# AVISTA CORP.
# RESPONSE TO REQUEST FOR INFORMATION

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|---|---|---|---|
| JURISDICTION: | WASHINGTON | DATE PREPARED: | 07/01/2016 |
| CASE NO.: | UE-160228 & UG-160229 | WITNESS: | Heather L. Rosentrater |
| REQUESTER: | Public Counsel/Energy Project | RESPONDER: | C. Kirkeby / L. La Bolle |
| TYPE: | Data Request | DEPT: | State & Federal Regulation |
| REQUEST NO.: | PC/EP – 059 Revised | TELEPHONE: | (509) 495-4710 |
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## REQUEST:

With respect to Avista’s response to Public Counsel and The Energy Project Joint Data Request Nos. 29 and 30, please document where in the evaluation of the Pullman conservation voltage reduction results (and the resulting report) that the existence of or potential impact of the AMI meters was identified or evaluated in the study of the conservation voltage reduction impacts.

## RESPONSE:

Conservation voltage reduction is an energy conservation program that relies on a method of operational control of the distribution system that corrects the power factor and simultaneously lowers the voltage (v) to the lower portion of the range Avista is required to operate within for serving its customers (114v to 126v). The reduction in operating voltage reduces the electricity requirement for meeting our customer’s end use needs and reduces the “losses” of electricity that occur as it “travels” on the distribution system. In the conventional operation of the distribution system, the utility uses “voltage regulators” in the substation to either boost or reduce the voltage on the feeder as needed, based on preset triggers that reflect the characteristics of the feeder and its loading (number of amps) at any given point in time. Because the utility does not know the actual voltage along the feeder (other than when readings were taken as part of the process of adjusting the voltage regulator settings), the voltage regulator is set to maintain the voltage in the upper part of the allowed range (known as a “buffer”) in order to ensure that the voltage will not fall below the required lower limit for any customer as the demand, types of loads such as motors, and usage fluctuates on a continuous basis.

Avista’s Smart Grid Projects in Pullman and Spokane provided the opportunity for Avista to dramatically increase its energy conservation savings achieved through the deployment of conservation voltage reduction on 72 electric feeders. Because Avista intended to apply these savings toward its state-mandated energy conservation targets, it was required to independently verify the distribution system energy efficiency savings it estimated and reported to the Commission. Specifically, Avista had to verify the values (savings) that were calculated using applicable parts of the Regional Technical Forum (RTF) “Automated CVR Protocol No. 1,” Voltage Optimization Protocol” (Protocol #1). The resulting study, commissioned by Avista and the Northwest Energy Efficiency Alliance, was performed by Navigant Consulting and was designed to verify the accuracy of the Automated CVR Protocol #1, and the resulting energy savings claimed by the Company. The Navigant study also evaluated two additional models for estimating CVR energy savings. As noted in PC/EP-086 and others, the study validated the accuracy of the Protocol #1 model and the amount of the energy savings (MWh) estimated by the Company. It was not within the scope of the Navigant study to evaluate the potential of various approaches or strategies (including the potential of advanced meters) for implementing conservation voltage reduction programs. The Navigant study is provided as PC/EP_DR_059 Revised Attachment A.

# Avista Utilities' Conservation Voltage Reduction Program

## Impact Evaluation

**Prepared for:**
**Northwest Energy Efficiency Alliance**

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Reference No.: 164638
May 1, 2014

# Acknowledgements

This evaluation was a part of a larger distribution efficiency project for the Northwest Energy Efficiency Alliance (NEEA). Christopher Frye managed this project for NEEA. David Thompson oversaw the project for Avista Utilities. John Gibson, Curt Kirkeby, and Dan Johnson of Avista Utilities also provided valuable input.

The Navigant Consulting, Inc. team included Kevin Cooney (managing director), Dan Greenberg (project manager for the distribution efficiency project), Frank Stern (task manager), Paul Higgins (statistical analysis), and Eugene Shlatz (distribution engineer lead).

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# Executive Summary

Avista Utilities (Avista) implemented a conservation voltage reduction (CVR) program in 2013 as part of larger Smart Grid projects. This report presents Navigant Consulting, Inc.'s (Navigant's) evaluation of the energy efficiency acquisition impact of that program.

## Overview of Program

CVR is a type of distribution efficiency, also known as conservation voltage regulation or voltage optimization. CVR is the long-term practice of controlling distribution voltage levels in the lower range of acceptable levels, as defined by the American National Standards Institute, to reduce demand and energy consumption.

Avista's CVR program is a part of its two Smart Grid 2.0 projects. Both projects incorporate Integrated Volt Var Control (IVVC). The IVVC module issues commands to the station or midline regulators to maintain the minimum voltage set-point within a specified voltage dead-band. Avista based the business case for IVVC on the avoided cost of energy resulting from the reduction of load by lowering the distribution line voltage.

Commissioning of IVVC in the Washington service territory, including the cities of Spokane and Pullman, began in September 2013 and concluded on December 31, 2013.

## Regulatory Requirement

Washington's public utilities (public utility districts, municipals) are required to report to the state Department of Commerce on their progress in the preceding biennium in meeting regulatory targets. Investor-owned utilities are required to supply the same information to the Utilities and Transportation Commission (UTC). Utilities are also required to make these reports available to their customers and the general public.

The UTC issued an order requiring Avista to provide third-party verification of distribution efficiency savings:

> *For savings claimed from distribution efficiency, Avista Corporation must provide third-party verified values calculated using applicable parts of the RTF's Automated CVR Protocol No. 1, Voltage Optimization Protocol, or any other protocol recognized by the RTF following the date of this order. This requirement does not prevent Avista Corporation from developing an additional EM&V methodology for distribution efficiency and advocating at a future Commission proceeding for the recognition of third-party verified savings calculated using that methodology.* (UTC 2012)

## Description of the Evaluation

As noted above, the UTC required that Avista have distribution efficiency savings evaluated using the Regional Technical Forum's (RTF's) Automated CVR Protocol No. 1, but allowed Avista to develop additional methodology.

The protocol specifies an approach for verifying energy savings on electric power distribution circuits and substations on which a utility has implemented CVR. It is flexible with respect to type of load and the utility can apply the approach to circuits serving any combination of residential, commercial, and industrial customers. The main requirements include the ability to measure and record voltage levels and energy usage at uniform intervals, and the ability to vary circuit target voltage levels on each controlled circuit at the same time every day for periods of up to a year. The protocol consists of an experimental design prescribing the procedures to follow for generating experimental data, and a recommended method for statistically estimating the conserved energy from the experimental data.

Navigant also considered two alternative methodologies.

### Washington State University (WSU) Voltage Optimization Validation Methodology

WSU has developed a methodology to derive CVR savings as part of a research effort it is conducting on behalf of Avista. WSU developed its approach to address limitations associated with RTF Automated CVR Protocol No. 1, including the need to conduct day-on, day-off measurements over an extended period. Navigant assessed the applicability of the WSU model to derive accurate energy savings for CVR.

### Navigant Regression Methodology

Navigant developed parallel savings estimation methodologies to evaluate alternative calculations in comparison to RTF Automated CVR Protocol No. 1. Navigant used the same data set as that specified in RTF Automated CVR Protocol No. 1, but relied instead on direct regression modeling to estimate energy savings. Navigant formulated several alternative model specifications and relied on empirical testing methods to select the ones with the most desirable properties.

## Summary of Results

Navigant completed an impact evaluation of Avista's CVR program. Navigant explored three methods:

1. RTF Automated CVR Protocol No. 1
2. WSU Voltage Optimization Validation Methodology
3. Navigant Regression Methodology

When fully implemented and tested, the WSU approach may present an acceptable alternative to savings estimated using industry protocols (or other methods). However, only two feeders have been modeled thus far (out of the more than seventy feeders with CVR), and Avista has not fully integrated the enhanced SynerGEE model with its Distribution Management System (DMS). Thus, at this time, Navigant is unable to conduct a rigorous comparison of savings calculated by the WSU model versus those estimated using RTF Automated CVR Protocol No. 1.

The RTF and Navigant approaches yielded savings estimates as shown in Table 1.

**Table 1. Summary of Savings Estimates**

| Approach | Savings Estimates (MWh) |
|---|---|
| RTF Automated CVR Protocol No. 1 | 42,292 |
| Navigant Regression Methodology | 42,374 |

The two estimates are statistically indistinguishable, giving confidence that the RTF method's value is reasonable. Navigant expects that inclusion of summer data would not substantially change the savings estimate and might well increase it.[1]

## Recommendations

Navigant recommends that Avista continue to cycle the CVR voltage levels per the RTF Automated CVR Protocol No. 1 for the remainder of 2014. This will enable a more robust estimate of annual savings.

Navigant also recommends that the RTF consider adopting Navigant's alternative regression approach for the evaluation, measurement and verification (EM&V) of savings for automated CVR programs. It produces similar results to the RTF Automated CVR Protocol No. 1, and is somewhat less burdensome to implement.

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[1] In previous evaluations, Navigant has found significantly higher savings during summer periods relative to the rest of the year.

# 1 Introduction

Avista Utilities (Avista) implemented a conservation voltage reduction (CVR) program in 2013 as part of larger Smart Grid projects. This report presents Navigant Consulting, Inc.'s (Navigant's) evaluation of the energy efficiency acquisition impact of that program.

## 1.1 Description of the Program

CVR is a type of distribution efficiency, also known as conservation voltage regulation or voltage optimization. CVR is the long-term practice of controlling distribution voltage levels in the lower range of acceptable levels, as defined by the American National Standards Institute (ANSI; ANSI 1995), to reduce demand and energy consumption.

The Northwest Energy Efficiency Alliance (NEEA) conducted a major study on the effects of CVR, known as the NEEA Distribution Efficiency Initiative (Leidos  2007). The objective of this initiative was to establish the viability of CVR as a conservation measure through pilot projects and demonstrations starting in 2003 through 2007. The results of the study conclusively showed that operating a utility distribution system in the lower half of the acceptable voltage range (120–114 volts) saves energy, reduces demand, and reduces reactive power requirements without negatively affecting the customer.

Avista's CVR program is a part of its two Smart Grid 2.0 projects, implemented in 2013. In Spokane, the utility smart circuits project involves upgrading fourteen substations and fifty-eight distribution feeders (Avista 2009).[2] In Pullman, Avista's Smart Grid Demonstration project encompasses updating and automating the distribution system, installing an advanced metering infrastructure, implementing a Web portal where customers can monitor their energy use, and a demand response pilot project, with upgrades to three substations and thirteen feeders (Avista 2010).

Both projects incorporate Integrated Volt Var Control (IVVC). The IVVC predictive application leverages existing power flow models, loading information, and network topology to calculate the minimum voltage on the feeder. The IVVC module issues commands to the station or midline regulators to maintain the minimum voltage set-point within a specified voltage dead-band. Avista based its business case for IVVC is on the avoided cost of energy resulting from the reduction of load by lowering the distribution line voltage (Avista 2010).

Commissioning of IVVC in Spokane and Pullman began in September 2013 and concluded on December 31, 2013.

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[2] This does not include one feeder originating at the Post Street substation in Spokane, PST12F1, which was part of the Smart Grid 2.0 project but does not currently have a smart voltage regulator and thus is not CVR-enabled.

## 1.2 Regulatory Requirements

The Energy Independence Act, enacted by voters in 2006 as Initiative 937, imposes targets for energy conservation and the use of eligible renewable resources on all electric utilities that serve more than 25,000 customers in Washington. By January 1, 2010, utilities were required to identify their "achievable cost-effective conservation potential" through 2019. Each utility must set a biennial target consisting of a certain share of this achievable cost-effective conservation potential, and will have to meet that share of conservation.

Utilities that fail to comply with either the energy conservation or the renewable energy targets will pay a penalty of fifty dollars for each megawatt-hour of shortfall, adjusted annually for inflation. Penalty payments will go into a special account that utilities can only use for the purchase of renewable energy credits or for energy conservation projects at state and local government facilities or publicly owned educational institutions.

Each year beginning in June 2012, Washington's public utilities are required to report to the state Department of Commerce on the utilities' progress in the preceding biennium in meeting the targets. Investor-owned utilities are required to supply the same information to the Utilities and Transportation Commission (UTC). Utilities are also required to make these reports available to their customers and the general public.

The UTC issued an order (UTC Docket UE-111882) requiring that Avista provide third-party verification of distribution efficiency savings:

> *For savings claimed from distribution efficiency, Avista Corporation must provide third-party verified values calculated using applicable parts of the RTF's Automated CVR Protocol No. 1, Voltage Optimization Protocol, or any other protocol recognized by the RTF following the date of this order. This requirement does not prevent Avista Corporation from developing an additional EM&V methodology for distribution efficiency and advocating at a future Commission proceeding for the recognition of third-party verified savings calculated using that methodology.* (UTC 2012)

## 1.3 Overview of the Impact Evaluation

As noted above, the UTC required that Avista have distribution efficiency savings evaluated using the Regional Technical Forum's (RTF's) Automated CVR Protocol No. 1, but allowed Avista to develop additional methodologies. The following sections discuss the RTF Automated CVR Protocol No. 1 and two other methodologies.

### 1.3.1 RTF Automated CVR Protocol No. 1

The protocol specifies an approach for measuring and verifying energy savings on electric power distribution circuits and substations on which a utility has implemented CVR. It is flexible with respect to type of load and the utility can apply the approach to circuits serving any combination of residential, commercial, and industrial customers. The main requirements include the ability to measure and record voltage levels and energy usage at uniform time intervals[3], and the ability to vary circuit target voltage levels on each controlled circuit at the same time every day for periods of up to a year.[4] The protocol consists of an experimental design prescribing the procedures to follow for generating experimental data, and a recommended method for statistically estimating the conserved energy from the experimental data (RTF 2004).

### *Experimental Design*

The protocol calls for an initial verification period lasting for one year, beginning with three months of alternating, on successive days, among full voltage reduction (CVR on), voltage set at the legacy level (CVR off), and voltage set at the nominal midpoint between CVR on and CVR off. During the next nine months, the protocol specifies that all test circuits are to be on full CVR reduction continuously except for three months, selected based on season and other factors, when the utility alternates the voltage between full voltage reduction and the controlled nominal midpoint on successive days.

During the verification period, the utility measures and records end-of-line voltages and low-side circuit loads at each time interval. The only additional information required to measure energy savings is local ambient temperatures, at uniform intervals of no more than one hour. The protocol recommends collecting the temperatures at each substation to which experimental circuits connect, as well as at the feeder end-of-line locations, in order to reduce the possibility of confounding due to localized microclimates.[5]

Recently Utilidata, the principal author of the RTF Automated CVR Protocol No. 1, proposed altering the experimental design of the protocol to eliminate the third set-point at the nominal voltage midpoint, so that all cycling of voltage settings occurs between full voltage reduction (CVR on) and CVR off on alternate days. Utilidata proposed this change because they now consider the third set-point unnecessary.[6]

### *Data Preparation*

The protocol recommends grouping the experimental voltage and load observations into twenty-four-hour periods, aggregating them up to hourly intervals, matching them to their corresponding hourly weather series, and separating the resulting twenty-four-hour ensembles into CVR and non-CVR categories.

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[3] Preferred interval length is anywhere between 5 seconds and 15 minutes (Donohue July 25, 2013).

[4] The need for systematic changes in voltage settings to take place at the same time every day over long periods makes this approach most suitable for automated CVR systems; hence, the title of the protocol document.

[5] However, hourly National Weather Service data from the closest available weather station is also acceptable (Donohue, July 25, 2013).

[6] The third set-point called for in the 2004 protocol at the nominal midpoint between the on and off CVR settings was originally included out of concern for the possibility that there may be significant nonlinearities in the relationship between voltage and load that would not be captured if the only experimental data corresponded to the extremes of full voltage reduction and removing CVR control altogether. However, with the benefit of experience it has become clear that this is unnecessary because CVR programs generally reduce nominal voltage settings by relatively small amounts, typically one to three percent. Over such short intervals, the third set-point is extraneous (Donohue, July 25, 2013; Utilidata 2011).

#### *Statistical Estimation Procedure*

The protocol recommends using robust time-series econometric techniques to identify "integrated demand profiles" for CVR-on and CVR-off periods, separately for each combination of season (summer, winter, shoulder) and day-type (weekday, weekend/holiday). The twenty-four-hour sums of the differences between the CVR-on and CVR-off demand profiles constitute the daily energy savings due to CVR for each season and day-type. To estimate the CVR factor (CVRf), or percent difference in energy usage per unit reduction in voltage, this difference is expressed as a percentage reduction relative to the non-CVR usage, and divided by the average percentage reduction in measured end-of-line voltage for the circuit over the same time interval.

No control group is required because with on-off and variable voltage set-point capability, the application group can act as its own control group during testing periods. Essentially, the protocol requires conducting an experiment with voltage control.

### 1.3.2 The Experimental Design

Avista began daily cycling between CVR and non-CVR set-points on a representative sample of test circuits on January 1, 2014, and concluded on April 8, 2014. Given the constraints of implementation and report timing, it was not possible to conduct a full year of cycling. Navigant worked with Avista personnel to conduct as thorough and defensible an evaluation as possible using the RTF Automated CVR Protocol No. 1, given the existing time constraints.

### 1.3.3 Alternative Methodologies

Navigant also considered two alternative methodologies.

#### *Washington State University (WSU) Voltage Optimization Validation Methodology*

WSU has developed an enhanced methodology to derive CVR savings as part of a research effort it is conducting on behalf of Avista. As part of the research effort, Avista and WSU have prepared two reports (Avista 2013 and Chanda 2014) that highlight progress it has made with respect to applying advanced algorithms and feeder simulation models to calculate CVR savings to a high degree of accuracy. WSU developed its approach to address limitations associated with RTF Automated CVR Protocol No. 1, including the need to conduct day-on, day-off measurements over an extended period. Navigant assessed the applicability of the WSU model to derive accurate energy savings for CVR.

#### *Navigant Regression Methodology*

Navigant developed parallel savings estimation methodologies to evaluate alternative calculations in comparison to RTF Automated CVR Protocol No. 1. Navigant used the same data set as that specified in RTF Automated CVR Protocol No. 1, but relied instead on direct regression modeling to estimate energy savings. Navigant formulated several alternative model specifications and relied on empirical testing methods to select the one(s) with the most desirable properties.

## 1.4 Overview of Report

The next section describes the available data. Section 3 discusses the RTF Automated CVR Protocol No. 1 analysis. Section 4 presents Navigant's review of the WSU model. Section 5 presents the Navigant methodology. Section 6 summarizes findings and recommendations.

# 2 Description of Data

The primary data Navigant used to evaluate Avista's CVR program savings consists of automated distribution line measurements recorded at fifteen-minute intervals on the quarter-hours by Avista's IVVC system on a representative sample of twenty-five distribution feeder circuits. The measurements include phase-specific kilovolts (kV), amperes (Amps), kilowatts (kW), and kilovolt-amperes-reactive (kvar). Because Navigant's primary purpose was estimating the total energy savings from the CVR program, Navigant focused mainly on aggregate kW and kV. Navigant evaluated measurements at several distinct points along each feeder: at the circuit breaker immediately downstream of the substation transformer, at up to three "smart" reclosers, and at a voltage regulator. Navigant also evaluated limited information at up to three capacitor banks. Besides these quantitative measurements, qualitative information pertaining to status of the IVVC system and its components was also provided at fifteen-minute intervals, including the date-time stamp, the feeder identifier, the measurement location on the feeder, whether CVR voltage reduction was on or off, whether capacitor banks were on or off, and whether the IVVC reporting and communication system was functioning. The system automatically delivered files containing each day's data to Navigant via the internet.

In addition to the interval data covering all of the sample feeders continuously from the point at which daily voltage cycling began on January 1, 2014, Avista provided Navigant with limited additional data from the commissioning phase of the IVVC program (i.e., September through December 2013). Avista recorded these observations while installing the system and testing it on each feeder participating in the program and, as such, the observations are intermittent and sparse, covering only some of the sample on any given day, and for only limited periods. Nevertheless, Navigant welcomed the opportunity to include these data, as they allowed Navigant to extend its analysis period back into the fall 2013 season.[7]

Navigant designed the sample of feeders studied for this evaluation in conjunction with Avista staff. Navigant used information provided by Avista on the distribution of loads by customer class on each of the seventy-one feeder circuits in Spokane and Pullman on which Avista commissioned IVVC to draw a representative sample of 25 feeders. The sample drawn targeted a maximum program-level relative precision of 10 percent with a one-tailed 90 percent confidence interval, stratified over five customer strata.[8] Navigant included in the sample all available

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[7] Navigant statistically tested whether inclusion of these data altered the results before including these data and found no evidence that they did so. Navigant's main purpose in including commissioning period data was to increase the reliability of the statistical results by increasing the sample size, and to strengthen the ability to identify "shoulder season" (i.e., spring and fall) CVR effects.

[8] Avista provided Navigant with a table of kilovolt-ampere (kVa) loadings attributable to each of several customer classes by feeder. Navigant used this information to sort the seventy-one IVVC feeder circuits into five broad strata:

circuits in the industrial and rural/agricultural categories, and randomly sampled from the residential and commercial-mixed strata in proportion to their relative shares in the number of IVVC feeders. Navigant also selected two Pullman feeders dedicated to delivering power to the WSU grid. Table 2 shows the list of sample feeders, along with their locations and characteristics.

**Table 2. Feeder Circuit Sample**

| No. | City | Substation | Feeder | Category |
|---|---|---|---|---|
| 1 | Spokane | GLN | GLN12F1 | Predominantly residential (7 of 26) |
| 2 | | L&S | L&S12F2 | |
| 3 | | SE | SE12F5 | |
| 4 | | 9CE | 9CE12F4 | |
| 5 | Pullman | SPU | SPU123 | |
| 6 | | TUR | TUR113 | |
| 7 | | | TUR117 | |
| 8 | Spokane | 3HT | 3HT12F1 | Commercial/mixed (9 of 32) |
| 9 | | | 3HT12F7 | |
| 10 | | F&C | F&C12F4 | |
| 11 | | | F&C12F5 | |
| 12 | | | F&C12F6 | |
| 13 | | L&S | L&S12F1 | |
| 14 | | ROS | ROS12F6 | |
| 15 | | SE | SE12F4 | |
| 16 | | SUN | SUN12F1 | |
| 17 | Spokane | GLN | GLN12F2 | Significant rural/ agricultural (census) |
| 18 | | NE | NE12F3 | |
| 19 | Spokane | 3HT | 3HT12F5 | Predominantly industrial (census) |
| 20 | | BEA | BEA12F3 | |
| 21 | | | BEA12F4 | |
| 22 | | | BEA12F5 | |
| 23 | | NE | NE12F5 | |
| 24 | Pullman | TVW | TVW131 | Express feeder (13.2 kV) |
| 25 | | SPU | SPU125 | Express feeder (13.2 kV to 4 kV) |

*Notes: Data from LoadingByFeederAndZone.xlsx (Avista) and Navigant analysis.*

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residential (at least 85 percent residential load); rural/agricultural (20-30 percent agricultural loads or with significant rural stretches); industrial (at least 50 percent industrial load); commercial/mixed (either predominantly commercial or mixed commercial-residential); and dedicated lines providing power to WSU.

Table 3 provides selected descriptive statistics on the wattage and voltage measurements observed in the interval data for each sample circuit.

**Table 3. Descriptive Statistics for Sample Feeder Circuits**

| # | Feeder | kW at Circuit Breaker | | | | kV at Regulator | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Mean** | **Std Dev** | **Min** | **Max** | **Mean** | **Std Dev** | **Min** | **Max** |
| 1 | 3HT12F1 | 4,834 | 871 | 2,899 | 7,382 | 7.75 | 0.09 | 7.59 | 7.92 |
| 2 | 3HT12F5 | 5,010 | 1,074 | 2,694 | 8,515 | 7.79 | 0.08 | 7.60 | 7.94 |
| 3 | 3HT12F7 | 2,191 | 463 | 1,305 | 3,524 | 7.74 | 0.09 | 7.57 | 7.91 |
| 4 | 9CE12F4 | 3,734 | 1,025 | 1,921 | 8,149 | 7.78 | 0.07 | 7.57 | 7.91 |
| 5 | BEA12F3 | 3,288 | 1,012 | 1,462 | 9,002 | 7.75 | 0.11 | 7.58 | 7.99 |
| 6 | BEA12F4 | 3,846 | 1,180 | 1,441 | 7,150 | 7.75 | 0.09 | 7.56 | 7.95 |
| 7 | BEA12F5 | 3,919 | 1,634 | 798 | 8,168 | 7.80 | 0.08 | 7.61 | 7.93 |
| 8 | F&C12F4 | 4,281 | 869 | 2,325 | 7,299 | 7.78 | 0.08 | 7.60 | 7.91 |
| 9 | F&C12F5 | 3,402 | 959 | 1,598 | 7,917 | 7.78 | 0.07 | 7.54 | 7.91 |
| 10 | F&C12F6 | 4,367 | 929 | 2,144 | 7,309 | 7.78 | 0.08 | 7.61 | 7.91 |
| 11 | GLN12F1 | 4,426 | 961 | 2,317 | 7,770 | 7.79 | 0.08 | 7.60 | 7.92 |
| 12 | GLN12F2 | 4,193 | 1,016 | 2,122 | 8,212 | 7.78 | 0.07 | 7.60 | 7.91 |
| 13 | L&S12F1 | 3,697 | 541 | 1,702 | 5,231 | 7.74 | 0.10 | 7.58 | 7.91 |
| 14 | L&S12F2 | 5,938 | 1,108 | 3,087 | 9,509 | 7.77 | 0.08 | 7.61 | 7.92 |
| 15 | NE12F3 | 2,526 | 542 | 1,198 | 4,741 | 7.82 | 0.09 | 7.60 | 7.97 |
| 16 | NE12F5 | 3,008 | 1,537 | 991 | 6,801 | 7.78 | 0.08 | 7.57 | 7.92 |
| 17 | ROS12F6 | 4,707 | 890 | 2,472 | 7,409 | 7.78 | 0.07 | 7.61 | 7.93 |
| 18 | SE12F4 | 4,593 | 1,010 | 2,469 | 8,531 | 7.80 | 0.07 | 7.62 | 7.95 |
| 19 | SE12F5 | 3,521 | 825 | 1,702 | 6,134 | 7.80 | 0.08 | 7.62 | 7.95 |
| 20 | SPU123 | 4,350 | 728 | 2,648 | 6,664 | 7.81 | 0.11 | 7.62 | 8.01 |
| 21 | SPU125 | 3,079 | 597 | 1,977 | 6,581 | 7.86 | 0.06 | 7.73 | 8.05 |
| 22 | SUN12F1 | 4,654 | 1,134 | 1,970 | 12,944 | 7.78 | 0.10 | 7.59 | 7.99 |
| 23 | TUR113 | 3,482 | 907 | 1,688 | 6,555 | 7.79 | 0.11 | 7.59 | 8.03 |
| 24 | TUR117 | 5,125 | 1,033 | 2,883 | 8,921 | 7.85 | 0.10 | 7.66 | 8.08 |
| 25 | TVW131 | 1,492 | 282 | 917 | 5,065 | 7.81 | 0.06 | 7.63 | 7.96 |

*Notes: The interval dataset contains separate kW and kV measurements for the A, B, and C phases on each feeder taken at the circuit breaker, at up to three reclosers, and at the voltage regulator. For purposes of this analysis, Navigant aggregated the phase-specific readings for each feeder and time interval. Navigant chose to use the kV measurements taken at the regulator and the kW measurements taken at the circuit breaker because they are the most complete, appear to be the most reliable, and conform most closely to the evaluation methodology described in RTF Automated CVR Protocol No. 1.*

Table 4 shows the mean voltage reductions between IVVC-off and IVVC-on states at each of the sample feeders.

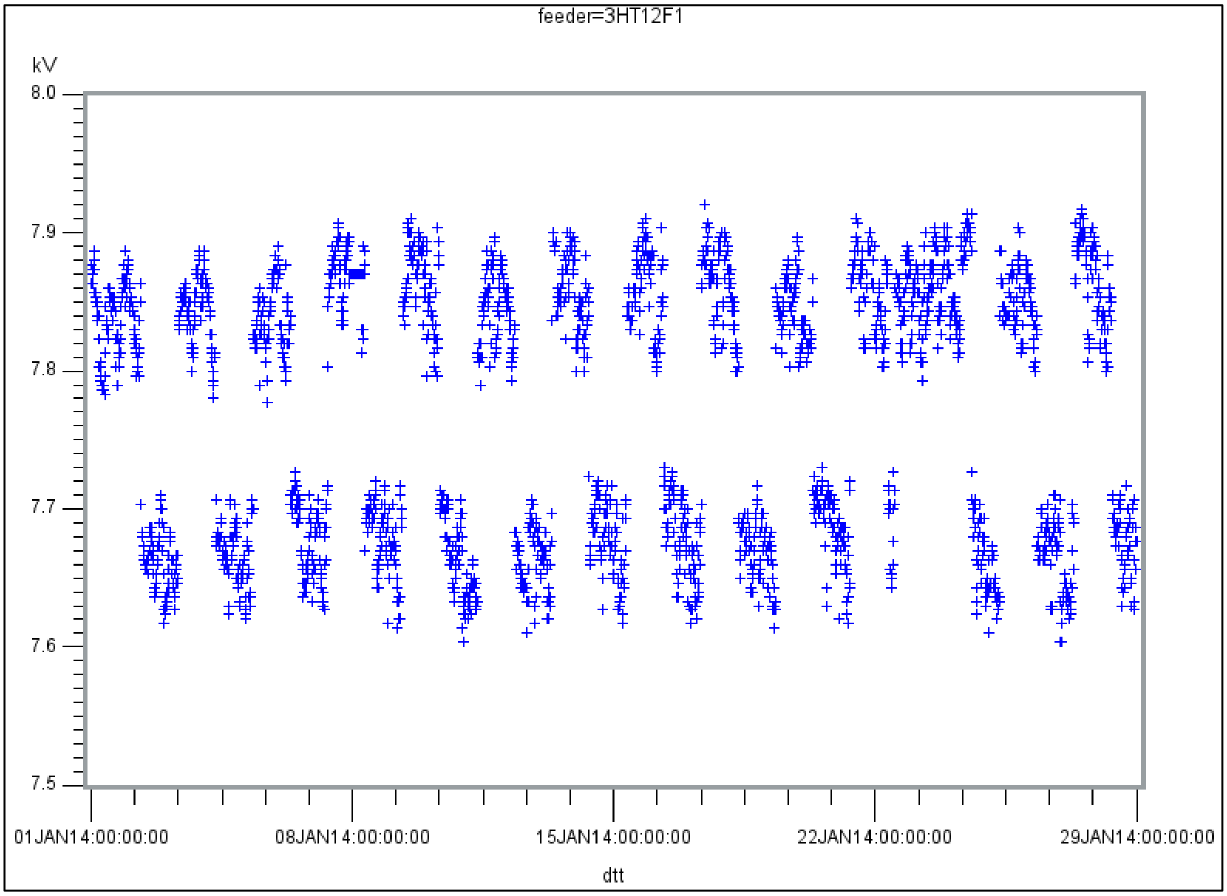
**Table 4. Voltage Reductions Observed in Sample**

| # | Feeder | Mean kV Measured at Regulator IVVC Off | IVVC On | % Difference |
|---|---|---|---|---|
| 1 | 3HT12F1 | 7.853 | 7.676 | 2.304% |
| 2 | 3HT12F5 | 7.843 | 7.698 | 1.875% |
| 3 | 3HT12F7 | 7.837 | 7.669 | 2.190% |
| 4 | 9CE12F4 | 7.837 | 7.716 | 1.562% |
| 5 | BEA12F3 | 7.870 | 7.670 | 2.606% |
| 6 | BEA12F4 | 7.843 | 7.676 | 2.177% |
| 7 | BEA12F5 | 7.848 | 7.703 | 1.890% |
| 8 | F&C12F4 | 7.837 | 7.687 | 1.955% |
| 9 | F&C12F5 | 7.833 | 7.700 | 1.729% |
| 10 | F&C12F6 | 7.835 | 7.693 | 1.847% |
| 11 | GLN12F1 | 7.844 | 7.684 | 2.090% |
| 12 | GLN12F2 | 7.836 | 7.707 | 1.675% |
| 13 | L&S12F1 | 7.846 | 7.662 | 2.400% |
| 14 | L&S12F2 | 7.849 | 7.708 | 1.833% |
| 15 | NE12F3 | 7.875 | 7.711 | 2.135% |
| 16 | NE12F5 | 7.833 | 7.692 | 1.824% |
| 17 | ROS12F6 | 7.853 | 7.725 | 1.661% |
| 18 | SE12F4 | 7.847 | 7.726 | 1.565% |
| 19 | SE12F5 | 7.863 | 7.719 | 1.861% |
| 20 | SPU123 | 7.928 | 7.716 | 2.746% |
| 21 | SPU125 | 7.911 | 7.816 | 1.215% |
| 22 | SUN12F1 | 7.884 | 7.701 | 2.369% |
| 23 | TUR113 | 7.911 | 7.691 | 2.858% |
| 24 | TUR117 | 7.959 | 7.761 | 2.545% |
| 25 | TVW131 | 7.827 | 7.762 | 0.828% |
| Weighted Average | | 7.861 | 7.705 | 2.020% |

*Notes: To obtain weighted averages, Navigant weighted the individual feeder values by their estimated 2014 annual MWh (see Table 12). All values are rounded to three decimal places.*

A representative example of the daily voltage cycling that was performed on the twenty-five sample feeders is shown in Figure 1, which is a time plot of the fifteen-minute interval kV measurements on one sample feeder (3HT12F1) for the month of January 2014.

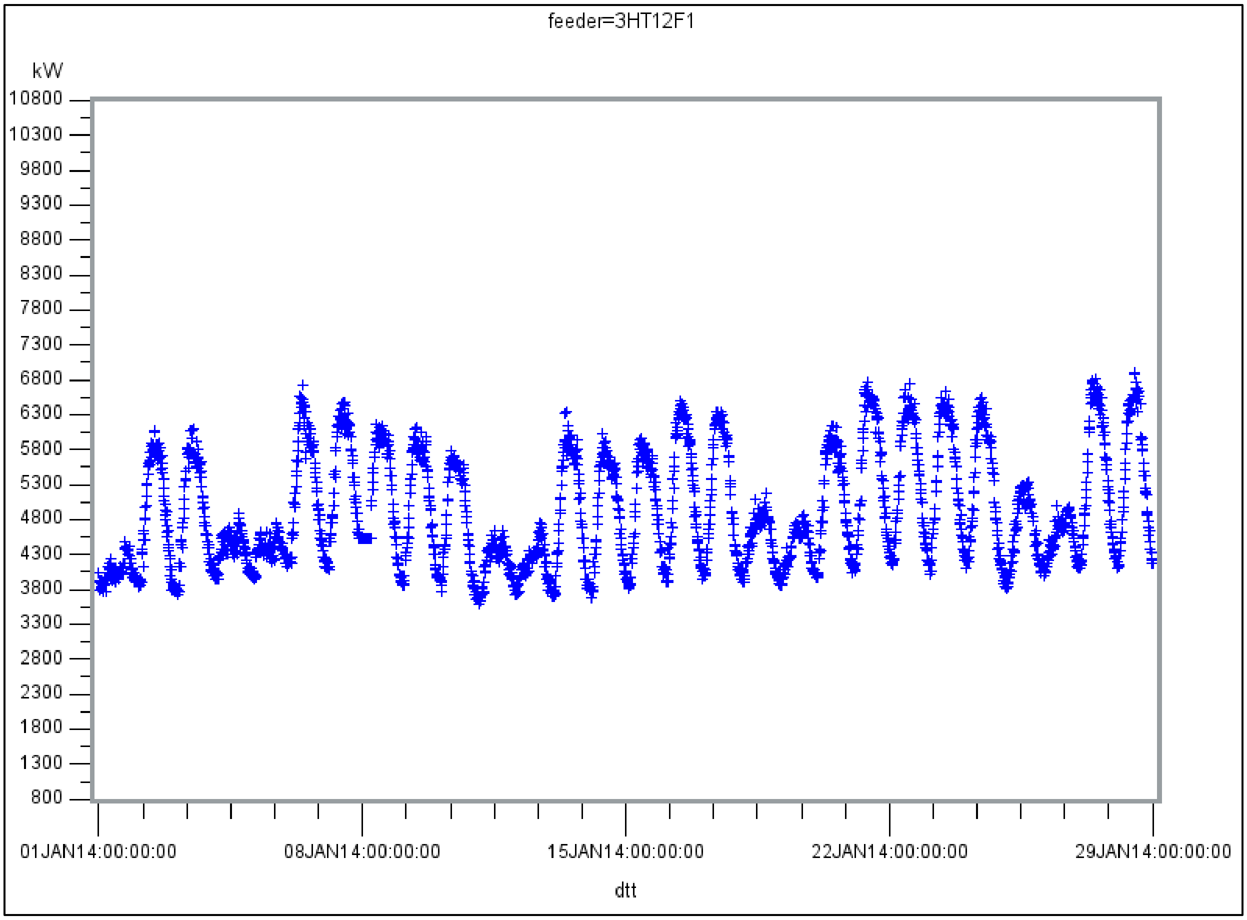
**Figure 1. Plot of Voltage Cycling on Feeder 3HT12F1, January 2014**



The figure illustrates how CVR works: a target reduction of approximately two percent is set. During each IVVC state (on and off) voltage continues to fluctuate about the set-point, but the separation between the set-points during the on and off states is clear.

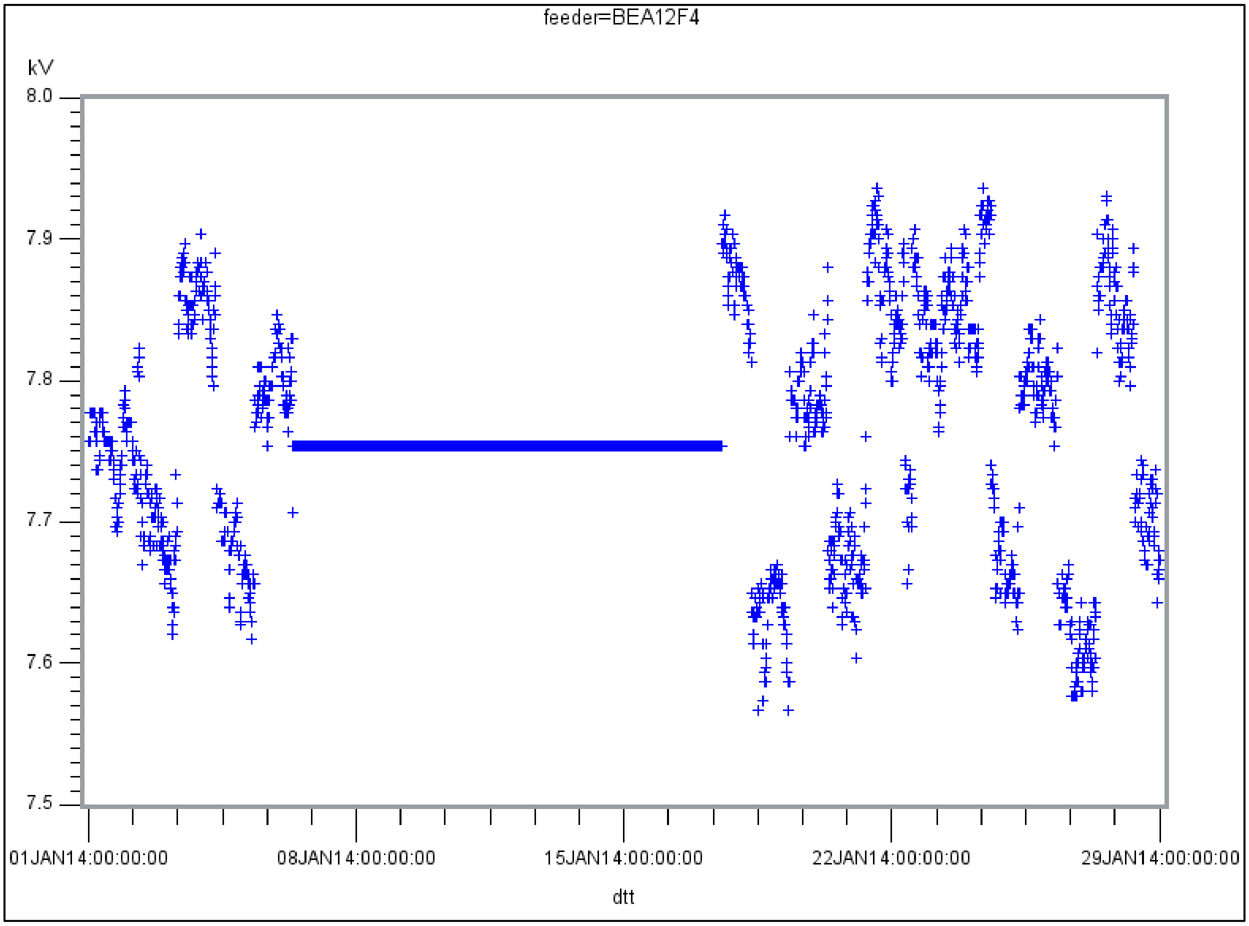
Figure 2 shows the time plot of the corresponding kW series for the same feeder and period (3HT12F1, January 2014). What is notable here is the strong daily cyclical pattern of aggregate load, with a characteristic humped or saw tooth shape with load rising to a peak during the day and falling back at night, superimposed on a clear weekly pattern with five similar weekday load shapes followed by notches on the weekends when the daily peaks are much less pronounced. The pattern observed in the kW series in Figure 2 underscores the need to develop a statistical model for explaining load fluctuations that accommodates these intra-day, daily, and weekly patterns. Failure to do so runs the risk of attributing load fluctuations to CVR that are actually due to these secular patterns.

**Figure 2. Plot of kW on Feeder 3HT12F1, January 2014**



For the most part, the IVVC interval data were clean and free from obvious problems. However, Navigant did discover a string of problematic data from two of the sample feeders in January 2014. The kV readings measured at the voltage regulator for BEA12F4 (shown in Figure 3 below) and BEA12F5 remained constant for a period of more than eleven continuous days; over the same period, the kW measured at the circuit breaker was flat at zero. Navigant dropped these values, as well as observations when the IVVC system reported being down, before performing any statistical analyses.

**Figure 3. Example of "Stuck" Voltage**



The other data Navigant used to evaluate Avista's CVR program savings consists of weather data obtained from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA). Navigant downloaded hourly temperature and humidity series from the NCDC's Quality Controlled Local Climatological Data site (NOAA 2014) for Spokane International Airport and Pullman/Moscow Regional Airport. After aligning the series to the nearest whole hour, Navigant used cubic spline interpolation to generate fifteen-minute series for each weather station that were then merged with the IVVC interval data (i.e., fifteen-minute observations on the quarter-hour).

# 3 RTF Automated CVR Protocol No. 1

RTF Automated CVR Protocol No. 1 establishes a method for measuring and verifying energy savings from CVR voltage reductions using experimental data produced by alternating the voltage set-points on a set of distribution circuits on successive days. The protocol uses data collected during an extended period of voltage cycling to estimate energy savings using time-series analysis and robust statistical methods.

To implement the protocol, Navigant worked with Avista staff to develop a sampling methodology that resulted in a representative sample selection of twenty-five distribution feeder circuits, as described in section 2. Avista began daily cycling of the voltage set-points on these circuits between full CVR voltage control (IVVC on) and no CVR control (IVVC off) on January 1, 2014, a process that continued through April 8, 2014.

Avista provided Navigant with fifteen-minute interval data from the twenty-five sample feeders collected over the ninety-eight-day period, as described in section 2. Navigant grouped the data for each feeder into twenty-four-hour ensembles identified by day-type (weekday or weekend/holiday), season (winter or shoulder), and IVVC system state (IVVC on, IVVC off, or IVVC system not operational). Navigant aggregated phase-specific data to feeder level by summing the phase-specific loads (kW) and taking the arithmetic means of the phase-specific voltages (kV). Navigant eliminated observations where IVVC reported being non-operational, or where kW was zero or kV was stuck (as described in section 2).

Navigant produced integrated demand profiles for each feeder by day-type, season, and IVVC state using robust time-series methods to isolate the effects of voltage reduction from the effects of other factors, such as weather, load characteristics, and customer behavior.[9] This resulted in two demand profiles per sample feeder for each combination of day-type and season: one when IVVC is off, the other when it is on. Figure 4 shows plots of the demand profiles for one of the feeder circuits in the sample, BEA12F3, for winter weekdays.

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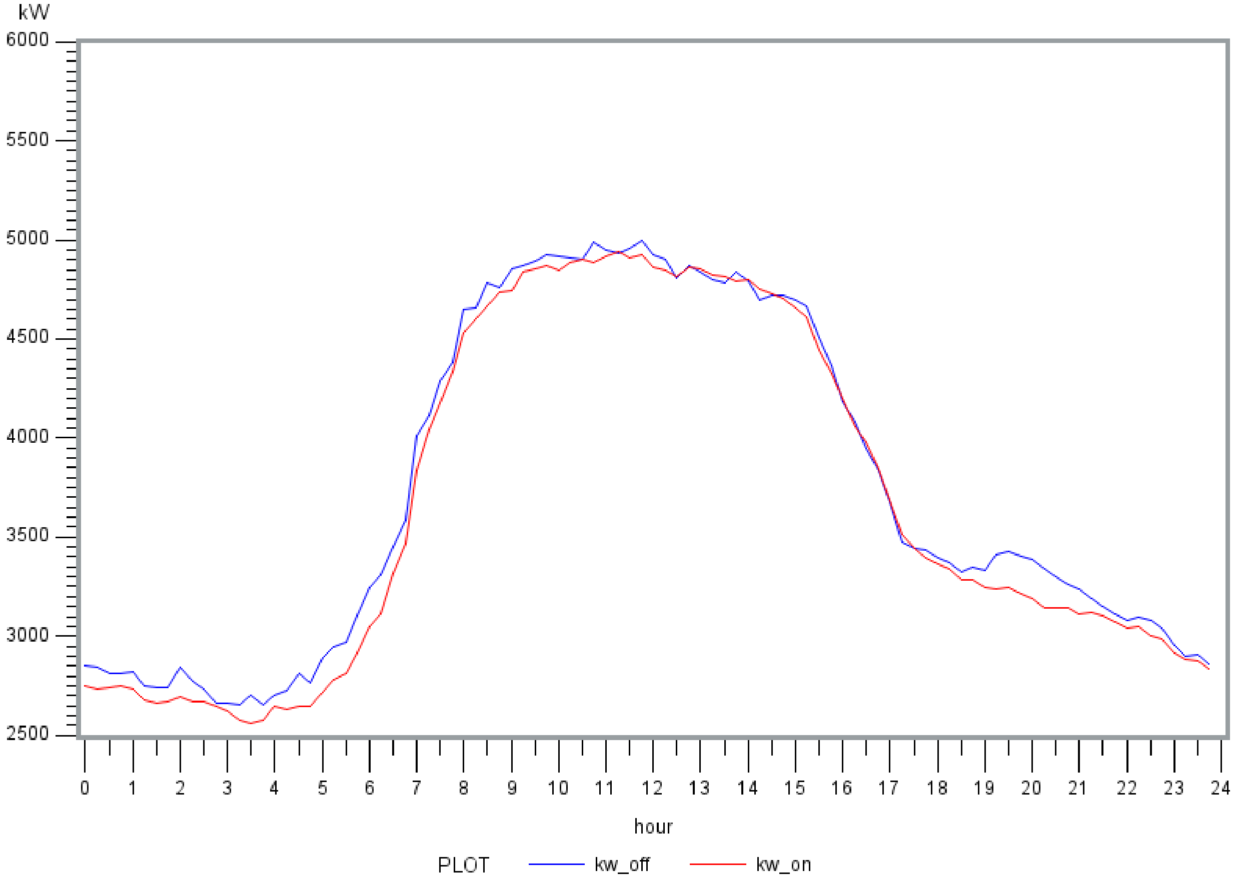
[9] Weather effects were explicitly modeled using data on ambient temperature and season. Load characteristics and customer behavior with respect to loads generally occur behind the customer meter and are thus not directly observed. However, the effects of time-invariant load characteristic differences across feeders are reflected in the load profiles estimated separately for each feeder. Time-varying effects due to shifting customer loads (intra-day, inter-day, inter-week) are accommodated through the use of high-frequency (15-minute) interval data; time-varying effects over longer intervals are accommodated by estimating separate load profiles by season.

**Figure 4. Integrated Demand Profiles, Feeder BEA12F3, Winter Weekdays**



Summing the vertical differences between the two demand profiles for each feeder over the twenty-four-hour period estimates the CVR energy savings for each day-type/season combination. To estimate the CVRf[10] for a given feeder, season and day-type, this sum is expressed as a percentage reduction relative to the corresponding baseline energy usage for the same feeder, day-type, and season, and divided by the corresponding mean percentage reduction in voltage on the circuit.

The resulting CVR factors range from 0.705 on weekends/holidays in the winter and 0.942 in the shoulder period on weekdays. Corresponding energy savings range from 1.440 to 1.919 percent. Table 5 summarizes these results.[11]

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[10] The CVR factor (CVRf) is defined as the ratio of the mean percentage energy saved to the mean percentage voltage reduction: $CVRf = \%\Delta E/\%\Delta V$.

[11] Detailed results by feeder, season and day-type are presented in Appendix A.

**Table 5. Summary of Findings from RTF Automated CVR Protocol No. 1**

| Day-Type | Measurement | Season<br>Winter | <br>Shoulder |
|---|---|---|---|
| Weekday | %ΔVolts | 2.020% | 2.016% |
| | %ΔkWh | 1.694% | 1.919% |
| | CVRf* | 0.833 | 0.942 |
| Weekend/Holiday | %ΔVolts | 1.984% | 1.810% |
| | %ΔkWh | 1.440% | 1.520% |
| | CVRf* | 0.705 | 0.834 |

* Weighted average of individual CVRfs shown in Table 12, these do not equal average %ΔkWh/ΔVolts.

To estimate the annual energy savings attributable to Avista's CVR program, Navigant calculated an average annual CVRf value of 0.881 as the weighted average of the four season/day-type specific factors by their relative shares of the year, and applied them to the post-implementation estimated annual energy usage for the seventy-one IVVC-controlled distribution circuits. Total estimated usage is 2,442,217 MWh (see Appendix A). Multiplying the estimated annual energy usage by the weighted-average 2 percent voltage reduction and 0.881 CVRf yields an estimated energy savings of 42,292 MWh.

The basis for these savings does not include summer data values; Navigant has extrapolated the results of winter and spring periods for the year. A recent study of CVR savings in Pennsylvania (Navigant 2011) found CVR factors and savings were significantly higher in summer periods than in the rest of the year. Therefore, the savings resulting from a year-round experimental design may well be higher than what is shown here.

# 4 WSU Voltage Optimization Validation Methodology

WSU developed its approach to address limitations associated with RTF Automated CVR Protocol No. 1, including the need to conduct day-on, day-off measurements over an extended period. Navigant assessed the applicability of the WSU model to derive accurate energy savings for CVR. Navigant's findings are informed by several discussions held with WSU and Avista in 2013 and early 2014.

The two WSU reports previously referenced in section 1 highlight several key advancements in the modeling of distribution feeder loads and integration of real-time data via supplemental logic used in the SynerGEE model. Each of these advancements should improve the accuracy of real-time estimation of energy savings achieved with CVR. The WSU approach calculates CVR savings using feeder simulation models (i.e., SynerGEE), with predicted savings tallied on a daily basis. All analyses and tests presented in the WSU reports are for distribution feeders located in Pullman, Washington.[12] Initial results for two representative feeders appear to confirm the accuracy of the algorithm and model results. As the reports state, additional studies need to be performed for a broader range of feeders and operating conditions.

When fully implemented and tested, the WSU approach may present an acceptable alternative to savings estimated using industry protocols (or other methods). However, only a few feeders have been modeled (out of the more than seventy feeders with CVR) and Avista has not fully integrated the enhanced SynerGEE model with its Distribution Management System (DMS). Thus, at this time, Navigant is unable to conduct a rigorous comparison of savings calculated by the WSU model versus those estimated using RTF Automated CVR Protocol No. 1. Discussions with WSU and Avista confirm that it is necessary to have additional testing and integration of the WSU model with Avista's DMS in order to measure savings for the full set of feeders with CVR control. Accordingly, Navigant is not yet able to develop an opinion on the effectiveness of the integration of model logic to Avista's DMS or the systems that Avista will use to collect RTES data, nor can Navigant speak to whether they will be a suitable alternative to current measurement protocols.

# 5 Navigant Regression Methodology

In addition to the measurement and verification (M&V) methodology specified in RTF Automated CVR Protocol No. 1, Navigant pursued a parallel statistical analysis to produce an alternative estimate of CVR savings using the same dataset described in section 2. The approach, which applies regression analysis to the data using a flexible, semi-parametric functional form, employs robust time-series econometric techniques similar to those used in the RTF approach. It has the advantage of producing CVRf estimates directly, rather than having to calculate them in a separate post-hoc analysis, which can save time and resources. It also permits direct estimation of standard program evaluation metrics, including statistical confidence and precision.

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[12] To test the accuracy of its approach, WSU conducted series of tests for representative feeders using both the SynerGEE model and the U.S. Department of Energy/Pacific Northwest National Laboratory's GridLAB-D model to predict real-time energy savings (RTES) using the advanced load models and an interactive IVVC algorithm.

To estimate the net effect of CVR voltage reductions on energy usage, Navigant performed regression analyses, modeling the average load in each fifteen-minute interval as a function of interval average voltage, interval heating degree-hours (HDH), and a set of time-of-day and day-type indicators. To allow the model to reflect differences in the characteristics of the loads served by each test feeder, which are largely unobserved, Navigant ran separate regressions for each feeder, as well as for each season.[13] The model is as follows:

$$f(kW_{it}) = \beta_{i1} g(kV_{it}) + \beta_{i2} HDH_t + \beta_{i3} HDH_t \cdot g(kV_{it}) + \sum_{t=1}^{96} \sum_{j=Weekday}^{Weekend} \beta_{itj}^{DTYPE} TOD_t \cdot DayType_j + \varepsilon_{it}$$

where:

- $i, t, and\ j$ are index feeder circuits, time intervals, and day-types, respectively;
- $kW_{it}$ and $kV_{it}$ are the instantaneous power demand and voltage, measured at the circuit breaker and voltage regulator, respectively, on feeder $i$ at time interval $t$;
- $TOD_t$ and $DayType_j$ are sets of ninety-six time-of-day and two day-type indicators, respectively; and
- $f(\cdot)$ and $g(\cdot)$ are functions of the variable contained in the parentheses.[14]

Navigant used robust regression methods to estimate the parameters of the above model for each combination of feeder and season, and calculated the system average CVRf as the weighted average of the individual feeder estimates, using the annual feeder MWh as weights. Table 6 summarizes these results.

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[13] This is a common method used in applied statistics when confronting panel data (i.e., multiple observations over time on a set of individual sample units) reflecting the influence of multiple unobserved factors that vary systematically across individual units – in this case, customer load characteristics. This technique allows the model results to reflect not only different mean load levels, but also differential effects of voltage, weather, time of day, day-type and season on the loads served by different circuits (Wooldridge 2010).

[14] Navigant tested several functional forms and selected the double-logarithmic form based on statistical testing.

**Table 6. Alternative Regression CVRf Values**

| | | CVRf Estimates | | |
|---|---|---|---|---|
| **#** | **Feeder** | **Winter** | **Shoulder** | **Combined** |
| 1 | 3HT12F1 | 0.711 | 0.847 | 0.813 |
| 2 | 3HT12F5 | 0.564 | 0.642 | 0.623 |
| 3 | 3HT12F7 | 0.447 | 0.592 | 0.556 |
| 4 | 9CE12F4 | 0.604 | 0.823 | 0.769 |
| 5 | BEA12F3 | 1.167 | 1.276 | 1.249 |
| 6 | BEA12F4 | 1.063 | 1.059 | 1.060 |
| 7 | BEA12F5 | 0.692 | 0.744 | 0.731 |
| 8 | F&C12F4 | 0.727 | 0.929 | 0.879 |
| 9 | F&C12F5 | 1.466 | 1.692 | 1.636 |
| 10 | F&C12F6 | 1.743 | 1.951 | 1.900 |
| 11 | GLN12F1 | 0.729 | 0.733 | 0.732 |
| 12 | GLN12F2 | 0.412 | 0.487 | 0.469 |
| 13 | L&S12F1 | 0.498 | 0.671 | 0.628 |
| 14 | L&S12F2 | 0.683 | 0.726 | 0.715 |
| 15 | NE12F3 | 0.294 | 0.299 | 0.298 |
| 16 | NE12F5 | 1.687 | 1.996 | 1.920 |
| 17 | ROS12F6 | 0.074 | 0.117 | 0.106 |
| 18 | SE12F4 | 0.348 | 0.518 | 0.476 |
| 19 | SE12F5 | 0.193 | 0.236 | 0.225 |
| 20 | SPU123 | 0.476 | 0.545 | 0.528 |
| 21 | SPU125 | 1.093 | 1.207 | 1.179 |
| 22 | SUN12F1 | 0.223 | 0.211 | 0.214 |
| 23 | TUR113 | 1.428 | 1.438 | 1.436 |
| 24 | TUR117 | 1.577 | 1.764 | 1.718 |
| 25 | TVW131 | 0.967 | 1.124 | 1.085 |
| Weighted Average | | 0.797 | 0.911 | 0.883 |

*Notes: Navigant weighted the individual feeder values by their cumulative kWh over the sample period to obtain the weighted averages. All values shown are rounded.*

To obtain estimates of the annual energy savings attributable to Avista's CVR program, Navigant applied the weighted average CVRf value above to the estimated annual energy usage for the seventy-one IVVC-controlled distribution circuits in calendar 2014, as was done for the RTF Automated CVR Protocol No. 1 calculation. Multiplying the estimated annual energy usage by the weighted-average 2 percent voltage reduction and 0.883 CVRf yields an estimated energy savings of 42,374 MWh, very similar to that produced by the RTF Protocol No. 1.

As with the RTF Automated CVR Protocol No. 1 results, the basis for these savings does not include summer data values. As noted previously, an analysis that includes summer data could well result in higher savings.

# 6 Summary

## 6.1 Findings

Navigant completed an impact evaluation of Avista's CVR program. Navigant explored three methods:

1. RTF Automated CVR Protocol No. 1
2. WSU Voltage Optimization Validation Methodology
3. Navigant Regression Methodology

When fully implemented and tested, the WSU approach may present an acceptable alternative to savings estimated using industry protocols (or other methods). However, only two feeders have been modeled (out of the over seventy feeders with CVR) and Avista has not fully integrated the enhanced SynerGEE model with its DMS. Thus, at this time, Navigant is unable to conduct a rigorous comparison of savings calculated by the WSU model versus those estimated using RTF Automated CVR Protocol No. 1.

The RTF and Navigant approaches yielded savings estimates as shown in Table 7.

**Table 7. Summary of Savings Estimates**

| Approach | CVRf | Savings Estimates (MWh) |
|---|---|---|
| RTF Automated CVR Protocol No. 1 | 0.881 | 42,292 |
| Navigant | 0.883 | 42,374 |

The two estimates are statistically identical, giving confidence that the RTF estimate is reasonable. Navigant expects that inclusion of summer data would not substantially change the savings estimate and might well increase it.

## 6.2 Recommendations

Navigant recommends that Avista continue to cycle the CVR voltage levels per the RTF Automated CVR Protocol No. 1 for the remainder of 2014. This will enable a more robust estimate of annual savings.

Navigant also recommends that the RTF consider adopting Navigant's alternative econometric approach to EM&V of savings for automated CVR programs. It produces similar results to the RTF Automated CVR Protocol No. 1, and is somewhat less burdensome to implement.

## 7 References

American National Standards Institute (ANSI). 1995. *C84.1 Electrical Power Systems and Equipment -- Voltage Ratings.* Washington, DC: American National Standards Institute.

Avista. 2009. *Spokane Smart Circuit Cost Justification*. DE-FOA-0000058. Spokane, WA.

Avista. 2010. *Business Case: NW Smart Grid Demonstration Project – Pullman, WA*. Spokane, WA.

Avista. 2013. *Avista SGDP Project Report. Spokane, WA.* Chanda, C., F. Shariatzadeh1, A. Srivastava, E. Lee, W. Stone, J. Ham. 2014. "Implementation of Non-Intrusive Energy Saving Estimation for Volt/VAr Control of Smart Distribution System." Submitted to Electric Power Systems Research. Elsevier.

Daliparthi, M., J. Burns, J. Doty, M. Johnson, M. Jakub-Wood, B. Shah, A. Srivastava, A. Bose. *Voltage Optimization Validation Methodology Report*. Pullman WA: Department of Electrical Engineering and Computer Science, Washington State University. Presented to Avista Corporation December 15, 2011.

Donohue, Mike. July 25, 2013. Personal communication with Utilidata.

Leidos. 2007. *Distribution Efficiency Initiative Project Final Report.* Portland, OR: Northwest Energy Efficiency Alliance. Accessed April 2014 from https://www.leidos.com/NEEA-DEI_Report.pdf.

National Oceanic and Atmospheric Administration (NOAA). *Quality Controlled Local Climatological Data (QCLCD)* [website]. Washington, DC: National Oceanic and Atmospheric Administration. Accessed April 2014 from http://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/quality-controlled-local-climatological-data-qclcd.

Navigant Consulting, Inc. (Navigant). 2011. *Annual Report to the Pennsylvania Public Utility Commission For the Period June 2010 through May 2011 Program Year Two For Pennsylvania Act 129 of 2008 Energy Efficiency and Conservation Plan*. Philadelphia, PA: PECO Energy Company.

Regional Technical Forum (RTF). 2004. *Automated CVR Protocol No. 1: Protocol Document v1.1*. Portland, OR: Regional Technical Forum. Retrieved from http://rtf.nwcouncil.org/measures/measure.asp?id=179.

Srivatava, Dr. Anurag K. 2014. WSU. Personal conversation.

Utilidata. 2011. *Standard Protocol #1 for Automated CVR*. Providence, RI: Utilidata. Accessed April 2014 from http://rtf.nwcouncil.org/subcommittees/cvr/.

Washington Utilities and Transportation Commission (UTC). 2012. *Docket UE-111882 Order Approving Avista's 2012-2021 Ten-Year Achievable Conservation Potential and 2012-2013 Biennial Conservation Target, Subject to Conditions*. Olympia, WA: Washington Utilities and Transportation Commission. Retrieved from http://www.wutc.wa.gov/rms2.nsf/177d98baa5918c7388256a550064a61e/a59ac690068d8ffe882579a0006fe177!OpenDocument.

Wooldridge, Jeffrey M. 2010. *Econometric Analysis of Cross Section and Panel Data*. Chapter 10. Cambridge, MA: MIT Press.

# 8 Appendix A. Feeder-Level Estimates using RTF Automated CVR Protocol No. 1 Methodology

Table 8 shows the mean voltage reductions, energy savings, and CVR factors for winter weekdays.

**Table 8. RTF Protocol Results, Winter Weekdays**

| # | Feeder | Mean Voltage Reduction | Mean Energy Saved | CVRf |
|---|---|---|---|---|
| 1 | 3HT12F1 | 2.354% | 1.747% | 0.742 |
| 2 | 3HT12F5 | 1.893% | 1.111% | 0.587 |
| 3 | 3HT12F7 | 1.538% | 0.743% | 0.483 |
| 4 | 9CE12F4 | 1.633% | 1.138% | 0.697 |
| 5 | BEA12F3 | 2.681% | 3.348% | 1.249 |
| 6 | BEA12F4 | 2.223% | 2.386% | 1.073 |
| 7 | BEA12F5 | 1.998% | 1.373% | 0.687 |
| 8 | F&C12F4 | 1.968% | 1.519% | 0.772 |
| 9 | F&C12F5 | 1.765% | 2.623% | 1.486 |
| 10 | F&C12F6 | 1.887% | 3.620% | 1.918 |
| 11 | GLN12F1 | 2.097% | 1.497% | 0.714 |
| 12 | GLN12F2 | 1.683% | 0.667% | 0.396 |
| 13 | L&S12F1 | 2.424% | 1.232% | 0.508 |
| 14 | L&S12F2 | 1.832% | 1.184% | 0.646 |
| 15 | NE12F3 | 2.209% | 0.625% | 0.283 |
| 16 | NE12F5 | 1.647% | 3.247% | 1.971 |
| 17 | ROS12F6 | 1.657% | 0.139% | 0.084 |
| 18 | SE12F4 | 1.571% | 0.600% | 0.382 |
| 19 | SE12F5 | 1.947% | 0.358% | 0.184 |
| 20 | SPU123 | 2.714% | 1.273% | 0.469 |
| 21 | SPU125 | 1.227% | 1.389% | 1.132 |
| 22 | SUN12F1 | 2.448% | 0.570% | 0.233 |
| 23 | TUR113 | 2.834% | 3.984% | 1.406 |
| 24 | TUR117 | 2.555% | 4.029% | 1.577 |
| 25 | TVW131 | 0.788% | 0.773% | 0.981 |
| Weighted Average | | 2.020% | 1.694% | 0.833 |

*Notes: To obtain weighted averages, Navigant used the 2014 feeder-level estimated annual MWh as weights (see Table 12). All values are rounded to three decimal places.*

**Error! Not a valid bookmark self-reference.** shows the mean voltage reductions, energy savings, and CVR factors for winter weekends and holidays.

**Table 9. RTF Protocol Results, Winter Weekends/Holidays**

| # | Feeder | Mean Voltage Reduction | Mean Energy Saved | CVRf |
|---|---|---|---|---|
| 1 | 3HT12F1 | 2.268% | 1.399% | 0.617 |
| 2 | 3HT12F5 | 1.900% | 0.905% | 0.476 |
| 3 | 3HT12F7 | 2.083% | 0.819% | 0.393 |
| 4 | 9CE12F4 | 1.602% | 0.553% | 0.345 |
| 5 | BEA12F3 | 2.491% | 2.431% | 0.976 |
| 6 | BEA12F4 | 1.990% | 2.024% | 1.017 |
| 7 | BEA12F5 | 1.781% | 1.167% | 0.655 |
| 8 | F&C12F4 | 2.012% | 1.270% | 0.631 |
| 9 | F&C12F5 | 1.815% | 2.580% | 1.422 |
| 10 | F&C12F6 | 1.855% | 2.367% | 1.276 |
| 11 | GLN12F1 | 2.023% | 1.560% | 0.771 |
| 12 | GLN12F2 | 1.621% | 0.677% | 0.418 |
| 13 | L&S12F1 | 2.414% | 1.180% | 0.489 |
| 14 | L&S12F2 | 1.814% | 1.381% | 0.761 |
| 15 | NE12F3 | 2.210% | 0.670% | 0.303 |
| 16 | NE12F5 | 1.948% | 1.923% | 0.987 |
| 17 | ROS12F6 | 1.536% | 0.083% | 0.054 |
| 18 | SE12F4 | 1.523% | 0.437% | 0.287 |
| 19 | SE12F5 | 1.818% | 0.404% | 0.222 |
| 20 | SPU123 | 2.630% | 1.365% | 0.519 |
| 21 | SPU125 | 1.080% | 1.083% | 1.003 |
| 22 | SUN12F1 | 2.376% | 0.461% | 0.194 |
| 23 | TUR113 | 2.709% | 4.004% | 1.478 |
| 24 | TUR117 | 2.442% | 3.893% | 1.594 |
| 25 | TVW131 | 0.818% | 0.784% | 0.959 |
| Weighted Average | | 1.984% | 1.440% | 0.705 |

*Notes: To obtain weighted averages, Navigant used the 2014 feeder-level estimated annual MWh as weights (see Table 12). All values are rounded to three decimal places.*

**Error! Not a valid bookmark self-reference.** shows the mean voltage reductions, energy savings, and CVR factors for shoulder-season weekdays.

**Table 10. RTF Protocol Results, Shoulder-Season Weekdays**

| # | Feeder | Mean Voltage Reduction | Mean Energy Saved | CVRf |
|---|---|---|---|---|
| 1 | 3HT12F1 | 2.233% | 1.966% | 0.881 |
| 2 | 3HT12F5 | 1.869% | 1.213% | 0.649 |
| 3 | 3HT12F7 | 2.176% | 1.306% | 0.600 |
| 4 | 9CE12F4 | 1.538% | 1.238% | 0.805 |
| 5 | BEA12F3 | 2.591% | 3.530% | 1.363 |
| 6 | BEA12F4 | 2.266% | 2.473% | 1.091 |
| 7 | BEA12F5 | 1.875% | 1.407% | 0.751 |
| 8 | F&C12F4 | 1.942% | 1.839% | 0.947 |
| 9 | F&C12F5 | 1.680% | 2.878% | 1.714 |
| 10 | F&C12F6 | 1.846% | 3.775% | 2.045 |
| 11 | GLN12F1 | 2.076% | 1.489% | 0.717 |
| 12 | GLN12F2 | 1.703% | 0.811% | 0.476 |
| 13 | L&S12F1 | 2.309% | 1.578% | 0.683 |
| 14 | L&S12F2 | 1.839% | 1.327% | 0.722 |
| 15 | NE12F3 | 2.194% | 0.676% | 0.308 |
| 16 | NE12F5 | 1.940% | 4.051% | 2.088 |
| 17 | ROS12F6 | 1.780% | 0.195% | 0.110 |
| 18 | SE12F4 | 1.736% | 0.923% | 0.532 |
| 19 | SE12F5 | 1.859% | 0.445% | 0.239 |
| 20 | SPU123 | 2.644% | 1.578% | 0.597 |
| 21 | SPU125 | 1.246% | 1.549% | 1.243 |
| 22 | SUN12F1 | 2.252% | 0.616% | 0.274 |
| 23 | TUR113 | 2.732% | 4.661% | 1.706 |
| 24 | TUR117 | 2.402% | 4.250% | 1.770 |
| 25 | TVW131 | 0.743% | 0.859% | 1.156 |
| Weighted Average | | 2.016% | 1.919% | 0.942 |

*Notes: To obtain weighted averages, Navigant used the 2014 feeder-level estimated annual MWh as weights (see Table 12). All values are rounded to three decimal places.*

**Error! Not a valid bookmark self-reference.** shows the mean voltage reductions, energy savings, and CVR factors for shoulder-season weekends and holidays.

**Table 11. RTF Protocol Results, Shoulder-Season Weekends/Holidays**

| # | Feeder | Mean Voltage Reduction | Mean Energy Saved | CVRf |
|---|---|---|---|---|
| 1 | 3HT12F1 | 1.993% | 1.575% | 0.790 |
| 2 | 3HT12F5 | 1.691% | 1.013% | 0.599 |
| 3 | 3HT12F7 | 1.921% | 1.120% | 0.583 |
| 4 | 9CE12F4 | 1.310% | 1.129% | 0.862 |
| 5 | BEA12F3 | 2.122% | 2.288% | 1.078 |
| 6 | BEA12F4 | 1.977% | 1.935% | 0.979 |
| 7 | BEA12F5 | 1.579% | 1.147% | 0.726 |
| 8 | F&C12F4 | 1.688% | 1.468% | 0.870 |
| 9 | F&C12F5 | 1.530% | 2.510% | 1.641 |
| 10 | F&C12F6 | 1.600% | 2.755% | 1.722 |
| 11 | GLN12F1 | 2.047% | 1.550% | 0.757 |
| 12 | GLN12F2 | 1.529% | 0.786% | 0.514 |
| 13 | L&S12F1 | 2.112% | 1.356% | 0.642 |
| 14 | L&S12F2 | 1.607% | 1.202% | 0.748 |
| 15 | NE12F3 | 1.715% | 0.496% | 0.289 |
| 16 | NE12F5 | 1.738% | 3.072% | 1.767 |
| 17 | ROS12F6 | 1.455% | 0.194% | 0.133 |
| 18 | SE12F4 | 1.312% | 0.644% | 0.491 |
| 19 | SE12F5 | 1.640% | 0.413% | 0.252 |
| 20 | SPU123 | 2.648% | 1.107% | 0.418 |
| 21 | SPU125 | 1.187% | 1.321% | 1.113 |
| 22 | SUN12F1 | 2.046% | 0.125% | 0.061 |
| 23 | TUR113 | 2.723% | 2.094% | 0.769 |
| 24 | TUR117 | 2.468% | 4.316% | 1.749 |
| 25 | TVW131 | 0.699% | 0.715% | 1.022 |
| Wt'd Average | | 1.810% | 1.520% | 0.834 |

*Notes: To obtain weighted averages, Navigant used the 2014 feeder-level estimated annual MWh as weights (see Table 12). All values are rounded to three decimal places.*

# 9 Appendix B. Estimated 2014 Annual MWh Sales for IVVC Feeders

**Table 12. Avista Estimated 2014 Energy Sales**

| # | Feeder | Annual MWh (mid-2012 to mid-2013) | Assumed Annual Growth Rate | Annual MWh (Calendar 2014)* |
|---|---|---|---|---|
| 1 | 3HT12F1 | 36,278.27 | 1.9% | 37,317.10 |
| 2 | 3HT12F2 | 35,670.13 | 1.9% | 36,691.54 |
| 3 | 3HT12F3 | 27,477.03 | 1.9% | 28,263.83 |
| 4 | 3HT12F4 | 35,185.73 | 1.9% | 36,193.27 |
| 5 | 3HT12F5 | 39,725.97 | 1.9% | 40,863.52 |
| 6 | 3HT12F6 | 28,745.10 | 1.9% | 29,568.21 |
| 7 | 3HT12F7 | 18,989.12 | 1.9% | 19,532.87 |
| 8 | 3HT12F8 | 46,023.45 | 1.9% | 47,341.33 |
| 9 | 9CE12F1 | 45,768.91 | 2.1% | 47,218.17 |
| 10 | 9CE12F4 | 33,008.18 | 2.1% | 34,053.38 |
| 11 | BEA12F2 | 40,060.15 | 2.0% | 41,267.94 |
| 12 | BEA12F3 | 26,862.57 | 2.0% | 27,672.46 |
| 13 | BEA12F4 | 33,961.58 | 2.0% | 34,985.50 |
| 14 | BEA12F5 | 5,618.23 | 2.0% | 5,787.62 |
| 15 | C&W12F1 | 33,191.42 | 2.0% | 34,192.12 |
| 16 | C&W12F2 | 25,350.52 | 2.0% | 26,114.83 |
| 17 | C&W12F3 | 40,244.70 | 2.0% | 41,458.06 |
| 18 | C&W12F4 | 50,006.74 | 2.0% | 51,514.42 |
| 19 | C&W12F5 | 23,604.21 | 2.0% | 24,315.87 |
| 20 | C&W12F6 | 35,052.69 | 2.0% | 36,109.51 |
| 21 | F&C12F1 | 40,414.59 | 2.2% | 41,755.58 |
| 22 | F&C12F2 | 28,812.37 | 2.2% | 29,768.39 |
| 23 | F&C12F3 | 32,184.98 | 2.2% | 33,252.90 |
| 24 | F&C12F4 | 36,652.51 | 2.2% | 37,868.67 |
| 25 | F&C12F5 | 30,786.56 | 2.2% | 31,808.08 |
| 26 | F&C12F6 | 37,615.24 | 2.2% | 38,863.35 |
| 27 | FWT12F1 | 29,581.19 | 2.1% | 30,517.87 |
| 28 | FWT12F2 | 31,378.49 | 2.1% | 32,372.08 |
| 29 | FWT12F3 | 33,066.91 | 2.1% | 34,113.97 |
| 30 | FWT12F4 | 28,245.42 | 2.1% | 29,139.81 |
| 31 | GLN12F1 | 36,992.32 | 2.3% | 38,275.87 |

| # | Feeder | Annual MWh (mid-2012 to mid-2013) | Assumed Annual Growth Rate | Annual MWh (Calendar 2014)* |
|---|---|---|---|---|
| 32 | GLN12F2 | 34,428.48 | 2.3% | 35,623.07 |
| 33 | L&S12F1 | 35,582.96 | 2.1% | 36,709.69 |
| 34 | L&S12F2 | 46,081.43 | 2.1% | 47,540.59 |
| 35 | L&S12F3 | 28,880.17 | 2.1% | 29,794.65 |
| 36 | L&S12F4 | 38,074.55 | 2.1% | 39,280.17 |
| 37 | L&S12F5 | 23,287.06 | 2.1% | 24,024.44 |
| 38 | NE12F1 | 30,860.67 | 2.1% | 31,837.87 |
| 39 | NE12F2 | 36,954.35 | 2.1% | 38,124.50 |
| 40 | NE12F3 | 19,459.38 | 2.1% | 20,075.56 |
| 41 | NE12F4 | 25,749.62 | 2.1% | 26,564.98 |
| 42 | NE12F5 | 40,324.68 | 2.1% | 41,601.55 |
| 43 | NW12F2 | 26,375.69 | 2.1% | 27,210.87 |
| 44 | NW12F4 | 33,351.94 | 2.1% | 34,408.02 |
| 45 | ROS12F1 | 50,209.41 | 1.4% | 51,267.49 |
| 46 | ROS12F2 | 44,648.77 | 1.4% | 45,589.67 |
| 47 | ROS12F3 | 29,395.92 | 1.4% | 30,015.39 |
| 48 | ROS12F4 | 43,290.52 | 1.4% | 44,202.80 |
| 49 | ROS12F5 | 57,493.33 | 1.4% | 58,704.91 |
| 50 | ROS12F6 | 43,336.62 | 1.4% | 44,249.87 |
| 51 | SE12F1 | 31,086.65 | 2.4% | 32,212.46 |
| 52 | SE12F2 | 49,494.83 | 2.4% | 51,287.29 |
| 53 | SE12F3 | 39,678.51 | 2.4% | 41,115.47 |
| 54 | SE12F4 | 38,713.39 | 2.4% | 40,115.40 |
| 55 | SE12F5 | 28,096.71 | 2.4% | 29,114.24 |
| 56 | SPU121 | 36,601.55 | 1.9% | 37,649.63 |
| 57 | SPU122 | 31,068.99 | 1.9% | 31,958.65 |
| 58 | SPU123 | 33,228.29 | 1.9% | 34,179.78 |
| 59 | SPU124 | 47,467.80 | 1.9% | 48,827.04 |
| 60 | SPU125 | 29,975.82 | 1.9% | 30,834.18 |
| 61 | SUN12F1 | 33,631.60 | 2.3% | 34,798.54 |
| 62 | SUN12F3 | 34,042.05 | 2.3% | 35,223.23 |
| 63 | SUN12F6 | 26,865.83 | 2.3% | 27,798.01 |
| 64 | TUR111 | 28,154.34 | 1.9% | 28,960.54 |
| 65 | TUR112 | 30,857.00 | 1.9% | 31,740.59 |

| # | Feeder | Annual MWh (mid-2012 to mid-2013) | Assumed Annual Growth Rate | Annual MWh (Calendar 2014)* |
|---|---|---|---|---|
| 66 | TUR113 | 24,569.53 | 1.9% | 25,273.08 |
| 67 | TUR115 | 30,818.36 | 1.9% | 31,700.84 |
| 68 | TUR116 | 28,836.07 | 1.9% | 29,661.79 |
| 69 | TUR117 | 38,576.25 | 1.9% | 39,680.88 |
| 70 | TVW131 | 34.49 | 1.9% | 35.48 |
| 71 | TVW132 | 14,607.37 | 1.9% | 15,025.65 |
|  | Total | 2,370,746.26 |  | 2,442,216.96 |

*Notes: Annual MWh sales (7/2012 to 7/2013) and assumed annual growth rate obtained from Avista Utilities, April 18, 2014.*
** Annual mid-2012 to mid-2013 figures are Avista audited sales data. Calendar 2014 annual figures were obtained by applying the assumed annual growth rates to the mid-2012 to mid-2013 values for a period of 18 months.*