

Power System
Engineering, Inc.

Implementing CVR through Voltage Regulator LDC Settings

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Conservation Voltage Reduction

"CVR"

Minimizing end-use voltage within ANSI limits to reduce peak demand & energy consumption

Minimum Voltage Levels Permitted (120V Base):

118V on Distribution Primary

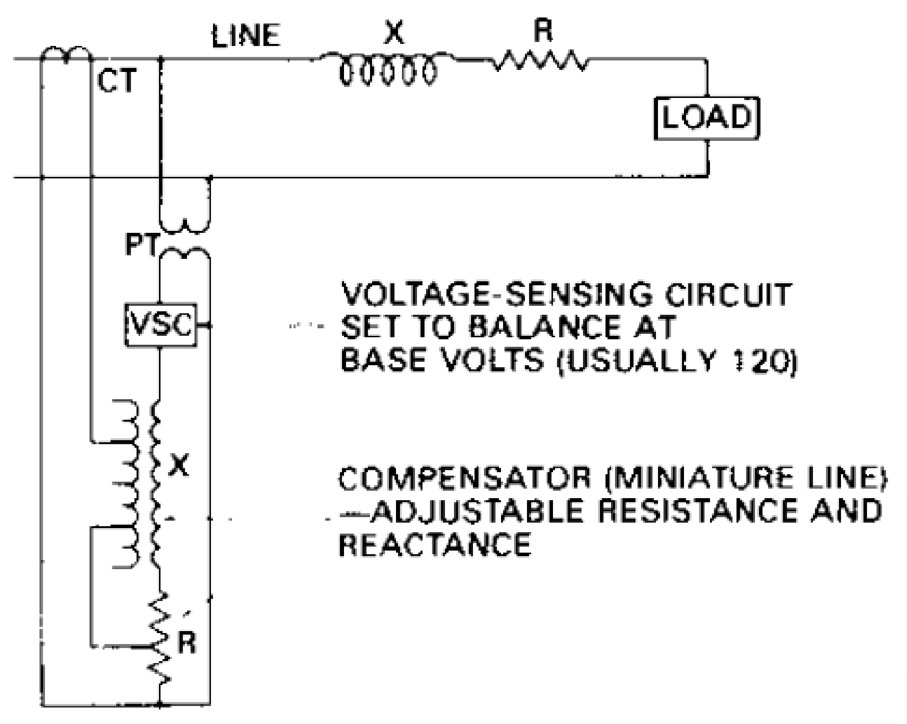
114V at Secondary Meter

Methods of Implementation

- CVR typically implemented using voltage regulators and LTCs
- Control settings
  - Manually adjust settings through SCADA or in the field
    - Typically used for only demand reduction strategies
  - Line Drop Compensation (LDC)
    - Voltage reduction on a continual basis
    - No real-time feedback
  - Dynamically through SCADA and end of the line voltage monitoring/feedback

Regulator Line Drop Compensation

- Uses a CT to monitor load current
- "R" and "X" settings (in volts) represent cumulative resistance and reactance of the downline feeder
- Regulator adjusts output to maintain a desired voltage at some downline point



Cooper Power Systems R225-10-1, "Voltage Regulating Apparatus, Determination of Regulator Compensator Settings"

Efficiency Measures

- To maximize benefits of CVR, cost effective measures to improve system voltage should be considered in advance
  - Feeder load balancing
  - Multi-phasing heavily-loaded single-phase taps
  - Feeder VAR flow control via capacitor placement
  - Voltage Regulators: placement & control settings

Case Study

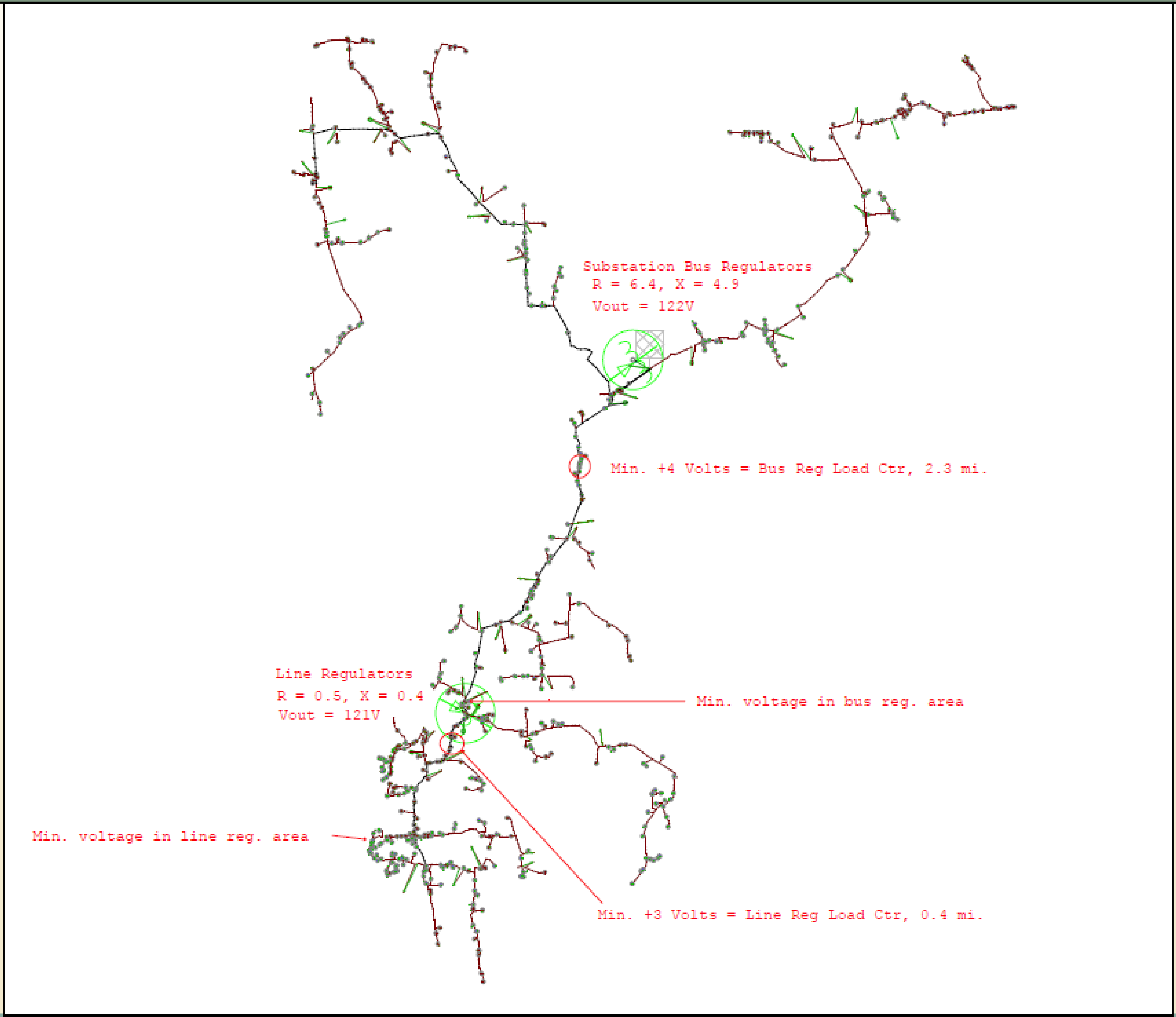
- Oneida-Madison Electric Cooperative – Upstate NY
- In recent years, OMEC has studied distribution optimization to improve efficiency
  - Implemented load balancing & multi-phasing, VAR optimization, and voltage regulation, and optimized substation boundaries & open points

Green Circuits Project

- OMEC participated in the EPRI Green Circuits project in 2009 & 2010
  - Attempted to identify ways to improve efficiency & reduce losses through modeling & simulation of feeders
- Simulations indicated that OMEC could reduce annual energy consumption by 0.9—1.1% and annual energy losses by 0.07—0.13% by using LDC settings on voltage regulators
- Based on the Project, OMEC moved forward with LDC implementation

LDC Settings Development & Implementation

- Used common “Load Center” method to calculate LDC settings for each regulator
- Settings were programmed & implemented in May 2011


Substation Bus Regulators
R = 6.4, X = 4.9
Vout = 122V
Min. +4 Volts = Bus Reg Load Ctr, 2.3 mi.
Line Regulators
R = 0.5, X = 0.4
Vout = 121V
Min. voltage in bus reg. area
Min. voltage in line reg. area
Min. +3 Volts = Line Reg Load Ctr, 0.4 mi.

Monitoring the Effects

- Twenty-seven meters around the system were selected for voltage-monitoring as representative of end-of-line voltage (lowest expected system voltage levels)
- Data was collected via OMEC’s AMI system on hourly or five-minute intervals, depending on the meter
- Reasons for monitoring:
  - Verify that minimum voltages were not below ANSI limits
  - Determine if voltage was being lowered as much as possible
  - Determine the impact of LDC on peak & non-peak voltage profiles
- August and November/December 2011 were periods chosen for analysis to represent summer & winter peaks

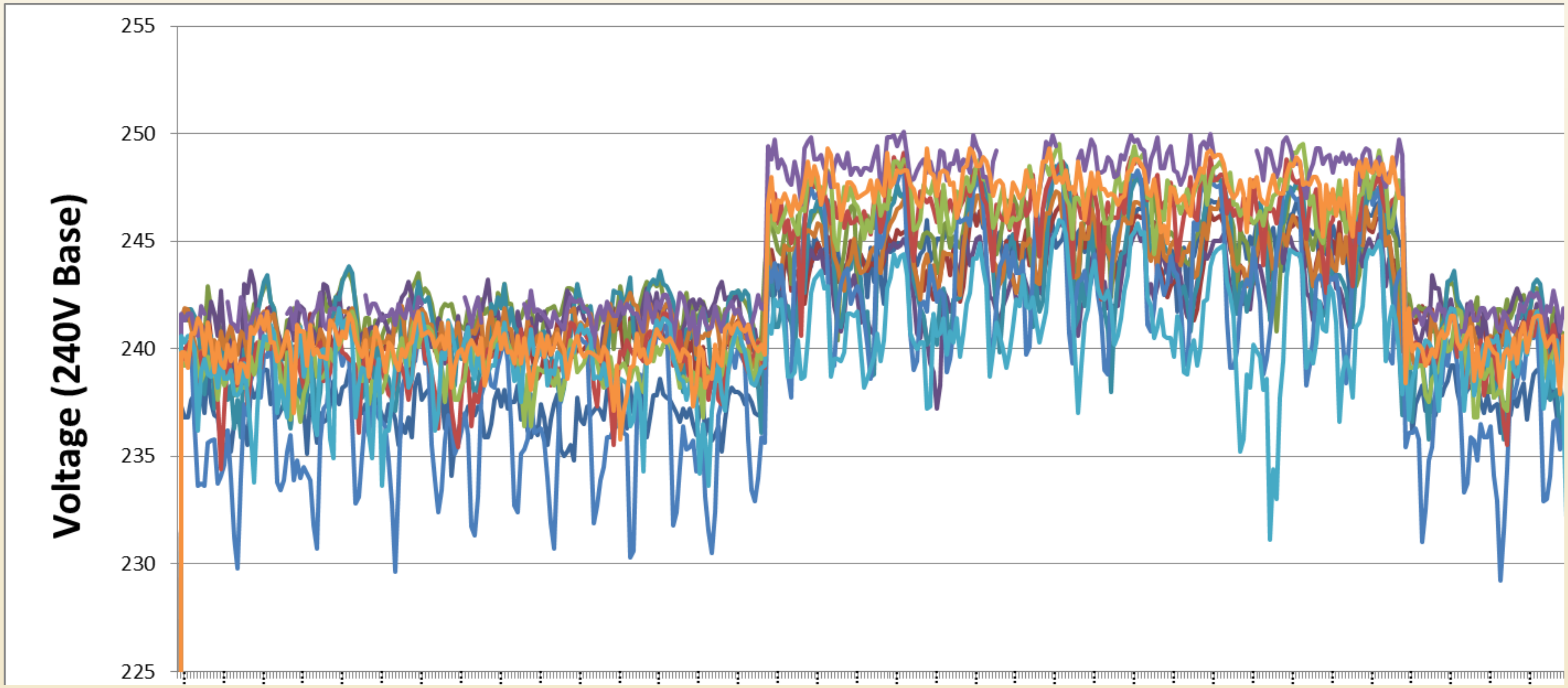
Monitoring the Effects

- LDC was disabled for a portion of each analysis period to observe the change in average voltage
- During these times, regulators were set at 125V output with 2-volt bandwidth and a 30-second delay (typical settings prior to LDC implementation)
  - Monitored August 1-31 (LDC off Aug. 8-16)
  - Monitored November 3—December 7 (LDC off Nov. 10-30)

OMEC is a strong winter-peaking system.

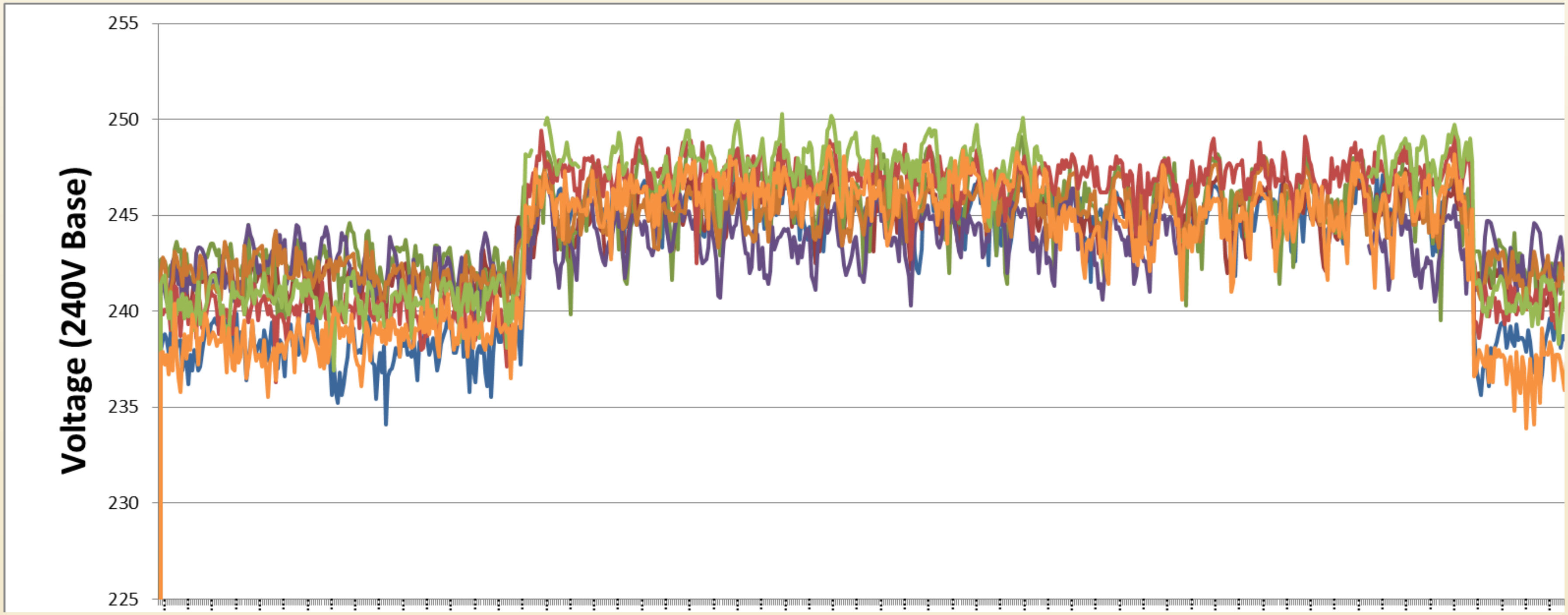
Results: August 2011

SUMMER	Change in Voltage (120V Base)	Change in Voltage (%, 120V Base)
Eaton Substation	2.3	1.9%
Oriskany Falls Substation	2.6	2.2%
Fenner Substation	2.0	1.7%



Results: November/ December 2011

WINTER	Change in Voltage (120V Base)	Change in Voltage (%, 120V Base)
Eaton Substation	2.04	1.7%
Oriskany Falls Substation	2.05	1.7%
Fenner Substation	1.84	1.5%



Results

Voltage profile was indeed lowered on an on-going basis using LDC settings

The Remaining Question:

Does a reduction in system voltage translate into energy savings?

IF SO, HOW MUCH?

CVR Factor

- Typically expressed as:

$$CVRf = \frac{\%\,\Delta Energy}{\%\,\Delta Voltage}$$

- CVR factor has been studied numerous times over two decades; average factors are highly varied.
- Since we have only collected voltage data, an appropriate CVR factor must be selected to estimate energy reduction.

CVR Factor Studies

- 1991, Snohomish Cty.: 0.5—1.5 (%ΔE/%ΔV)
- 2006, MicroPlanet:
  - 0.8 %-ΔkW/%-ΔV
  - 3.0 %-ΔkVAR/%-ΔV
- 2007, NEEA: 0.57—0.7 (%ΔE/%ΔV)
- 2010, EPRI Green Circuits (selected):
  - 0.8 %-ΔkW/%-ΔV
  - 3.0 %-ΔkVAR/%-ΔV

CVR Factor Selection

- To promote consistency with the EPRI study (which included two of the same feeders) the same CVR factor was selected:

CVRf = 0.8

- This factor was applied to the average voltage reductions to predict energy reduction.

Important note: These results are **seasonal** figures, whereas EPRI's estimates are **annual** reductions

Summary of Results

SUMMER	Change in Voltage (120V Base)	Change in Voltage (%, 120V Base)	Percent Energy Reduction[1]	Percent Loss Reduction
Eaton Substation	2.3	1.9%	1.5%	0.15%
From EPRI Study[2]			*0.9%*	*0.07%*
Oriskany Falls Substation	2.6	2.2%	1.7%	0.17%
From EPRI Study[2]			*1.1%*	*0.13%*
Fenner Substation	2.0	1.7%	1.3%	0.13%

WINTER	Change in Voltage (120V Base)	Change in Voltage (%, 120V Base)	Percent Energy Reduction[1]	Percent Loss Reduction
Eaton Substation	2.04	1.7%	1.3%	0.16%
From EPRI Study[2]			*0.9%*	*0.07%*
Oriskany Falls Substation	2.05	1.7%	1.3%	0.16%
From EPRI Study[2]			*1.1%*	*0.13%*
Fenner Substation	1.84	1.5%	1.2%	0.14%

[1] Based on a CVR of 0.8

[2] Note that the EPRI values are annualized, and not directly comparable to the seasonal value indicated.

CVR Factor	Summer		Winter	
	ΔE	Δ-Loss	ΔE	Δ-Loss
0.5	0.9%	1.9%	0.8%	1.6%
0.6	1.1%	2.2%	1.0%	1.9%
0.7	1.3%	2.6%	1.1%	2.2%
0.8	1.5%	3.0%	1.3%	2.6%
0.9	1.7%	3.3%	1.5%	2.9%
1.0	1.9%	3.7%	1.6%	3.2%
1.1	2.1%	4.1%	1.8%	3.5%
1.2	2.2%	4.4%	1.9%	3.8%
1.3	2.4%	4.8%	2.1%	4.2%
1.4	2.6%	5.2%	2.3%	4.5%
1.5	2.8%	5.6%	2.4%	4.8%

Notes

- November 2011 (winter study period) was not as cold as is typical during a winter peak; energy and loss reductions would likely be lower during true winter peaks

- EPRI's annualized calculations are probably indicative of the potential energy reductions across the entire OMEC system

Conclusions

- Line Drop Compensation feature of regulator controls can be successfully used to lower voltage within acceptable limits
- LDC settings must be carefully developed, considering loading and characteristics of the electrical system, to achieve long-term voltage reduction.
- Ongoing voltage monitoring is recommended to confirm the effectiveness of LDC settings.

Additional Conclusions

- Determining average voltage reduction levels is relatively straight-forward
- Estimating demand savings during peak time periods (not the focus of this paper) can be done relatively easily with engineering models
- Estimating energy savings is challenging and complex
  - Loads over time react differently to changes in voltage
    - Example: thermostat controlled loads
    - CVR factor attempts to quantify this
  - *Remember that energy reductions are primarily derived from reductions in sales, not losses!*

Questions?