Conservation Voltage Reduction (CVR)

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DNV GL Energy

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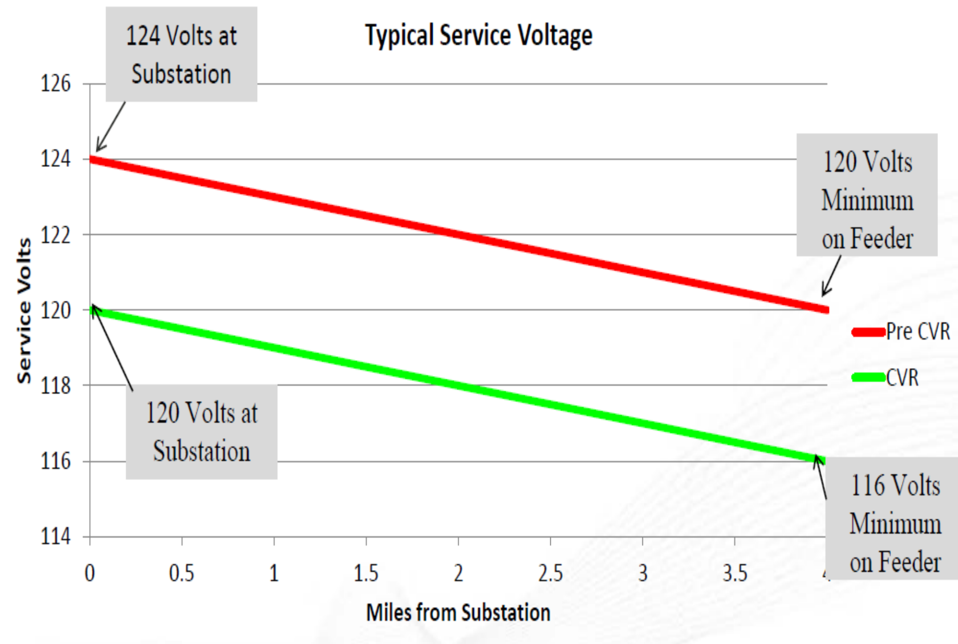
What Does Conservation Voltage Reduction (CVR) Do?

Reduce voltage to a feeder within allowable limits (ANSI C84.1: 114-126) and get energy efficiency gains on both sides of the meter.

- Typical total system energy reduction due to CVR is 0.5% - 4% depending on the specific feeder.
  - Commercial Load has higher energy savings than Residential load due to increases in lighting, motor, and air conditioning loads

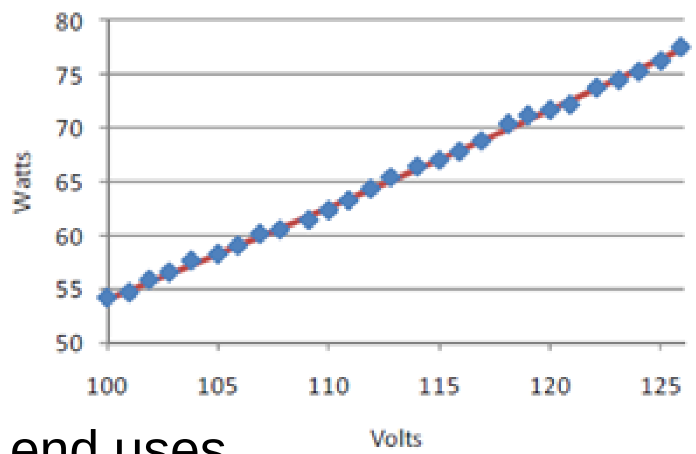


"CVR Factor" measures the latter: % change in energy / % change in voltage

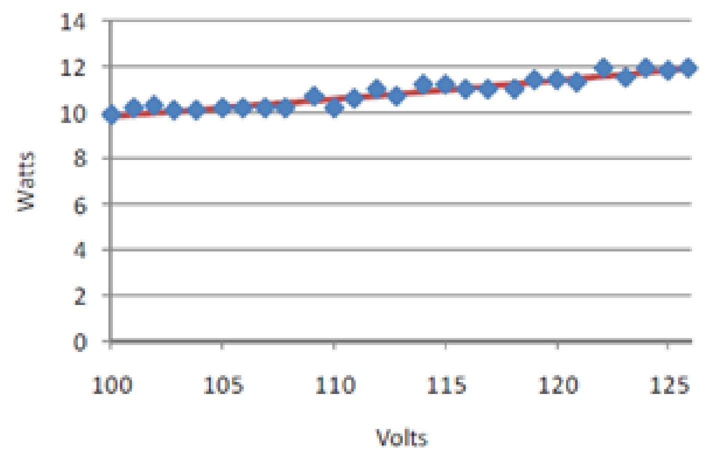
Why Does CVR Work?

- Each end use of electricity responds differently to voltage changes.
  - Example: CVR produces significantly more savings from incandescent lamps than CFLs.

Incandescent lamp



Compact Fluorescent lamp



- For some end uses,
  - CVR saves demand but not energy e.g. space heating
  - CVR saves watts and watt-hours by reducing the delivered level of service e.g. incandescents (lower lumens, “brownout”)
  - CVR saves almost nothing e.g. LED lamps, LCD televisions
  - CVR at some levels can damage equipment e.g. some motors

DNV GL Energy's CVR Project Experience

- Energy and load impacts of CVR at substation and customer site levels, using statistical and engineering models
- End-use load and consumption profiles by region, weather zone, and customer class, tied to end-use level CVR impacts
- Development of settlement protocols for participating distributors
- Implementation strategy support
- Projection of CVR benefits with respect to feeder characteristics
- Economic analysis of CVR in AMI/smart grid business cases
- Architectural analysis of enabling CVR via telecom networks
- CVR system design and implementation

Needs Related to CVR

Implementation and Planning Strategies

- Control scheme to use?
- Primary use: emergency response, load reduction or energy savings?
- What are the system requirements, with or without AMI?
- Which substation/feeder configurations are feasible?
- What is the benefit/cost a distribution system?
- What capital investments would improve CVR impact?
- …

Evaluation, Measurement, and Verification

- Voltages at "first" and "last" customers on the circuit
- What are the energy and demand savings to the customer and the utility?
- What is the expected savings potential for expanded deployments?
- How does CVR affect customer satisfaction, and power quality?
- How to disentangle savings from CVR versus other DR and EE programs?

Elements for CVR

- **Substation Transformers Load Tap Changers (LTC)**
  - The regulation of the LTCs is typically accomplished by a number of **steps.**
  - The voltage **bandwidth** is determined by LTC size and controller accuracy, and may also be limited by the fluctuation of supplied transmission voltage.
  - A **time delay** is applied when there is a short voltage excursion outside the bandwidth that does not merit a tap change. Most often the time delay is 30 to 60 seconds.
- **Voltage Regulators**
  - The purpose of voltage regulators is to boost or buck the distribution system voltage to maintain an acceptable utilization voltage level throughout the length of the distribution circuit.
  - This is usually done with multi-tap auto-transformers with auto tap changers giving ±10% voltage regulation.
  - The maximum available time-delay setting for field regulators is **120 sec**.
- **Shunt Capacitors**
  - Capacitor bank sizes installed on feeders may vary from 600 – 2,400 kVAR, and they can be fixed or switched (controlled) capacitors. Voltage rise is ~0.5% to a limit of 4%.

How to Control Voltage to Lower Half of Allowable Range?

- Targeted control of Load Tap Changer (LTC) at the substation and with downstream voltage regulators and capacitors.
- More recent techniques rely on visibility of voltage throughout the circuit and feedback mechanisms to ensure minimum levels are maintained for customers on the feeder circuits
  - Monitoring and feedback via SCADA and AMI systems, when available
  - Low voltage points can be estimated with engineering circuit models and limited telemetry for systems without full visibility and feedback
  - Monitoring allows for greater confidence that voltage levels are maintained, and can therefore enable greater voltage reductions

CVR Impact Analytical Evaluation Methods

Statistical Approaches

- On/Off Evaluation Periods
  - Alternate CVR-on to CVR-off each day throughout an evaluation period, and model the effect of CVR controlling for weather, day type, and other factors using linear regression.

Engineering Approaches

- Ability to estimate savings via circuit models
- Can assist with deemed savings and planning for CVR
  - What are the potential savings (kW, kWh) and how do they vary across circuits?
  - Where should investments for increased savings be targeted?
    - Voltage improvements to flatten the voltage profile and enable greater voltage reductions
    - Investment in equipment to manage voltage further down the line
  - How do operational changes affects savings?

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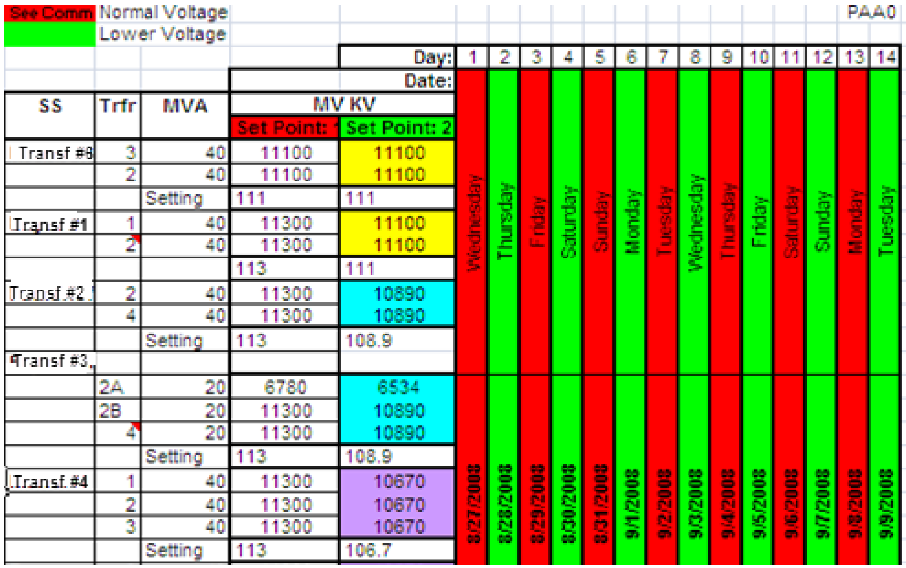
Sample Project Properties

- The pilot program used existing equipment only.
- It involved controlling transformer load tap changers (LTC)
- System operators can change the station set voltages through SCADA.

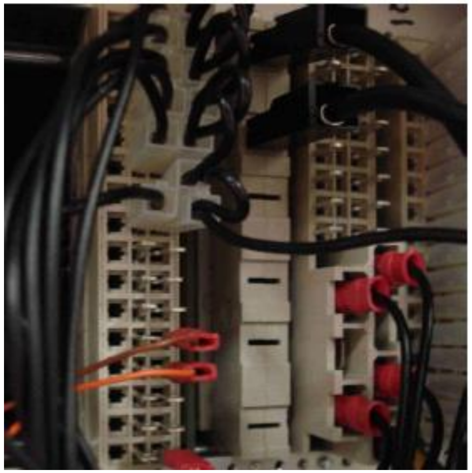


See Comm — Normal Voltage
Lower Voltage

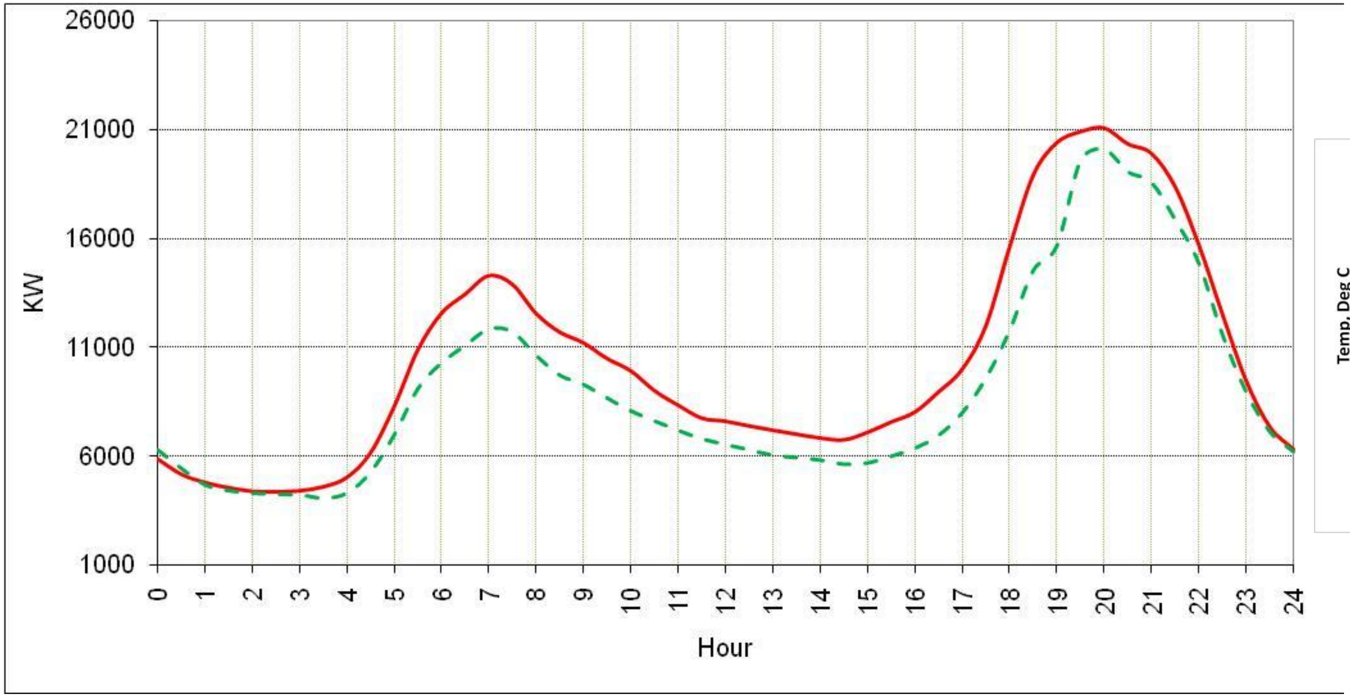
PAA0

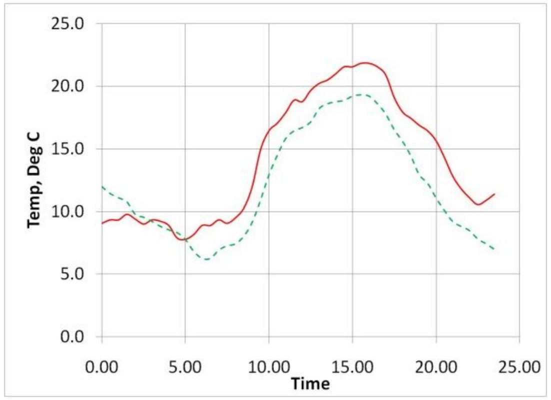
SS	Trfr	MVA	MV KV Set Point: 1	MV KV Set Point: 2
Transf #6	3	40	11100	11100
	2	40	11100	11100
		Setting	111	111
Transf #1	1	40	11300	11100
	2	40	11300	11100
			113	111
Transf #2	2	40	11300	10890
	4	40	11300	10890
		Setting	113	108.9
Transf #3				
	2A	20	6780	6534
	2B	20	11300	10890
	4	20	11300	10890
		Setting	113	108.9
Transf #4	1	40	11300	10670
	2	40	11300	10670
	3	40	11300	10670
		Setting	113	106.7

Day:	Date:	
1	8/27/2008	Wednesday
2	8/28/2008	Thursday
3	8/29/2008	Friday
4	8/30/2008	Saturday
5	8/31/2008	Sunday
6	9/1/2008	Monday
7	9/2/2008	Tuesday
8	9/3/2008	Wednesday
9	9/4/2008	Thursday
10	9/5/2008	Friday
11	9/6/2008	Saturday
12	9/7/2008	Sunday
13	9/8/2008	Monday
14	9/9/2008	Tuesday



Transformer T2   ΔV= 3.4%

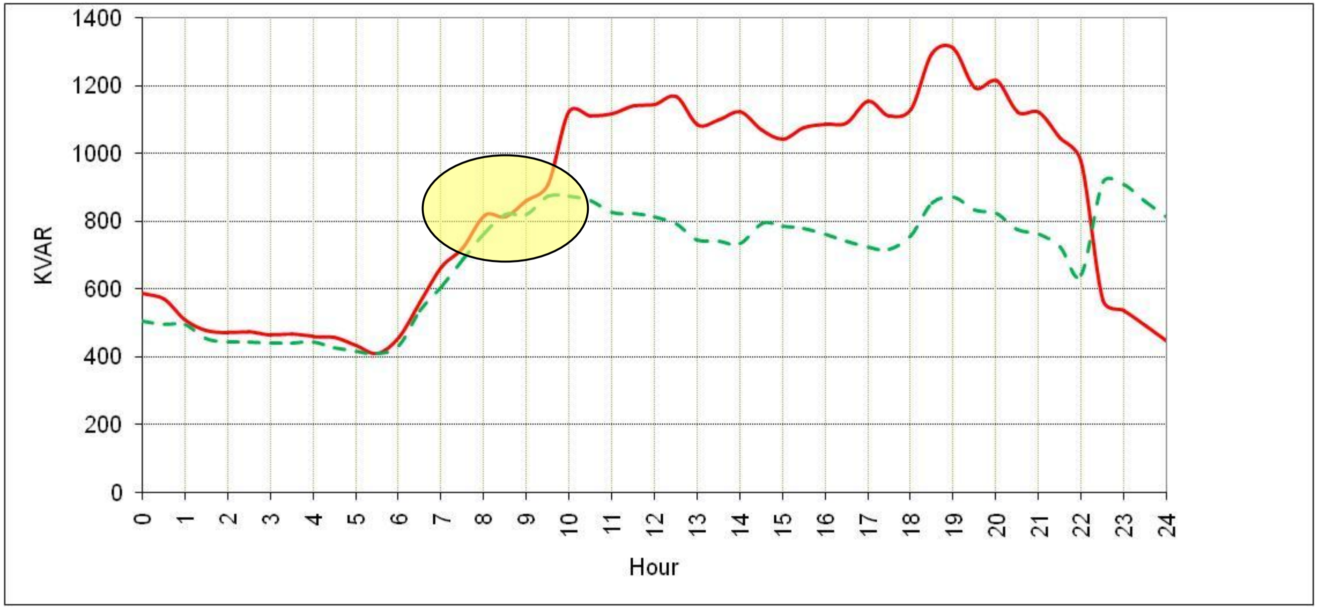




Note green represents transformer on reduced voltage setting. Red and black are for normal setting

Tapping at Odd Times

Mistakes can be good (*sometimes!*)



Actual tapping of the transformers was not performed strictly against the schedule (on few occasions, tapping did not take place at the scheduled time, but at a different time of the day, or even did not take place at all).

Effect on kw and Kvar

One example* of load research: % kW/kvar reduction for 1% voltage reduction

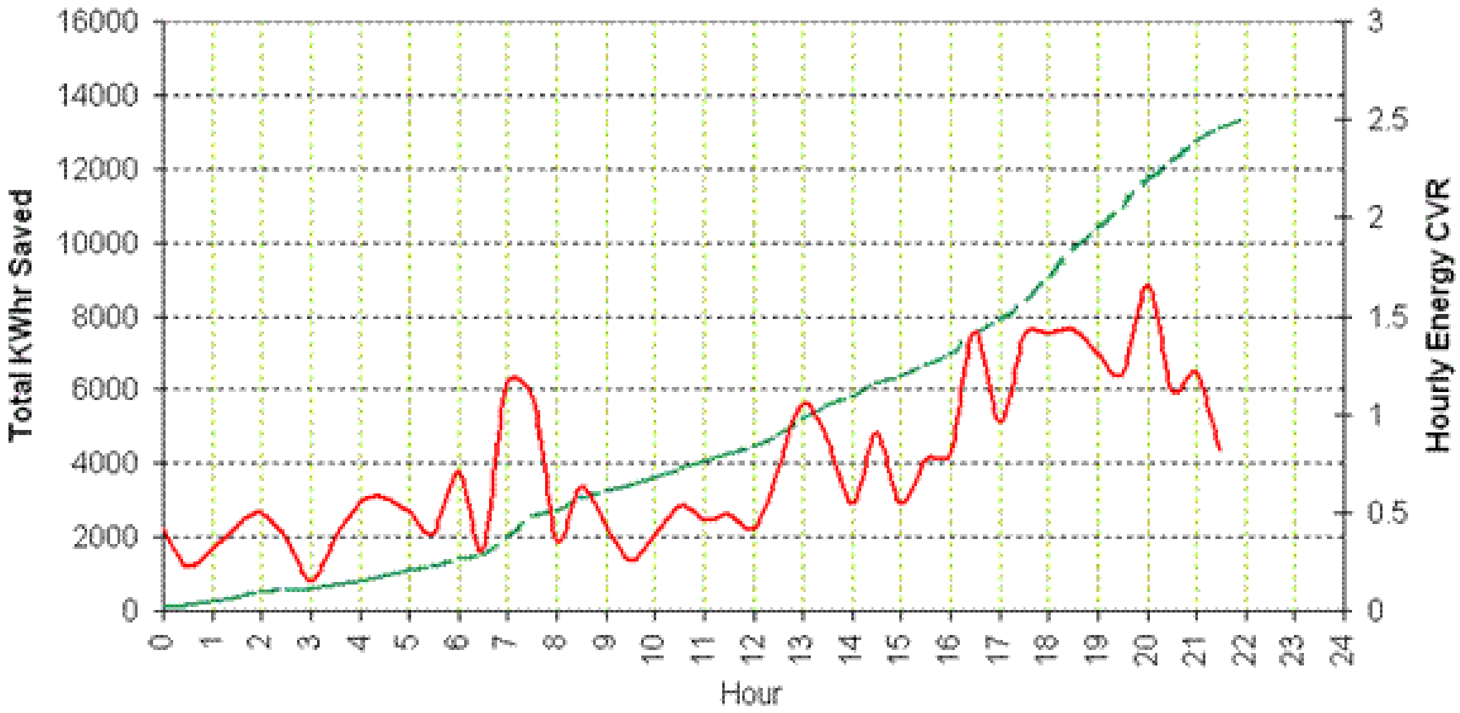
Variation of load with voltage	kW	kvar
Residential; Summer Day	0.72	2.96
Residential, Winter Night	1.30	4.38
Commercial, Summer Day	1.25	3.50
Commercial, Winter Night	1.51	3.40
Industrial	0.18	6.00

* IEEE Transaction PAS, No. 9, pp. 3365-72; 1982

For a full bibliography, see IEEE Trans. PAS, Vol 10, pp 523-38, Feb. 1995

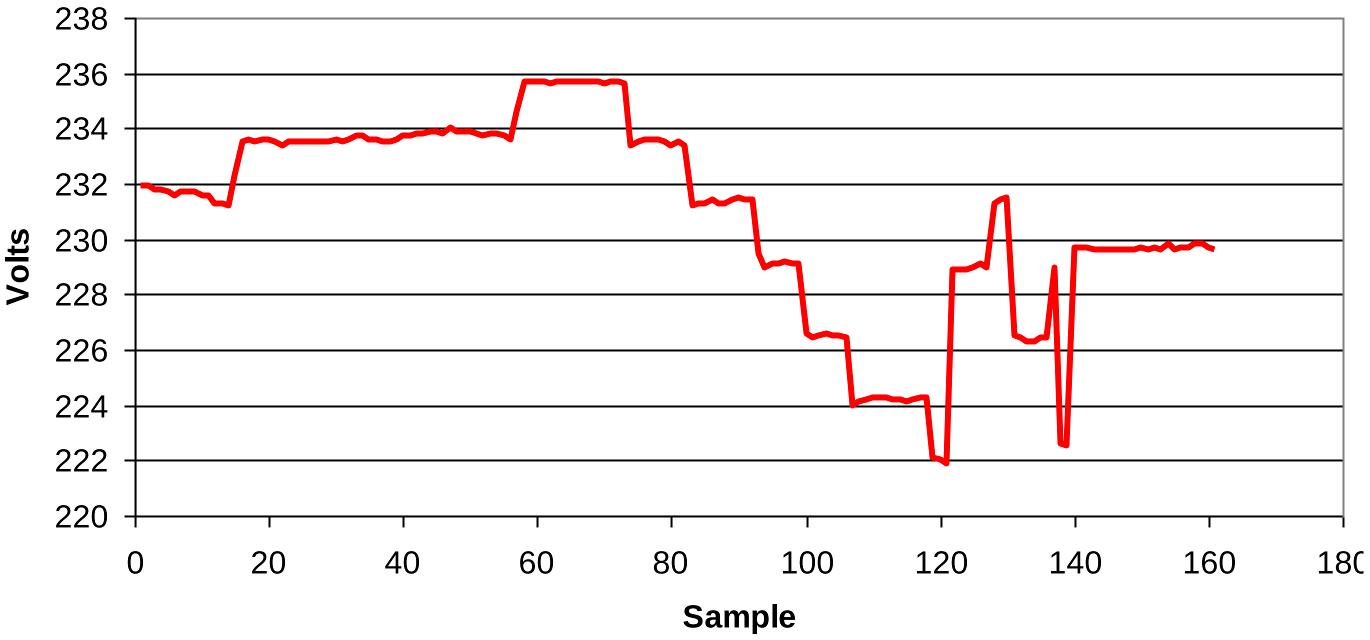
Caution: Depending on the types of load served, voltage reduction may increase load – Georgia Power study

Sample Results

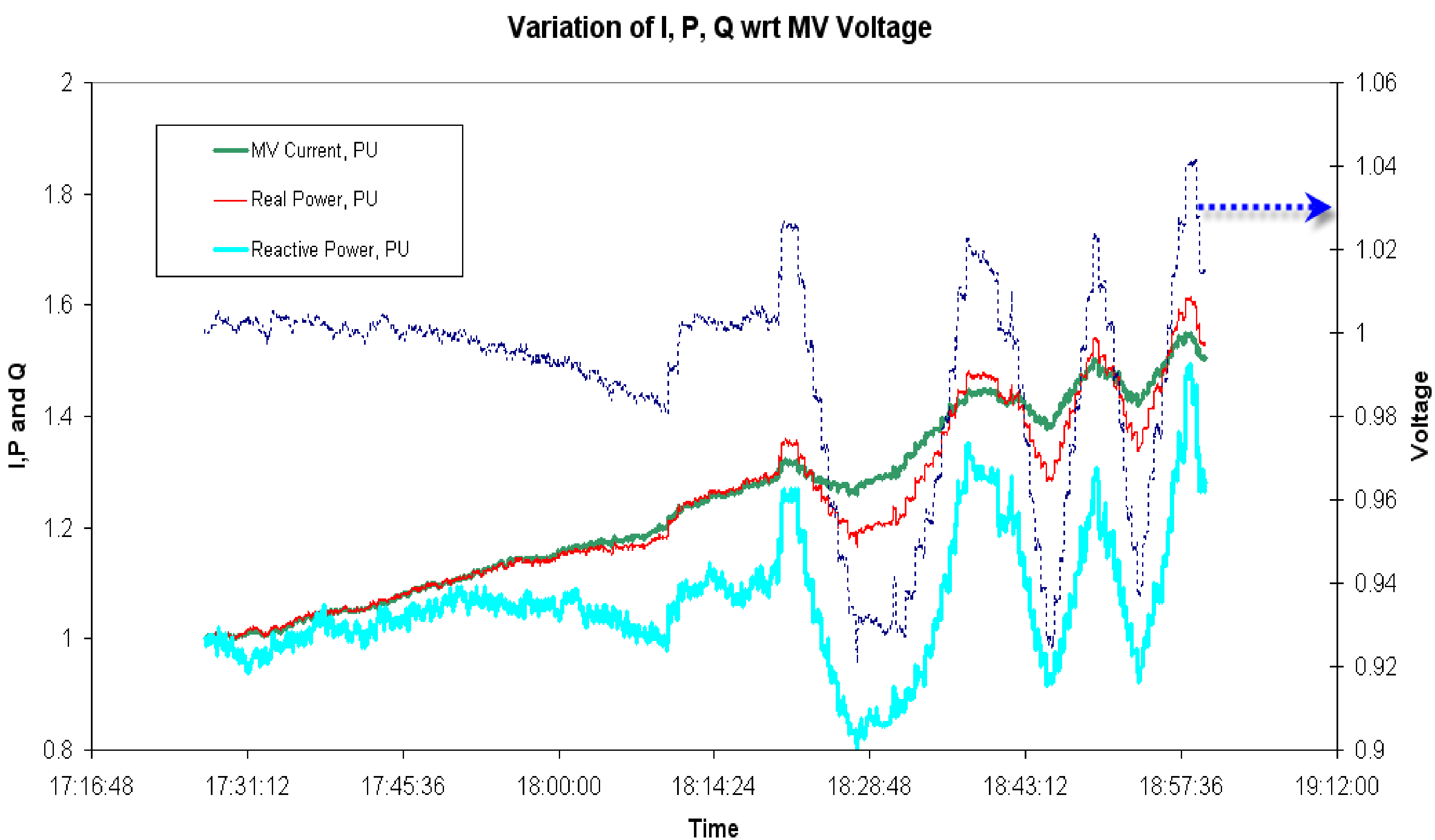


Energy CVR (ratio of % savings of energy to % change in voltage) varies from about 0.5 to above 1.

Measurements at a Remote Mini Sub



Changing Substation Voltage



Modelling Example: Circuit Model

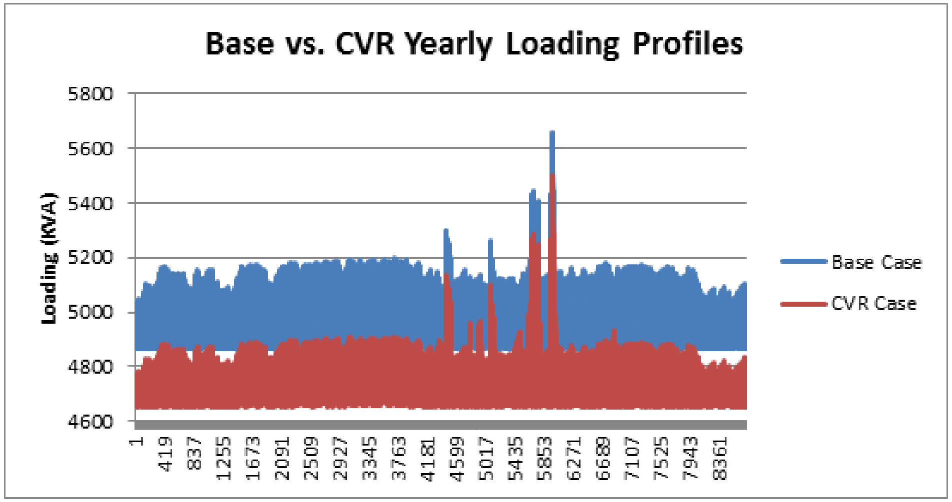
- Taxonomy feeder created by PNNL for DOE
- 12.47kV, 10kVA substation, Temperate West Coast Region
- Heavily loaded commercial / residential suburban
- Short, underground circuit (~3 km)
- No V.R. nor capacitor

Base Case

- Regulate substation transformer to ~1.05- PU
- Results
  - ~ 32 GWh annual energy demand
  - Substation transformer overloaded for ~ 10 hours

Simulation

- Base Case
  - Regulate substation transformer to ~1.05- PU
  - ~32 GWh annual energy demand
- Results
  - ~5% total kWh savings
    - ~3% kWh losses reduction
    - ~5% kWh load demand reduction
  - Substation transformer at 89% capacity (no overload)



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