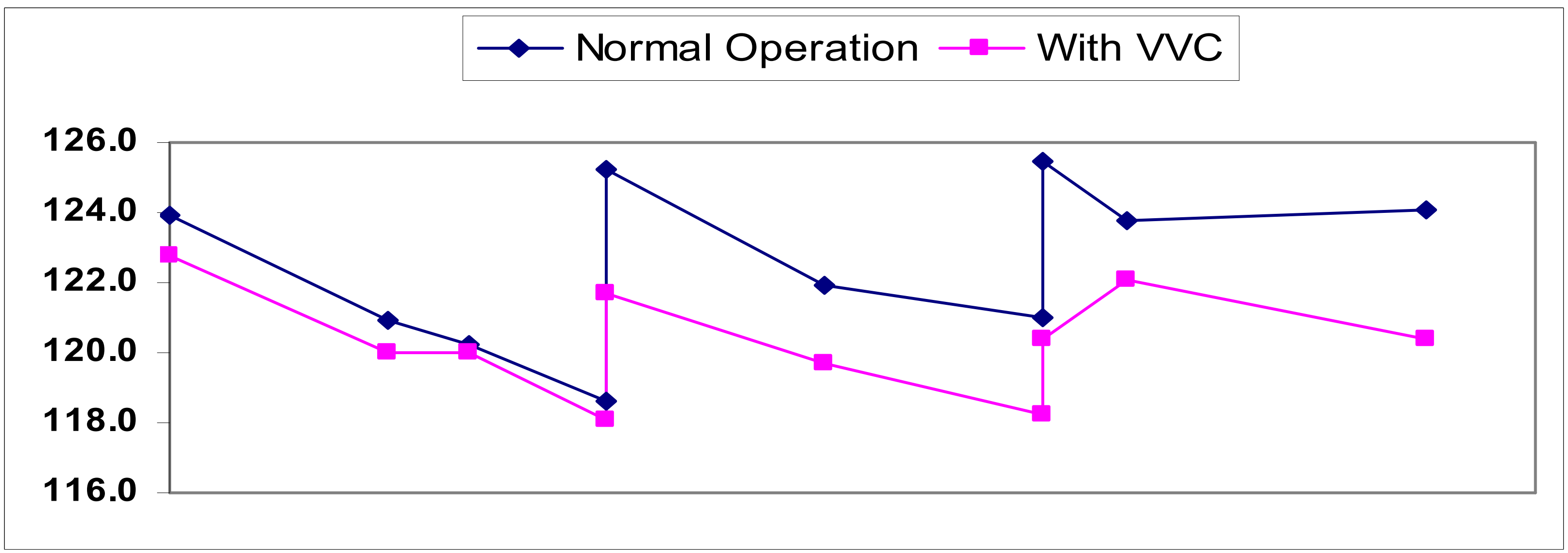
AEP Ohio: East Broad – 1406 Voltage Profile

Normal Operation = 7-23-10 @4:44pm
Volt / Var Control Operating = 7-24-10 @4:44pm





Demand and Energy Reduction Results

- **IVVC technology works as-expected**
  - Testing demonstrates ~2-4% energy and demand reduction is achievable.

Circuit Level Results Averaged Across 11 Circuits	Industry Experience	Battelle Projections AEP Ohio Project	Initial Results AEP Ohio Project
Customer Energy Reduction	2.0%	3.3%	2.9%
Customer Peak Demand Reduction	2.0%	3.0%	2 - 3 %

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Example: Customer Demand and Energy Savings

1100 kW
609,000 kWh

1067 kW
590,730 kWh

Volt Var Control will reduce customer peak demand and energy consumption

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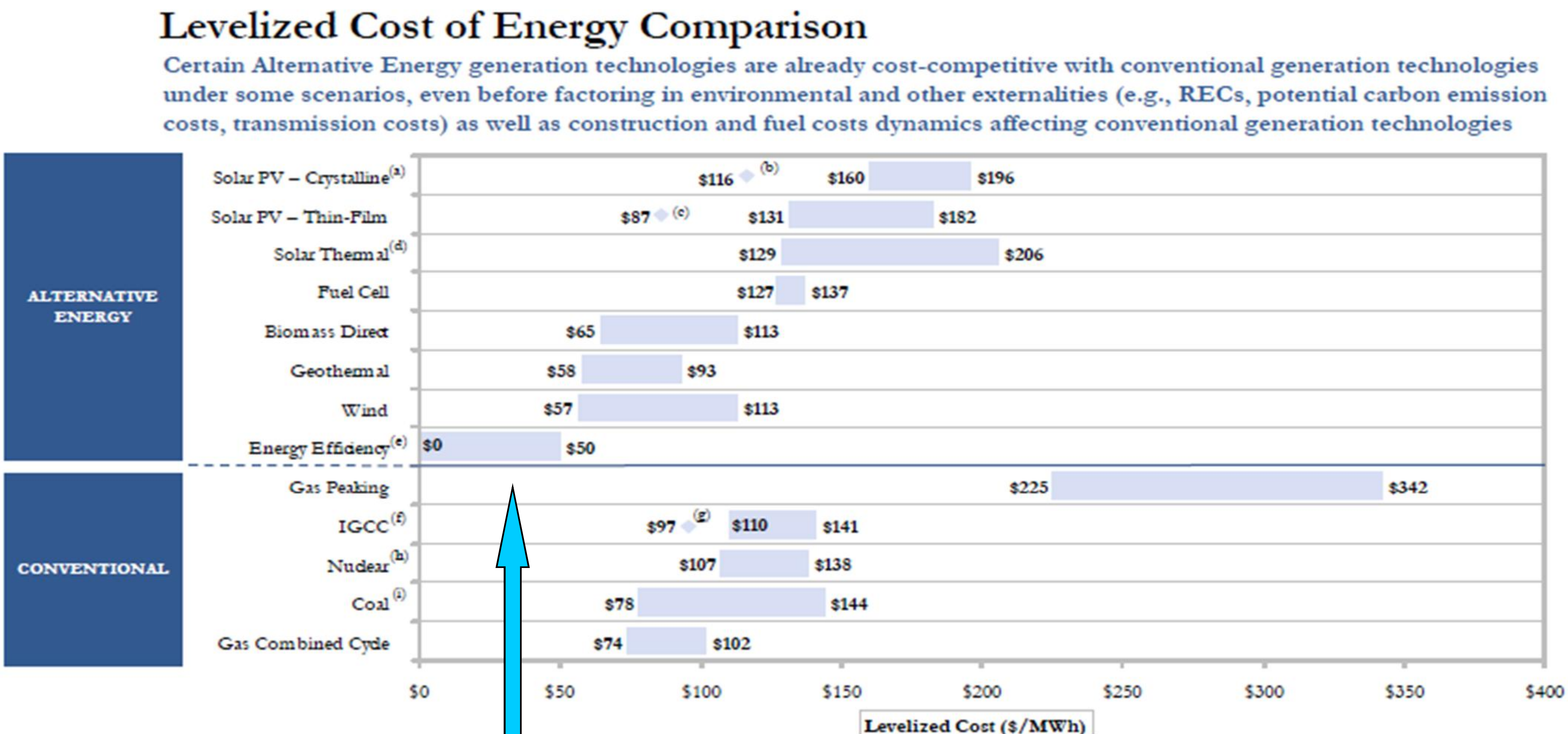
Value of IVVC Compared to Generation Alternatives



"LEVELIZED COST OF ENERGY ANALYSIS "– VERSION 3.0 Lazard, February 2009

Levelized cost of IVVC is in the low part of the Energy Efficiency range due to low initial capital cost and no on-going fuel cost

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Questions