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December 8, 2014

Public Utility Commission of Oregon
Electric and Natural Gas Division
PO Box 1088
Salem, Oregon 97308-1088

Re: PGE's Conservation Voltage Reduction (CVR) Pilot Final Report (UM 1657)

Filing Center:

Pursuant to OPUC Commission Order No. 14-333, PGE is to report to the Commission on the findings from PGE's CVR pilot program in the first quarter of 2015. Enclosed is the original and three copies of PGE's CVR Pilot Cost-Benefit Analysis Report that PGE will address at the CVR workshop (date to be determined). The work papers are provided in electronic format (CD) due to the size of the files.

If you have any questions, please call me at (503) 464-7580, or Spenser Williams at (503) 464-7490.

Sincerely,

A handwritten signature in blue ink, appearing to read "Patrick G. Hager", is written over the typed name.

Patrick G. Hager
Manager, Regulatory Affairs

PGH:kr
encl.

cc: Bob Jenks, CUB
UM 1657 Service List
LC 56 Service List

Conservation Voltage Reduction

Cost-Benefit Analysis



November 24, 2014

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I. Introduction

This report presents the results of a cost-benefit analysis of conservation voltage reduction (CVR) on Portland General Electric's (PGE) distribution system. This analysis was conducted to meet Oregon Public Utility Commission (OPUC) requirements to assess the potential for distribution system energy savings from CVR. PGE is required to "consider conservation voltage reduction (CVR) for inclusion in its best cost/risk portfolio and identify in its action plan steps it will take to achieve any targeted savings" (see OPUC Order No. 10-457 at 22).

This report is organized as follows. In section II, we provide an overview of CVR. In section III, we describe the feasibility study and pilot project that PGE has completed to evaluate the technical potential for energy savings from CVR implementation on PGE's system. In section IV, we explain how the cost-benefit analysis was performed and, for the two substations in the pilot project study, provide estimates of the present values of program costs and benefits. In section V, we discuss extension of the results to possible system-wide implementation. In section VI, we summarize our conclusions.

II. Overview of CVR

CVR is a means of lowering consumer power demand by operating distribution feeders within the lower portion of the acceptable voltage bandwidth¹. Consistent with the Northwest Energy Efficiency Alliance's (NEEA) Utility Distribution System Efficiency Initiative Project, this should reduce customers' energy consumption.

III. PGE's CVR Feasibility Study and Pilot Project

In 2012, PGE conducted a feasibility study to determine the viability of implementing a CVR program without incurring power quality issues (e.g., reducing a customer's voltage below the lower limit of the acceptable voltage bandwidth). Also, the study was performed to quantify the relationship between operating voltage and power demand on PGE's distribution system. Simulation results² confirmed the conclusion made by the NEEA: CVR implementation will reduce demand by lowering the amount of energy a customer consumes.

The simulation results led to the funding and implementation of the CVR pilot project at two substations within PGE's service territory: one distribution power transformer in the City of Gresham (i.e., Hogan South WR4) and one distribution power transformer in the City of Beaverton (i.e., Denny WR2). Implementation in Gresham was energized in July 2013; Beaverton in December 2013. Pilot results have validated the conclusions reached based on the feasibility study simulations: at qualified locations, CVR implementation will result in a reduction of customers' energy consumption.

¹ ANSI Standard C84.1-1989 establishes a "Range A" operating secondary voltage of +/-5% of the voltage base.

² See PGE's 2014 Smart Grid Report, Appendix D, published June 1, 2014.

The physical implementation of CVR included the following operational functions:

- Day-on/Day-off operation to provide a data comparison between “normal” mode and “CVR” mode.
- Auto/Manual control for use during contingencies and peak shaving.
- Hourly voltage data monitoring at targeted residential customer meters to ensure acceptable voltage levels.

Table III-1 shows the results of physical CVR implementation in Gresham and Beaverton.

Table III-1
CVR Pilot Project Customer Energy Reduction

Season	Hogan South WR4		Denny WR2	
	% kWh : 1% V ¹	Total % kWh ²	% kWh : 1% V ¹	Total % kWh ²
Winter	0.87 : 1	2.17%	0.99 : 1	2.47%
Summer	0.91 : 1	1.37%	0.94 : 1	1.41%

¹ Corresponds to percentage of kilowatt-hour reduction per one percent voltage reduction

² Corresponds to total percentage of kilowatt-hour reduction

Measured quantities confirmed that customer demand and energy consumption were reduced as a direct result of CVR implementation. Whether constantly implemented, or used as a peak-shaving method, CVR is more beneficial in the winter due to the higher proportion of resistive loads (e.g., electric furnaces) relative to summer load composition; however, benefits are realized year-round.

IV. CVR Cost-Benefit Analysis

The cost-benefit analysis described in this section of this report is based on data from the completed pilot project study described in section III. As such, the results are based on data from two substations and cannot be immediately extrapolated to PGE’s total system; however, the analysis should provide useful guidance as to the relative magnitudes of the costs and benefits of CVR on the PGE system.

The cost-benefit analysis was performed from a “total resource cost” perspective. The analysis considered all direct and quantifiable resource costs. Because the CVR investments are made by the utility, the costs are expressed as revenue requirements. The benefits consist of energy savings that are valued at their avoided costs. The avoided costs are the estimated value of the energy savings at the wholesale market level. The results of the analysis are expressed as the net present value of revenue requirements (NPVRR).

A. Program Costs

For the cost-benefit analysis of CVR, it is important to determine those costs that are “incremental” to the adoption of CVR. Analysis and design work specific to each distribution power transformer and distribution feeder must be performed. The principal costs incremental to CVR operation include the costs of:

- Engineering design and analysis (performed at the distribution level).
- Updated substation drawings.
- Project management.
- Labor for equipment installation.
- Equipment required for CVR implementation.
- Labor for operating the CVR system over time.
- Maintenance and repair costs for the CVR system over time.

Four pieces of equipment used in CVR are clearly installed to facilitate CVR operations:

- Switched distribution shunt capacitor banks.
- A substation capacitor protection package.
- A load tap changer (LTC) voltage regulation controller.
- A substation communication gateway.

The switched distribution shunt capacitor banks provide reactive power compensation that keeps the power factor at the distribution power transformer within a prescribed range, and provide a voltage boost to customers throughout the feeder. The substation capacitor protection package ensures safe and efficient operation of the switched substation capacitors. The LTC voltage regulation controller maintains a dynamic feeder voltage at the substation to ensure acceptable voltage is delivered to all customers during variable loading conditions. The substation communication gateway ensures a secure connection to the system control center for proper monitoring.

CVR implementation on a feeder also relies on substation equipment already in place. For the purposes of this analysis, we assume that the costs of this pre-existing equipment are not incremental and therefore do not belong in the cost-benefit calculations for the two substations. Implementation of CVR on a system-wide basis will have to be integrated with future investments in PGE's "smart grid." In section V of this report, we provide a brief roadmap of the expected rollout of these investments and explain the relationship of system-wide CVR implementation to these system upgrades.

The details of CVR implementation costs are provided in Attachment A.

B. Program Benefits

The pilot project study discussed in section III indicated that CVR produces material energy savings. The level of energy savings resulting from CVR implementation is season dependent. The savings are higher (2.3%) for "winter" months (November through April) and lower (1.4%) for "summer" months (May through October).

Table IV-1 below shows the estimated energy savings by month for the two substations, based on the seasonal percentage factors in Table III-1.

Table IV-1
CVR Energy Savings at
Hogan South and Denny Substations

<u>Month</u>	<u>MWh</u>	<u>MWa</u>
January	415	0.56
February	387	0.58
March	363	0.49
April	327	0.45
May	197	0.26
June	190	0.26
July	218	0.29
August	159	0.21
September	148	0.21
October	152	0.20
November	390	0.54
December	421	0.57
Annual	3,367	0.38

The details of the benefit calculations are provided in Attachment A.

C. Net Program Benefits

The net benefit resulting from CVR implementation at the two substations is calculated by comparing the present values of program costs and benefits. As indicated, program costs are the utility revenue requirements resulting from the incremental costs of CVR implementation. Implicitly, the “CVR Net Present Value” assumes the completion of the three “smart grid” initiatives described in section V. Program benefits are the realized energy savings multiplied by the corresponding per-unit avoided costs.

The results of the cost-benefit analysis are summarized below in Table IV-2. The table reports NPV and the benefit-cost ratio. The table shows that the present value of benefits exceeds the present value of costs by \$1,859,073 with a benefit-cost ratio of 3.77.

Table IV-2
CVR Net Present Value
For the Two Pilot Program Substations

Present Value of System Benefits	\$2,530,945
Present Value of Costs	\$671,872
Net Present Value ¹	\$1,859,073
Benefit Cost Ratio	3.77

¹The Net Present Value analysis was based on a 25-year study period.

V. System-Wide Implementation

A. CVR's Place in Smart Grid Planning

Due to the manual intervention required to maintain the CVR pilot project, subsequent CVR installation will be unsustainable without first implementing certain "smart grid" initiatives. Chart V-1 below shows the timing of three elements of the Smart Grid program that PGE expects will precede any system-wide CVR implementation:

- **The Communication Network Pilot** – The pilot will analyze the feasibility of utilizing the existing Sensus FlexNet Base Station Multiple Access System (MAS) radio spectrum transceivers as a reliable and secure mode of communication to "smart" devices in the field. Currently, the MAS radio spectrum transceivers are used to gather and deliver Advanced Metering Infrastructure (AMI) information. This pilot will transfer the AMI information to existing Personal Communication Service (PCS) radio spectrum transceivers, in order to allow both datasets (i.e., "smart" device data and AMI data) to coexist. After completion of the pilot, PGE will have selected a communication spectrum to monitor switched distribution shunt capacitor banks associated with dynamic CVR expansion.
- **AMI Voltage Data Bandwidth Expansion** – The bandwidth expansion will upgrade the Sensus Regional Network Interface (RNI) software, and upgrade customer meter encryption and firmware. These upgrades will enable PGE to retrieve all customer voltage data at the meter base in 15 minute intervals. At the time of the CVR pilot project, only a small percentage of customer meter voltage data was able to be obtained at one hour intervals. The resultant addition of all customer meter voltage data, and increased customer voltage resolution, will allow PGE to utilize data analytics software to assist in continuously delivering customers acceptable voltage.
- **Data Analytics Research and Development** – The data analytics research and development will examine which data analytics tool will be utilized to analyze data obtained as the result of "smart grid" implementation, including CVR. Establishing the usage of a proven data analytics tool will provide an interactive user interface where engineers can efficiently observe the status of CVR implementation.

During the "data integration" phase, utility data (e.g., AMI data, asset geospatial information) will be incorporated into the analytics tool. Data reliability, usability, and software functionality will be examined during this phase.

At the conclusion of the "data integration" phase, and the concurrent AMI voltage data bandwidth expansion project, the analytics tool will be examined during the "project implementation" phase. An experimental CVR implementation project will be developed and analyzed using the analytics tool, in order to show "proof of concept" prior to system-wide dynamic CVR expansion.

For example, the analytics tool will leverage the increased customer meter information, acquired as a part of the AMI voltage data bandwidth expansion, by providing the user with real-time customer voltage data. The analytics tool will evaluate the voltage data and set an alarm for those meter voltages that travel outside of the user defined criteria (e.g., outside the acceptable voltage bandwidth). Subsequently, engineers will use the analytics tool to assist in fine tuning CVR control settings.

**Chart V-1
Timing of Smart Grid Initiatives with CVR Elements**

Smart Grid Initiative	2014				2015				2016				2017				2018				2019			
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Communication Network Pilot																								
AMI Voltage Data Bandwidth Expansion																								
Data Analytics R&D																								
Dynamic CVR Expansion																								

After completion of the three elements described above, PGE will be able to optimally expand its dynamic CVR program. CVR settings and controls will be managed locally, inside the substation control house, with centralized performance monitoring. Gaining the ability to obtain all customer meter voltage data at a higher resolution, will allow PGE to utilize data analytics software to assist in continuously delivering customers acceptable voltage. Choosing a reliable and secure communication spectrum will allow switched distribution shunt capacitor banks to communicate efficiently and effectively. Establishing the usage of a proven data analytics tool will provide an interactive user interface where engineers can efficiently observe the status of CVR implementation. When necessary, engineers will be able to use this tool to fine tune CVR control settings, in order to obtain the maximum CVR benefit.

B. Pre-Screening Transformers for CVR Implementation

Initial screening of existing distribution power transformers identified 94 optimal candidates for CVR implementation. These transformers are deemed to be optimal sites for CVR because modern communication equipment (e.g., SCADA) is already installed inside the substation. In addition, these transformers primarily serve residential and commercial load, which reduces the likelihood of customers incurring power quality issues due to the reduced voltage and the existence of industrial machinery. Additional transformers may be deemed CVR candidates upon subsequent screening.

Table V-1 below shows the estimated energy savings by month for the 94 transformers.

**Table V-1
CVR Energy Savings at
94 CVR Candidate Transformers**

<u>Month</u>	<u>MWh</u>	<u>MW_a</u>
January	16,677	22
February	15,337	23
March	14,318	19
April	13,019	18
May	7,852	11
June	7,685	11
July	9,372	13
August	9,133	12
September	8,340	12
October	8,185	11
November	14,373	20
December	18,644	25
Annual	142,934	16

VI. Conclusions

This report presents the results of a cost-benefit analysis of a conservation voltage reduction pilot study performed by PGE. This analysis was conducted to meet Oregon Public Utility Commission (OPUC) requirements to assess the potential for distribution system energy savings from CVR. The CVR pilot project study validated the results of a prior feasibility (simulation) study: CVR can produce material energy savings. Based on the pilot study, average percent energy savings realized at two substations were 2.3% for “winter” months and 1.4% for “summer” months.

An analysis of the costs and benefits of CVR implementation demonstrated that CVR was cost-effective for the two substations in the pilot study. The analysis resulted in a benefit-cost ratio of 3.77.

Extrapolation of these results to system-wide implementation is not immediate. PGE has identified a total of 94 transformers on its system that are optimal candidates for system-wide CVR implementation. Expected savings will vary across these transformers.

Due to the manual intervention required to maintain the CVR pilot project, a system-wide rollout of CVR must be coordinated with related “smart grid” investments. These related investments must be in place before CVR can be fully effective. After completion of three elements: the Communication Network Pilot, AMI Voltage Data Bandwidth Expansion, and Data Analytics Research and Development, PGE will be able to optimally expand its dynamic CVR program.