**BEFORE THE PUBLIC UTILITIES COMMISSION**
**OF THE STATE OF COLORADO**

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|---|---|---|
| **RE: IN THE MATTER OF THE APPLICATION OF PUBLIC SERVICE COMPANY OF COLORADO FOR AN ORDER GRANTING A CERTIFICATE OF PUBLIC CONVENIENCE AND NECESSITY FOR DISTRIBUTION GRID ENHANCEMENTS, INCLUDING ADVANCED METERING AND INTEGRATED VOLT-VAR OPTIMIZATION INFRASTRUCTURE** | **)<br>)<br>)<br>)<br>)<br>)<br>)<br>)<br>)<br>)** | **PROCEEDING NO. 16A-____E** |

**<u>DIRECT TESTIMONY AND ATTACHMENTS OF CHAD S. NICKELL</u>**

**ON**

**BEHALF OF**

**PUBLIC SERVICE COMPANY OF COLORADO**

**August 2, 2016**

**BEFORE THE PUBLIC UTILITIES COMMISSION
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## SUMMARY OF THE DIRECT TESTIMONY OF CHAD S. NICKELL

Mr. Chad S. Nickell is Manager, System Planning and Strategy South for Xcel Energy Services Inc. (“XES”). In this position Mr. Nickell is responsible for providing strategic direction and ensuring a reliable and cost-effective distribution system for Xcel Energy operating companies, including Public Service Company of Colorado ("Public Service" or "Company"), one of four utility operating company subsidiaries of Xcel Energy Inc. (“Xcel Energy”). His duties include, among other things, developing and leading a distribution system advancements and renewal strategy for Public Service and Southwestern Public Service Company, one of the other Xcel Energy utility operating companies.

In his testimony, Mr. Nickell provides a description of several key components of Public Service’s Advanced Grid Intelligence and Security (“AGIS”) initiative. The AGIS initiative is a comprehensive plan that will make Public Service's electric distribution system more automated, resilient, and interactive by utilizing advances in sensing, controls, information, computing, communications, materials, and components. Specifically, Mr. Nickell discusses the following components of AGIS:

- Advanced Distribution Management System ("ADMS");
- Integrated Volt-VAr Optimization ("IVVO"); and
- Fault Location Isolation and Service Restoration ("FLISR"), including the Fault Location Prediction ("FLP") component.

While IVVO is part of Public Service's application for a Certificate of Public Convenience and Necessity in this proceeding and therefore one of the "CPCN Projects," Mr. Nickell also describes ADMS and FLISR because they are an integral part of the AGIS initiative. In particular, Mr. Nickell describes that:

- An ADMS is a collection of applications that form a single system to manage and optimize each underlying component of AGIS. This single foundational system assists the control room, field operating personnel, and engineers with the monitoring, control, and optimization of the electric distribution system.
- Through IVVO, Public Service can more efficiently and accurately maintain proper voltage levels throughout the electric distribution system, thereby reducing energy usage without requiring active customer usage changes. Historically, utilities have controlled voltage on the distribution system by regulating the voltage at the substation. Absent the ability to monitor voltage levels along the feeders, the system is often operated

based on the modeling of peak load conditions. IVVO automates and optimizes the operation of the distribution voltage regulating devices located on distribution feeders. This application will enable Public Service to operate its feeders at the lower end of acceptable voltage ranges.

- FLISR will facilitate fault isolation and service restoration activities. Currently, Public Service generally relies on calls from customers to identify faults. With FLISR, devices located on feeders will automatically detect a fault and take action to isolate it. FLISR's automated switching devices help decrease the duration and number of customers affected by any outage. FLP is a subset application of FLISR that uses sensor data from field devices to more quickly locate a faulted section of a feeder line.

In addition to describing these technologies and the need for them, Mr. Nickell describes Public Service's implementation plan for these technologies. Mr. Nickell also provides an overview of the costs of IVVO as well as its benefits, including avoided energy (and associated fuel savings) and avoided capital investment (including generation capacity, as well as deferred transmission and distribution investments). The qualitative benefits from IVVO include reducing customers' energy consumption, environmental benefits arising from deferred generation and fuel savings, and increased capacity to host distributed energy resources. Mr. Nickell also explains the supporting qualitative benefits that will be gained from ADMS and FLISR, including greater visibility into the distribution grid and operational and reliability benefits. Finally, Mr. Nickell discusses why alternatives to the IVVO solution do not displace the public convenience and necessity of IVVO.

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**DIRECT TESTIMONY AND ATTACHMENTS OF CHAD S. NICKELL**

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## GLOSSARY OF ACRONYMS AND DEFINED TERMS

| Acronym/Defined Term | Meaning |
|---|---|
| ADMS | Advanced Distribution Management System |
| AGIS | Advanced Grid Intelligence and Security |
| AMI | Advanced Metering Infrastructure |
| AMR | Automated Meter Reading |
| ANSI | American National Standards Institute |
| BPL | Broadband over Power Line |
| C&I | Commercial and Industrial |
| CAIDI | Customer Average Interruption Duration Index |
| CBA | Cost-Benefit Analysis |
| CIS | Customer Information System |
| CMO | Customer Minutes Out |
| Commission | Colorado Public Utilities Commission |
| Company | Public Service Company of Colorado |
| CPCN | Certificate of Public Convenience and Necessity |
| CPCN Projects | AMI, IVVO, and the components of the FAN that support these components |
| CPE | Customer premise equipment |
| CRS | Customer Resource System |
| CSF | Cyber Security Framework |
| CVR | Conservation Voltage Reduction |
| DA | Distribution Automation |
| DDOS | Distributed Denial of Service |
| DER | Distributed Energy Resources |
| DOS | Denial-of-service |
| DR | Demand Response |
| DSM | Demand Side Management |
| DVO | Distribution Voltage Optimization |
| EPRI | Electric Power Research Institute |
| ERT | Encoder Receiver Transmitter |
| ESB | Enterprise Service Bus |
| FAN | Field Area Network |
| FLISR | Fault Locate Isolation System Restoration |

| Acronym/Defined Term | Meaning |
|---|---|
| FLP | Fault Location Prediction |
| GFCI | Ground Fault Circuit Interrupter |
| GIS | Geospatial Information System |
| HAN | Home Area Networks |
| ICE | Interruption Cost Estimation |
| IDS | Intrusion Detection System |
| IEEE | Institute of Electrical and Electronics |
| IPS | Internet Provider Security |
| IT | Information technology |
| IVR | Interactive Voice Response |
| IVVO | Integrated Volt-VAr Optimization |
| kVAr | Kilovolt-amperes reactive |
| kVArh | Reactive power |
| kW | Kilowatt |
| kWh | Kilowatt hours |
| LTCs | Load Tap Changers |
| LTE | Long-Term Evolution |
| MDM | Meter Data Management |
| MitM | Man-in-the-Middle Attack |
| MPLS | Multiprotocol Label Switching |
| NCAR | National Center for Atmospheric Research |
| NOC | Network Operations Center |
| NPV | Net Present Value |
| O&M | Operations and Maintenance |
| OMS | Outage Management System |
| OT | Operational Technology |
| PTMP | Point-to-multipoint |
| Public Service | Public Service Company of Colorado |
| RF | Radio frequency |
| RFP | Request for Proposal |
| RFx | Request for Information and Pricing |
| RTU | Remote Terminal Units |

| Acronym/Defined Term | Meaning |
| --- | --- |
| SAIDI | System Average Interruption Duration Index |
| SAIFI | System Average Interruption Frequency Index |
| SCADA | Supervisory Control and Data Acquisition |
| SGCC | Smart Grid Consumer Collaborative |
| SGIG | Smart grid investment grants |
| SIEM | Security Incident and Event Management |
| SVC | Secondary static VAr compensators |
| TOU | Time-of-use |
| USEIA | United States Energy Information Administration |
| WACC | Weighted Average Costs of Capital |
| WAN | Wide Area Network |
| WiMAX | Worldwide Interoperability for Microwave Access |
| WiSUN | 802.15.4g Standard |
| Xcel Energy Inc. | Xcel Energy |
| XES | Xcel Energy Services Inc. |

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## I. INTRODUCTION, QUALIFICATIONS, PURPOSE OF TESTIMONY

**Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.**

A. My name is Chad S. Nickell. My business address is 1123 West 3rd Avenue, Denver, Colorado 80223.

**Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT POSITION?**

A. I am employed by Xcel Energy Services Inc. ("XES") as Manager, System Planning and Strategy South. XES is a wholly-owned subsidiary of Xcel Energy Inc. ("Xcel Energy"), and provides an array of support services to Public Service Company of Colorado ("Public Service" or "Company") and the other utility operating company subsidiaries of Xcel Energy on a coordinated basis.

**Q. ON WHOSE BEHALF ARE YOU TESTIFYING IN THE PROCEEDING?**

A. I am testifying on behalf of Public Service.

**Q. PLEASE SUMMARIZE YOUR RESPONSIBILITIES AND QUALIFICATIONS.**

A. As the Manager of System Planning and Strategy South for Xcel Energy, I am responsible for providing strategic direction and for ensuring a reliable and cost-effective distribution system for Xcel Energy operating companies, including Public Service. My key responsibilities include developing and leading a system advancements and renewal strategy and managing the current year and five-year distribution capital budget for Public Service and Southwestern Public Service Company, one of the other Xcel Energy operating companies. A description of my qualifications, duties, and responsibilities is set forth after the conclusion of my testimony in my Statement of Qualifications.

**Q. WHAT IS THE PURPOSE OF YOUR DIRECT TESTIMONY?**

A. I provide a description of Public Service's forthcoming Advanced Distribution Management System ("ADMS"); the Integrated Volt-VAr Optimization ("IVVO") application (including secondary static VAr compensators ("SVCs")); and the Fault Location Isolation and Service Restoration ("FLISR") function, including the Fault Location Prediction ("FLP") component.

Public Service is seeking a Certificate of Public Convenience and Necessity ("CPCN") in this proceeding for the IVVO technology, an advanced function that will automate and optimize the Company's distribution voltage regulating devices and VAr control devices. These technologies, as well as the Company's proposed Advanced Metering Infrastructure ("AMI") and supporting

Field Area Network ("FAN") (collectively, the "CPCN Projects") are critical parts of Public Service's Advanced Grid Intelligence and Security ("AGIS") initiative. The AGIS initiative is a comprehensive plan that will advance Public Service's distribution system, provide customers with more choices, and enhance the way the Company serves its customers. AGIS will lay the foundation for an interactive, intelligent, and efficient grid system that will be even more reliable and better prepared to meet the energy demands of the future.

A more thorough discussion of Public Service's AGIS initiative, and its request for CPCN Projects approval, is provided in the CPCN Projects Application and in the Direct Testimonies of Company witnesses Ms. Alice K. Jackson and Mr. John D. Lee.

**Q. ARE YOU SPONSORING ANY ATTACHMENTS AS PART OF YOUR DIRECT TESTIMONY?**

A. Yes, I am sponsoring the following:

- Attachment CSN-1: IVVO Quantifiable Benefits Summary
- Attachment CSN-2: IVVO Costs Summary

## II. TECHNOLOGIES

**Q. WHAT IS PUBLIC SERVICE'S ADVANCED GRID INTELLIGENCE AND SECURITY (AGIS) INITIATIVE?**

A. As described in more detail in the CPCN Projects Application and in the Direct Testimonies of Company witnesses Ms. Jackson and Mr. Lee, AGIS is a comprehensive plan to advance Public Service's distribution system to a state where (1) operators have more visibility into the system; (2) customers are able to access more information in near real-time; and (3) future products and services are enabled through technology. AGIS will help to bring about an intelligent, automated, and interactive electric distribution system that will utilize advances in sensing, controls, information, computing, communications, materials, and components to optimize the performance of the electric distribution system and ensure safe operation. The more intelligent distribution system will be able to better meet customers' energy needs, while also integrating new sources of energy and delivering power over a network that is increasingly interoperable, efficient, and resilient.

**Q. WHICH COMPONENTS OF AGIS WILL YOU DISCUSS IN YOUR TESTIMONY?**

A. As mentioned above, I will discuss ADMS, followed by IVVO, and then FLISR, in Parts II.A, II.B, and II.C, respectively. My testimony also explains how these technologies will interact with each other and other foundational programs of AGIS.

**Q. WHICH OF THE TECHNOLOGIES ARE PART OF PUBLIC SERVICE'S CPCN PROJECTS APPLICATION?**

A. As noted above, Public Service's CPCN Projects Application includes the IVVO technology. ADMS and FLISR are not part of Public Service's CPCN Projects Application in this proceeding, as explained in more detail in the Direct Testimonies of Company witnesses Ms. Jackson and Mr. Lee. However, because of their interrelationship to IVVO and AMI, I will discuss ADMS and FLISR in my testimony below.

## A. <u>Advanced Distribution Management System ("ADMS")</u>

**Q. WHAT IS THE ADMS?**

A. As mentioned above, ADMS stands for Advanced Distribution Management System. An ADMS is a foundational system that consists of a collection of hardware and software applications designed to monitor and control the entire electric distribution system safely, efficiently, and reliably. The key objectives of an ADMS are to improve the reliability and quality of service in terms of reducing outages, minimizing outage time, and maintaining acceptable voltage levels on the system. An ADMS acts as a centralized decision support system that assists the control room, field operating personnel, and engineers with the monitoring, control, and optimization of the electric distribution system. It will manage the complex interaction of distributed energy resources, outage events, feeder switching operations, and advanced applications such as FLISR and IVVO. ADMS will enable access to real-time and near real-time data to provide all information on operator console(s) at the control center in an integrated manner.

**Q. DOES PUBLIC SERVICE CURRENTLY MONITOR ITS DISTRIBUTION SYSTEM?**

A. Yes. Public Service currently monitors the distribution system through the use of a Supervisory Control and Data Acquisition ("SCADA") system—a system for remote monitoring and control of telemetered points from substations and distribution automation devices. In addition, Public Service monitors the grid through customers reporting outages and power quality issues. The Company also currently uses a connectivity model constructed from the Geospatial Information System ("GIS") for the Outage Management System ("OMS"). GIS contains the static physical attribute information about all physical assets that make up the electric distribution system. This model enables outage awareness and improves decision-making when dispatching field personnel to restore power.

However, the OMS connectivity model does not include substation one-line diagrams; instead, it consists of feeder-, tap-, and transformer-level grid components. It does not include the functionality to control and optimize the system and does not manage the complex interaction of distributed energy resources, outage events, feeder switching operations, and advanced applications such as FLISR and IVVO.

**Q. ARE THERE ALSO LIMITATIONS TO THE INFORMATION THE COMPANY'S SCADA SYSTEM PROVIDES?**

A. Yes. SCADA is limited to the remote monitoring and control of distribution devices without interfacing with the GIS system connectivity model. SCADA limits the functionality for advanced functions like IVVO, FLISR, and the integration of Distributed Energy Resources ("DER"), as there would be limited or no ability to assess the impact of device operation(s) on the system as a whole. In the past, the Company's SCADA systems have been used primarily to provide remote monitoring and control of generation, transmission system, and substations but have had limited functionality to monitor and control distribution assets.

For instance, when performing switching either manually or automatically, SCADA and the network management system do not provide the voltage profile along the feeders. Therefore, the Company is only able to understand the voltage performance of the system beyond the substation in the limited instances where devices with remote monitoring and control are installed. For the remainder of the system, Company is generally only aware of voltage issues by way of customer complaints. Advanced applications like IVVO require information about the voltage profile along a feeder so the voltage can be optimized and maintained within acceptable levels not only for normal operation but also during maintenance and switching events.

**Q. HOW WILL ADMS BE AN IMPROVEMENT OVER THE CURRENT SITUATION?**

A. ADMS will constitute a single system that will enable the optimization of each application by using one operating model and the same power flow measurements and calculations. ADMS will also make adjustments for real-time grid conditions and topology that are impacted by each application. In addition, when DER and sensor measurements are available, ADMS will use the measurements to improve power flow calculation accuracy and display the measurements and results with geospatial accuracy. This data will be available for use by Operations personnel and advanced applications for both human and automated decision-making. This functionality will enable optimization of (both manual and automated) switching sequences, IVVO and FLISR functionality, improved reaction time to outage events, increased awareness of voltage levels throughout the grid, awareness of the DER impact to power flow on the grid, and validation of grid operations prior to switching.

**Q. HOW WILL ADMS ACHIEVE THESE IMPROVEMENTS?**

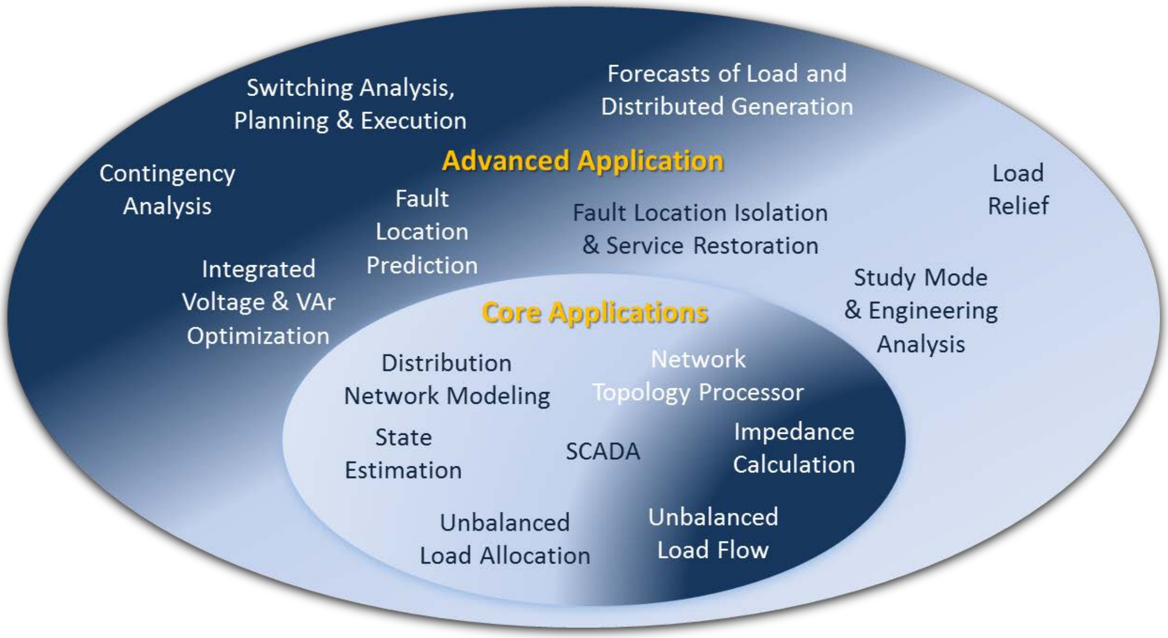
A. ADMS will utilize an enhanced distribution grid model that will include substations, feeders, taps, and services, in one user interface, to more accurately represent the entire distribution grid. Because the Geospatial Information System ("GIS") will provide the nominal geo-spatial electrical model to ADMS, accuracy of the GIS model including impedance data will be essential, because this data will improve the model when operating advanced applications like IVVO and FLISR. ADMS will maintain the as-operated GIS electrical model and advanced applications in near real-time. This model will provide the Company with greater visibility into the distribution system and provide information about the system at a more granular level. In particular, Public Service's ADMS will integrate existing SCADA measurements with the enhanced model to provide power flow calculations everywhere on the grid, and will accurately adjust power flow calculations with changes in grid topology. This will allow the Company to monitor and control power flow from substations to the edge of the grid. The improved capability over today's systems will enable multiple grid performance objectives to be realized over the entire grid.

**Q. PLEASE DESCRIBE THE FUNCTIONS OF ADMS.**

A. ADMS will have core applications, which will make up the foundation of ADMS, as well as advanced applications. The core applications include distribution network modeling, network topology processor, impedance calculation, unbalanced load allocation, unbalanced load flow, state estimation, and distribution SCADA. These applications provide the basis for running load flow and state estimation on the distribution system providing near real-time calculations of the state of the network including factors such as voltages, currents, real and reactive power, amps, voltage drops, and losses.

The ADMS advanced applications will utilize the core applications and provide additional capability. Public Service now plans to utilize two such advanced applications: IVVO and FLISR. These applications will rely on accurate power flow calculations to determine the power flow at points on the grid where sensor information does not exist. For example, if there are no sensors on a feeder, the Unbalanced Load Flow core application will apply power flow measurements taken at the substation to calculate power flow throughout the feeder. The applications discussed above are listed in Figure CSN-1 below.

**Figure CSN-1**




ADMS will utilize sensor and equipment information, located at strategic points on the grid, to continuously improve upon the power flow calculations made by the power flow application. Where sensor data is available, power flow results will be refined and utilized through the ADMS application. For example, State Estimation is an ADMS application that will use measured power flow values from select sensors on a feeder to adjust power flow calculations to more accurately represent the power flow at all points on a feeder.

The specific functions of ADMS with respect to IVVO and FLISR are discussed below in Section II.B and Section II.C, respectively, of my testimony.

**Q. CAN YOU PROVIDE EXAMPLES OF HOW ADMS WILL PROVIDE THE CAPABILITY TO ENABLE MULTIPLE APPLICATIONS AND OBJECTIVES?**

A. Yes, the IVVO and FLISR functions (which are discussed in more detail below) will be applied to the same feeders in a given portion of the distribution grid. FLISR will facilitate fault isolation and service restoration activities. IVVO technology will be able to manage voltage and power quality objectives both before and after fault isolation and service restoration activities are carried out by automatic FLISR and manual switching operations. IVVO and FLISR systems can be implemented independently, but the lack of awareness of the performance of the separate standalone systems would reduce the overall effectiveness of each system. By implementing IVVO and FLISR in ADMS, the applications are integrated and coordinated together to realize the full benefits of each application.

**Q. WHAT WILL BE THE PHYSICAL COMPONENTS OF ADMS?**

A. ADMS will be composed of hardware, software, distribution SCADA, and an impedance model, which is an accurate electrical representation of the distribution grid, including substations, core, and advanced applications. ADMS will leverage sensor data for use by the core and advanced applications to make accurate and informed decisions to manage power flow on the distribution grid.

**Q. WILL ADMS HAVE SENSORS?**

A. No, sensors will not be integral components of ADMS. Instead, ADMS will utilize voltage and power quality data provided by sensors and equipment located on the grid.

For example, AMI meters will be able to measure and transmit voltage, current, and power quality data and can act as a "meter as sensor" providing near real-time monitoring information between the meter and ADMS. AMI is discussed in more detail in the Direct Testimony of Company witness Mr. Russell E. Borchardt.

Other devices that will provide sensor data for ADMS to accurately calculate power flow on the grid include distribution automated device Remote Terminal Units ("RTU") and power sensors that are located on feeders.

**Q. DO YOU FORESEE FURTHER USES FOR ADMS IN THE FUTURE?**

A. Yes. ADMS will provide a dynamic model and real-time power flow information that will facilitate increased penetration and integration of DERs, energy storage, integration of micro-grids, and future customer choice. The need for ADMS arose, at least in part, because of the increase in two-way power flow resulting from the growth of DERs, including renewable resources, on Public Service's distribution system. The visibility enabled by ADMS will provide the Company with information about these resources and their impacts that will be necessary to manage the system. The ADMS platform's ability to monitor, incorporate, and manage the higher penetration levels of DER, storage, and micro-grids, will also enable it to limit the potential negative impacts of these technologies on traditional electric customers, such as higher-than-necessary voltage that results from greater penetrations of solar on the distribution feeders. As DER penetration levels continue to rise, and as new storage and micro-grid technologies emerge and need to be connected to the grid, other ADMS applications will be necessary to study and manage the behavior of the grid to ensure maintained reliability.

### B. <u>Voltage Management and Integrated Volt-VAr Optimization ("IVVO")</u>

**Q. WHY IS VOLTAGE MANAGEMENT ON AN ELECTRIC DISTRIBUTION SYSTEM IMPORTANT?**

A. Maintaining proper voltage levels throughout the electric distribution system is one of the most important challenges utilities face. Utilities seek to provide electric service to customers within a specific voltage range because customer equipment, appliances, and devices may not operate satisfactorily when electricity is supplied at voltages outside of the appropriate range. Customer demand for electricity changes throughout the day, which means the power flowing through distribution systems and voltage levels on feeders increase and decrease throughout the day to meet changing loads.

**Q. DOES PUBLIC SERVICE CURRENTLY MONITOR VOLTAGE LEVELS ON ITS DISTRIBUTION SYSTEM?**

A. Public Service monitors the voltage at substations; however, the Company has limited capability to monitor voltage along distribution feeders.

**Q. WHAT IS THE APPROPRIATE VOLTAGE LEVEL FOR ELECTRIC SERVICE ON PUBLIC SERVICE'S DISTRIBUTION SYSTEM?**

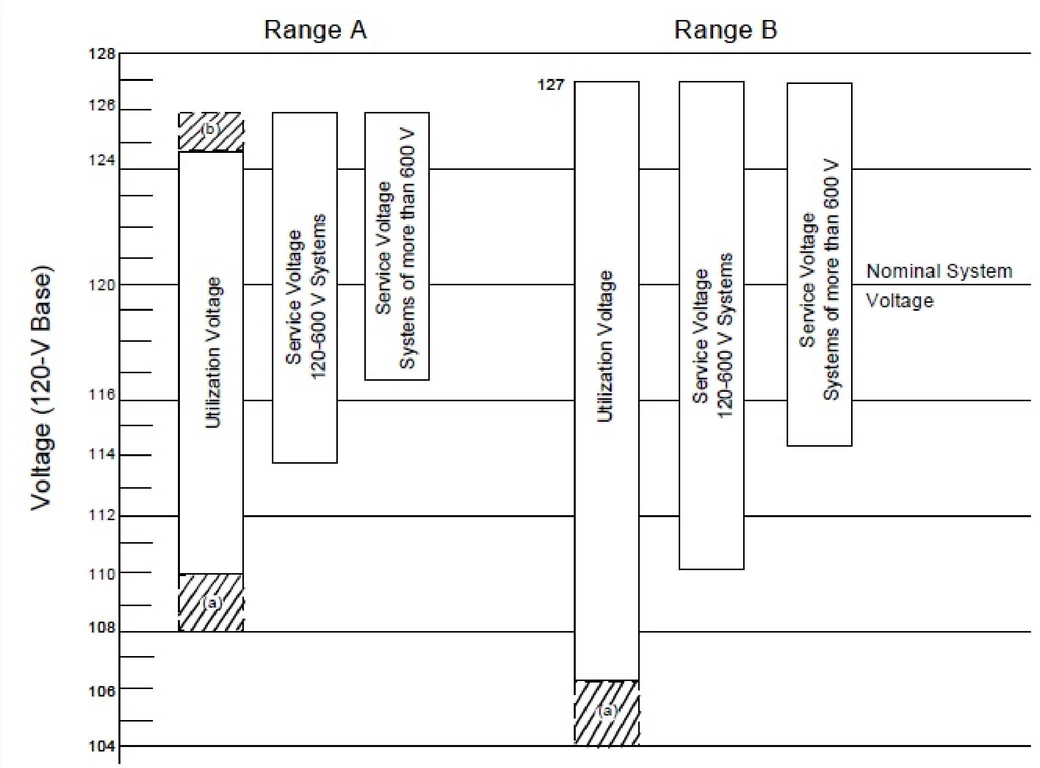
A. Public Service regulates the voltage along its feeders, or distribution circuits, in accordance with established standards such as American National Standards Institute ("ANSI") Standard C84.1, which has established a nominal voltage level of 120 V for residential customers. Standard C84.1 designates two voltage ranges:

- Range A, which consists of a 5% tolerance (+/- 5%) from the nominal voltage of 120 V (114-126 volts AC); and
- Range B, which consists of an operating range of 106-127 volts AC.

Generally, utilities seek to provide electric service to customers at voltages within Range A; the provision of service outside of Range A should be limited.

Many electric devices are designed to operate at a voltage between 110-127 volts AC in order to perform satisfactorily. Although ANSI C84.1 Range B allows an operating range of 106-127 volts AC, such conditions should be limited in extent, duration, and frequency, and reserved for emergency conditions. Figure CSN-2 illustrates ANSI Standard C84.1 Ranges A and B.

**Figure CSN-2**




ANSI C84.1 Voltage Ranges

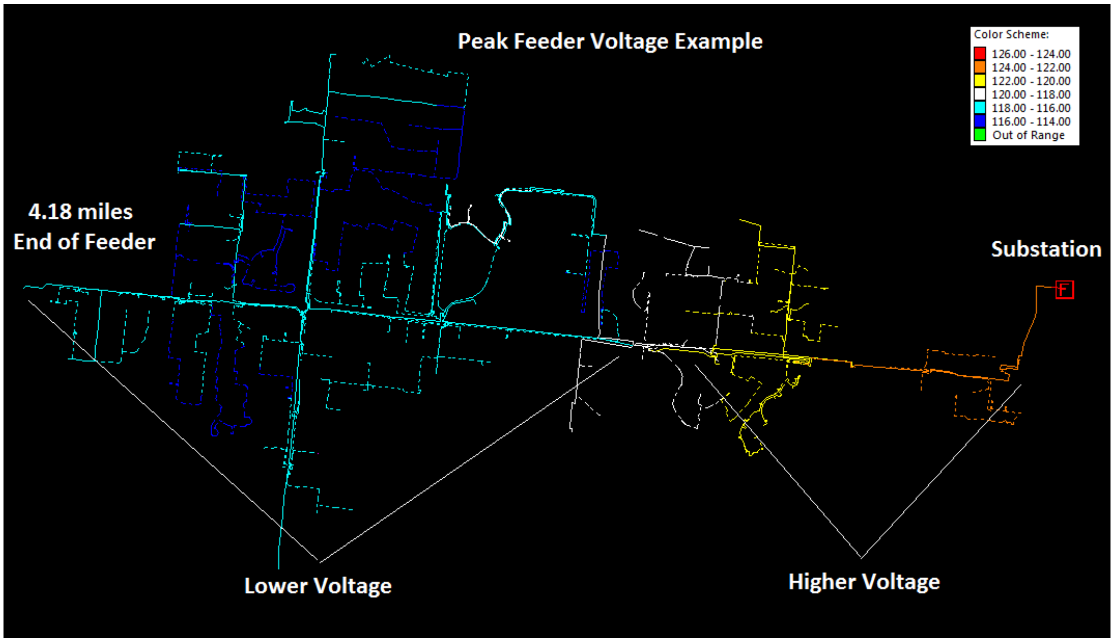
**Q. WHAT HAPPENS WHEN VOLTAGE LEVELS ARE TOO HIGH OR TOO LOW?**

A. Ideally, utilities provide electric service to customers at a voltage level within ANSI Standard C84.1 Range A, and service outside that range should be limited. Operating outside of Range B may result in problems with equipment performance and can even cause premature failure of equipment and electrical components. Typical symptoms of voltage problems include dimming or overly bright lights, overheating of equipment, premature equipment failure on electronic devices, and protective equipment (like circuit breakers) opening to prevent equipment from failure or damage.

**Q. HOW DOES THE COMPANY CURRENTLY ENSURE THAT VOLTAGES STAY WITHIN ACCEPTABLE LIMITS IN ORDER TO PROVIDE SERVICE?**

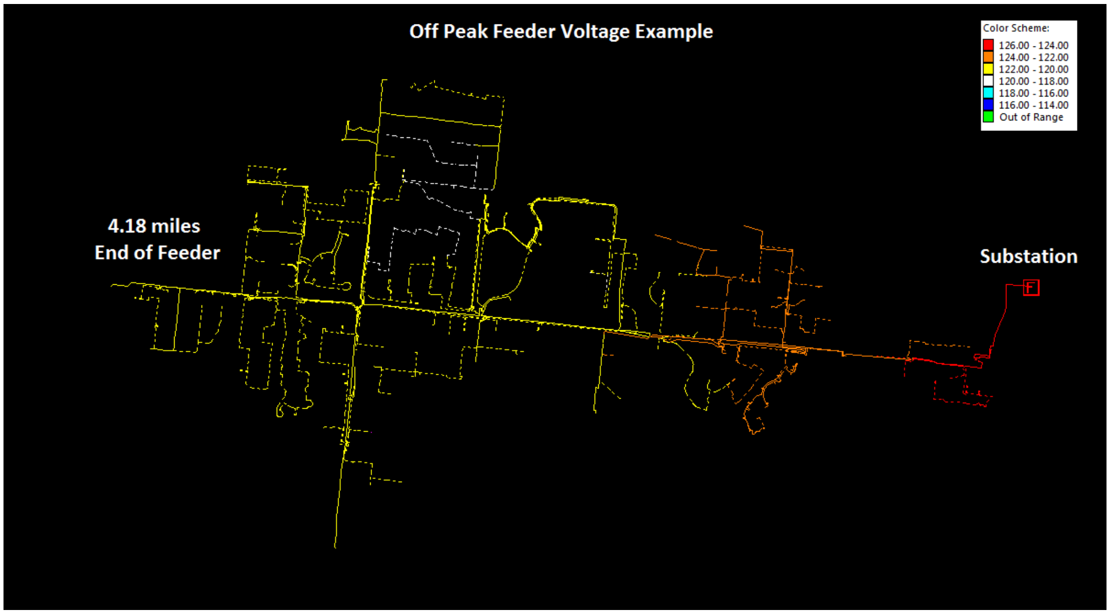
A. Historically, utilities have controlled voltage on the distribution system by regulating the voltage at the substation so that all voltage points along the feeder, or distribution circuit, are maintained within established standards such as ANSI Standard C84.1 Range A. Due to having limited monitoring along feeders, the determination of the voltage required at the substation to ensure appropriate voltage levels throughout the system is done through modeling of peak load conditions (as displayed in Figure CSN-3), including switching under emergency conditions. Utilities like Public Service have traditionally used voltage regulating equipment and capacitor banks located at substations and on feeders to keep customer voltages within a desired range to meet demand. As displayed in Figure CSN-3, during peak demand conditions, the voltage is regulated at the substation in the upper range of the ANSI standard and the voltage at the end of the feeder is at the bottom of the ANSI standard range.

**Figure CSN-3**




However, as displayed in Figure CSN-4, during non-peak conditions voltage is still regulated at the substation in the upper range of the ANSI standard. Because there is less demand during non-peak times, the associated voltage drop is lower, resulting in voltage at the end of the feeder that is still in the upper range of the ANSI standard.

**Figure CSN-4**




**Q. ARE THERE DRAWBACKS TO THE WAY PUBLIC SERVICE CURRENTLY MANAGES VOLTAGE LEVELS ON ITS SYSTEM?**

A. Yes. While the current equipment works properly and allows Public Service to provide safe and reliable service at a reasonable cost, performance could be improved if there were devices that could also track loads and voltages with greater precision, and could be operated to respond when conditions change. Because the Company is not currently able to constantly monitor voltage levels along its feeders, the Company often must operate the system at a higher voltage than what otherwise would be required in order to ensure appropriate voltage levels at the end of the feeder. Regulating voltage in this manner means that a customer near the substation receives a higher voltage (although still within permissible limits, as displayed in Figure CSN-4) than one at the end of the feeder.

**Q. WHAT IS IVVO?**

A. Integrated Volt-VAr Optimization, or IVVO, is an advanced application that automates and optimizes the operation of the distribution voltage regulating devices and VAr control devices to achieve operating objectives, including:

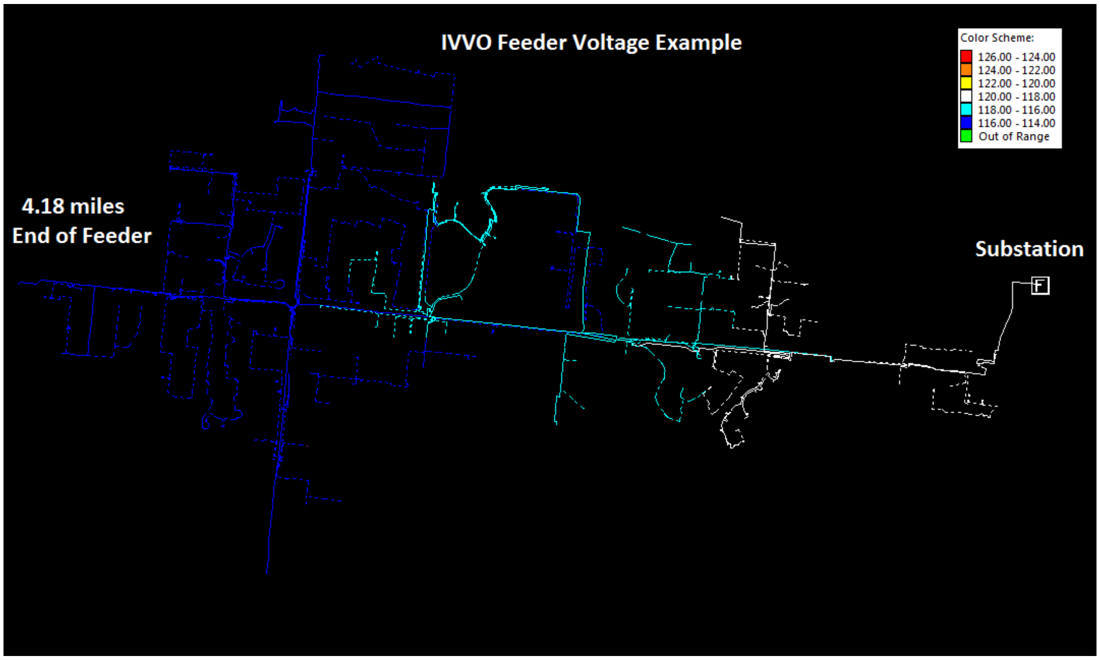
- Reduction of distribution electrical losses;
- Reduction of electrical demand;
- Reduction of energy consumption; and
- Increased ability to host DER.

**Q. HOW WILL THE TECHNOLOGY OPTIMIZE VOLTAGE?**

A. Voltage optimization is accomplished by "flattening" a feeder line's voltage profile - or, in other words, narrowing the bandwidth of the voltage from the head-end of the feeder to the tail-end in concert with capacitors and other voltage regulating devices (discussed below) for voltage support. In the proposed IVVO model, voltage will be monitored along the feeder and at select end points (rather than only at the substation), allowing the head-end voltage to be significantly lower at most times.

Voltage optimization (i.e., managing the overall voltage profile of the feeder) will reduce demand and energy consumption while still ensuring that voltage levels are adequate for providing safe and reliable power to customers at all points along the distribution feeders, including the end of the feeders, as shown in Figure CSN-5.

**Figure CSN-5**




**Q. HOW WILL IVVO REDUCE THE ELECTRICAL LOSSES ON THE DISTRIBUTION SYSTEM?**

A. For any conductor in a distribution network, the current flowing through it can be broken down into two components – active and reactive power. Active power is measured in watts or kilowatts (one thousand watts) and is the energy required to perform actual work. Reactive power is measured in “VAr” or “kVAr” (one thousand VAr); it does not do real work but uses the current-carrying capacity of the distribution lines and equipment, and contributes to the power loss. Reactive power compensation devices (such as capacitors) are designed to reduce the unproductive component of the electric current, thereby reducing current magnitude, and thus, reducing energy losses.

For Public Service's system, ADMS will turn the capacitors installed along the distribution circuit on and off in an optimal manner to limit the reactive power flowing on the distribution system. This improves the efficiency of the system and reduces system losses.

**Q. HOW WILL IVVO REDUCE THE ELECTRICAL DEMAND AND ENERGY CONSUMPTION?**

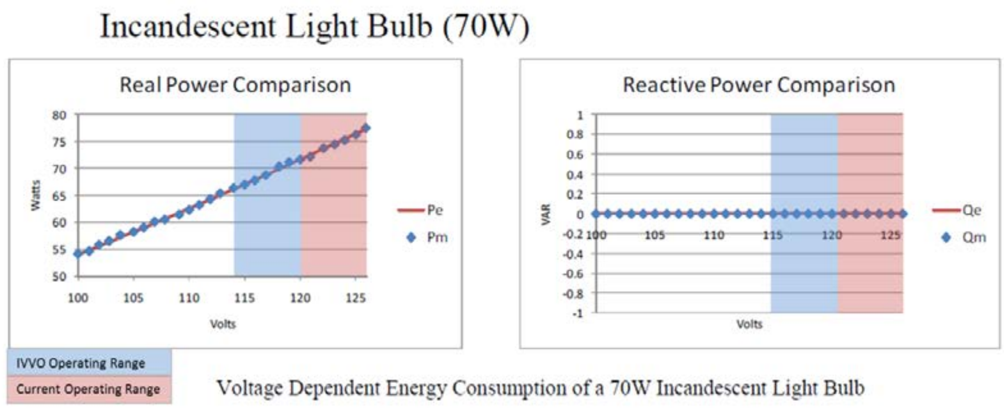
A. Flattening the voltage profile along a feeder and operating in the lower range of 114V to 120V reduces energy consumption for certain devices. The industry term used to describe operating in the lower voltage range is Conservation Voltage Reduction ("CVR"). Studies have shown that the CVR benefit varies with the load type and feeder characteristics.

One example of how IVVO will result in electricity savings is incandescent lighting, where the power consumed is directly proportional to the voltage. A 70W incandescent light bulb will consume around 77W at 126V and around 66W at 114V.

Motors, such as those found in air conditioners, dryers, and refrigerators, provide other examples. Some motors operate more efficiently at a lower voltage (114V to 120V). A higher voltage (120V to 126V) generates more heat, which makes these motors less efficient.

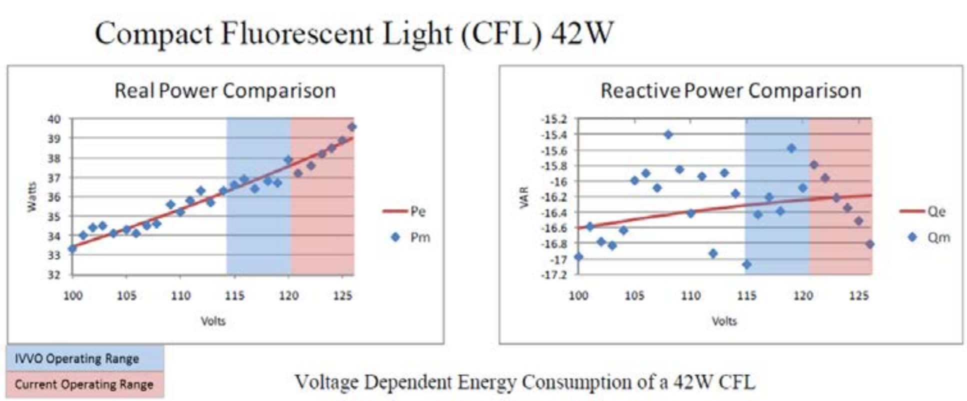
One of the main objectives of IVVO is to ensure these types of devices are operated in the lower voltage range making them more energy efficient. The Pacific Northwest National Laboratory ("PNNL") evaluated the effects of CVR on a national level for the United States Department of Energy.[1] Displayed in Figure CSN-6 through CSN-9 below are results from PNNL's study on how the energy consumption for different devices varies based on voltage.

**Figure CSN-6**



Voltage Dependent Energy Consumption of a 70W Incandescent Light Bulb

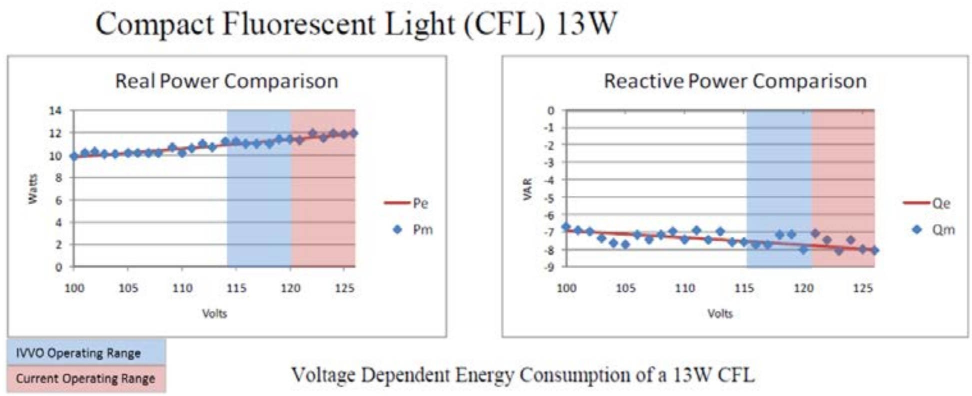
**Figure CSN-7**



Voltage Dependent Energy Consumption of a 42W CFL

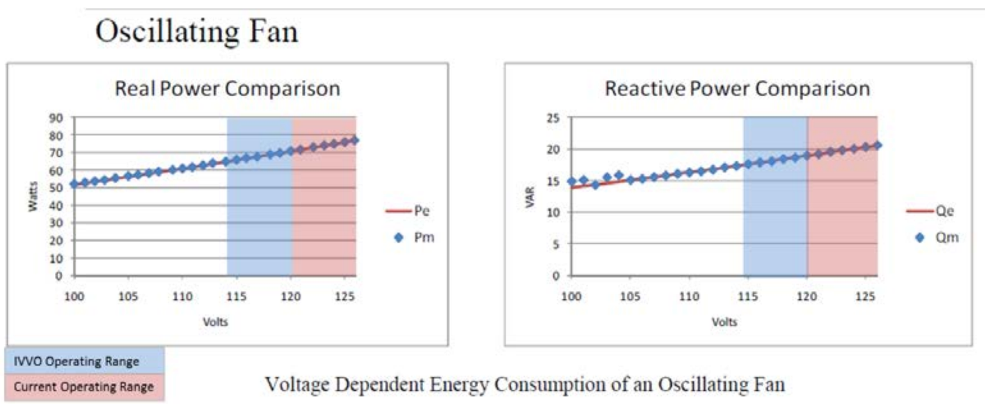
[1] Pacific Northwest National Laboratory, Evaluation of Conservation Voltage Reduction (CFR) on a National Level (July 2010), *available at*: http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19596.pdf.

**Figure CSN-8**



Voltage Dependent Energy Consumption of a 13W CFL

**Figure CSN-9**



Voltage Dependent Energy Consumption of an Oscillating Fan

As shown above, electric energy consumption is lower for each device when the voltage level is lower.

**Q. WHY DOES THE COMPANY NOW NEED TO ENHANCE ITS ABILITY TO MONITOR AND CONTROL VOLTAGE LEVELS ON ITS FEEDERS?**

A. Customers' energy consumption is more dynamic than ever. Residential customers can have on-site solar, batteries, electric vehicles, smart appliances, smart thermostats, and many more electronic devices. Traditionally, the Company has based control settings of devices like capacitors on the peak demand of a feeder and these devices operate with very little awareness of the energy consumption upstream or downstream. The current operation process worked well enough in the past, although not as efficiently as possible. ADMS will provide a centralized system that will dynamically react to changes in conditions on the distribution system and will improve the Company's ability to monitor and control voltage levels based on the actual conditions along a feeder.

**Q. DOES PUBLIC SERVICE HAVE ANY EXPERIENCE WITH A PROGRAM LIKE IVVO?**

A. Yes, the Company has experience with voltage optimization from its two pilot projects and through participation in the Electric Power Research Institute's ("EPRI") Green Circuit Program. The pilot projects have been on two of the Company's substations, the National Center for Atmospheric Research ("NCAR") substation and the Englewood substation.

The NCAR substation pilot, which included two feeders, was chosen to be one of the pilot projects monitored and evaluated by EPRI as part of its Green Circuits program. The results from that pilot found that the voltage can be lowered on average about 2.5%. The corresponding energy savings, as calculated by EPRI using their statistical modeling, were about 2.5% in 2011.[2] The results of the NCAR pilot were higher than the national average for the field trials in the EPRI Green Circuits study. The results from the field trials with other utilities showed an energy reduction range of 1.6-2.7%.

[2] Electric Power Research Institute, Green Circuits: Efficiency Case Studies (October 2011), *available at* http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001023518.

Results from the Englewood pilot have shown a voltage reduction of 1.5%, which resulted in energy savings of approximately 2.55% in 2011 and 4.05% in 2012.

**Q. WHAT WILL BE THE PHYSICAL COMPONENTS OF IVVO?**

A. There will be four principal utility equipment components of IVVO:

- Capacitors;
- Secondary static VAr compensators (“SVC”);
- Voltage sensing devices; and
- Load Tap Changers (“LTC”).

**Q. PLEASE DESCRIBE THE CAPACITORS.**

A. Electric loads like motors require two types of power to operate: active and reactive power. Distribution line capacitors provide local static VAr support or reactive power. By doing so, they help to limit both voltage drop and line losses across the distribution system. Capacitors are currently switched on and off based only on local conditions. The Company will continue to use its existing capacitor banks and will install new capacitors as part of this project. There will typically be three to six capacitors installed per feeder.

**Q. PLEASE DESCRIBE THE SVCS.**

A. The SVCs are electronic secondary capacitors that will provide fast, variable voltage support to help stabilize and regulate the voltage. Aside from the pilot program (discussed above), these devices will be a new technology introduced to Public Service’s distribution system. Each device will be able to act in less than a cycle (a cycle is defined as 1/60 of a second since the United States AC frequency is 60 Hz), as opposed to a traditional utility capacitor device that operates on 60-90 second time delay. These devices will provide dynamic voltage response for load, and will be located closer to customers or nearer the edge of the grid than the Company's existing capacitors. The devices' capabilities will enhance the system's ability to respond to the variability of renewable DERs such as solar facilities and intermittent distributed resources. The Company will strategically place approximately 4,350 SVC devices along feeders that need additional voltage support.

**Q. PLEASE DESCRIBE THE VOLTAGE SENSING DEVICES.**

A. IVVO requires end-of-line voltage sensing to monitor the voltage and ensure it is compliant with ANSI Standard C84.1. The Company intends to use AMI meters as sensors to provide near real-time voltage sensing. AMI is discussed in more detail in the Direct Testimony of Company witness Mr. Borchardt.

**Q. PLEASE DESCRIBE THE LOAD TAP CHANGERS.**

A. Substation transformers equipped with LTCs will enable voltage regulation by varying the transformer ratio or tap. LTCs typically have 16 taps above and below neutral (33 taps total) and each tap adjusts the transformer turns ratio by 0.375%. LTCs are currently monitored and locally controlled based on the local bus voltage. LTCs raise or lower the voltage by tapping up or down based on the settings of the local controller and the demand of the substation transformer.

**Q. TO WHAT EXTENT DID THE PILOT PROGRAMS DISCUSSED ABOVE USE THE SAME PHYSICAL COMPONENTS AS THOSE PROPOSED IN THE IVVO PROGRAM IN THIS CASE?**

A. The pilot programs were initially operational in May 2011. The NCAR and Englewood pilot programs both utilized capacitors, voltage sensing devices, and load tap changers. These pilot programs optimized the operation of the capacitors and load tap changers based on the end of line voltage sensing readings. In December of 2014, the Company installed 30 SVCs on one of the Englewood feeders. During July and August of 2015, the Company performed additional testing and based on the testing results, an additional 1.5% voltage reduction was achievable with the 30 SVCs. In the second quarter of 2016, the Company installed an additional 131 SVCs on the same feeder and three other Englewood feeders. The Company will perform additional testing in the third and fourth quarters of 2016 with the additional 131 SVCs.

**Q. CAN YOU PROVIDE MORE DETAILS EXPLAINING HOW IVVO WILL INTERACT WITH ADMS?**

A. Yes, IVVO will be an advanced application within ADMS. ADMS will operate as a centralized system that monitors inputs from devices such as substation RTUs, capacitor banks, AMI meters, LTCs, and other distribution automation devices. ADMS will take the inputs from these devices and compute the most efficient way for the system to operate and respond to changes. IVVO, through ADMS, will implement automated activities such as opening and closing of capacitors, and sending new settings to LTCs and SVCs. ADMS will also compute the most efficient way for the system to operate based on both manual switching and FLISR (e.g., for both maintenance and outages). The LTC control devices will take direction from ADMS, which will make decisions based on knowledge about the entire system, rather than only about voltage at the local bus. As a centralized system, ADMS will be able to control the distribution devices to work in unison and dynamically react to an increasingly complex system in a safe, efficient, and reliable manner.

**Q. CAN YOU PROVIDE A COMPARISON TO A COMMON HOUSEHOLD APPLICATION?**

A. Yes, a normal home thermostat controls the home's temperature based only on the temperature in the room where the thermostat is installed. However, a "smart" thermostat system would have temperature sensors in every room and the smart system would receive readings from each sensor. The smart system would also have the ability to use vents in each room to control the temperature of each individual room at any point in time.

ADMS operates IVVO in a similar manner, optimizing the system based on many localized inputs and directing activities to specific points on the system.

### C. Fault Location Isolation and Service Restoration ("FLISR")

**Q. WHAT ARE FLISR AND FLP?**

A. As mentioned above, FLISR stands for Fault Location Isolation and Service Restoration. FLISR involves deploying automated switching devices with the objective of decreasing the duration and number of customers affected by any individual outage. FLISR can noticeably reduce the amount of time customers will experience outages from faults, which I discuss in more detail below. It can also improve utility performance metrics such as system average interruption duration index ("SAIDI") and the system average interruption frequency index ("SAIFI").

Fault Location Prediction, or FLP, is a subset application of FLISR that leverages sensor data from field devices to locate a faulted section of a feeder line and reduce patrol times needed to physically locate the fault.

**Q. CAN YOU DESCRIBE IN MORE DETAIL A FAULT AND FAULT CURRENT?**

A. Yes. Faults are either temporary or permanent. A permanent fault is one where permanent damage is done to the system and a sustained outage (i.e., greater than five minutes) is experienced by the customer. Permanent faults may be the result of insulator failures, broken wires, equipment failure (e.g., cable failure, transformer failure), and public damage (e.g., an automobile accident impacting a utility pole). Temporary faults are those where customers experience a momentary interruption (i.e., less than five minutes). Causes of temporary faults include lightning, conductors slapping in the wind, and tree branches that fall across conductors and then fall or burn off.

When there is a fault—either temporary or permanent—the current or fault current is several to many times larger in magnitude than the current that normally flows due to load. The general profile for fault current is based on the distance from the substation (fault current is generally highest at the substation, decreasing as the location is further from the substation), type of fault (e.g., line-ground fault, three-phase fault), system voltage, and conductor type and size.

**Q. WHY DOES PUBLIC SERVICE NEED THIS APPLICATION?**

A. Today, Public Service has an average of 1,745 customers on each feeder. Because of the Company's current lack of visibility into the conditions on the distribution system feeders, when a fault occurs Public Service generally relies on calls from customers to inform the Company of the problem. Once customers have reported an outage in a given area, Public Service operators dispatch crews to patrol the area where they believe the fault occurred, based on the information gathered from the calls. Crews then proceed to isolate the fault and manually close switches to restore service to customers affected by the fault. The average time to restore a feeder-level fault is 68.3 minutes. Such a fault affects all customers on that feeder (1,745 on average).

**Q. DOES FLISR OPERATE FOR ALL OUTAGE EVENTS?**

A. No, FLISR devices will operate for outages that occur on the distribution mainline. Outages that occur on laterals will benefit from fault location prediction information and outages that occur on the secondary system will benefit from the proposed deployment of AMI meters. Although mainline outages only account for 3% of distribution outage events, today they account for over 30% of the distribution SAIDI.

**Q. ARE THERE CURRENTLY DEVICES ON PUBLIC SERVICE'S DISTRIBUTION SYSTEM TO ASSIST IN FAULT ISOLATION AND SERVICE RESTORATION?**

A. Yes. Public Service currently has small automation programs existing across its distribution system. In general, reclosers and sectionalizers are used to limit potential impacts of faults. Reclosers are tuned to operate in tandem with existing fuses or sectionalizers. They act as circuit breakers and are able to interrupt a fault event, meaning the recloser opens and the customers downstream of the recloser experience an outage. This is comparable to a household ground fault circuit interrupter ("GFCI") that opens when it detects a fault or issue, only affecting the devices downstream of the fault or issue, and not opening the breaker in a household breaker panel. Reclosers can also try to close a circuit (that has opened due to the fault) a certain number of times (to clear a temporary fault) before de-energizing all customers downstream. If successful, the process ensures that all customers upstream of the recloser would not experience any interruption of service. In addition, the reclosers will measure line current during faults (fault current) and report that data to ADMS. This will allow for not only identification of the type of fault that occurred, but also the identification of line sections where the fault may have occurred.

Sectionalizers are tuned so they de-energize downstream customers during a breaker or recloser-reclose cycle. This allows upstream customers to only experience a momentary interruption of service rather than a sustained outage.

However, without a centralized management scheme (such as ADMS) these devices cannot automatically restore customers located outside the fault zone.

**Q. WHAT WILL BE THE COMPONENTS OF FLISR AND FLP?**

A. There will be four principal components of FLISR:

- Reclosers;

- Automated overhead switches;
- Automated switch cabinets; and
- Substation Relaying.

There will be two main components to FLP:

- Power sensors; and
- Substation Relaying.

**Q. WHAT ARE RECLOSERS?**

A. Reclosers will be pole-mounted remote supervisory reclosing and switching devices. The Company currently has reclosers on the distribution system. The new devices will perform the functions of existing reclosers as described above. The devices will also be able to interrupt a fault event and will be able to report fault current to ADMS, which can then use that information to execute FLP to determine the location of the fault. The reclosers will be able to "re-close" after a fault event to determine if a fault still exists. If the fault does not exist, the recloser will reclose and restore service. If the recloser determines that there is a permanent fault after multiple attempts to reclose, the device will communicate the fault information to ADMS, which will inform the Company of the need to dispatch a crew to the fault location. In addition, the reclosers will be controlled by ADMS when there is a permanent fault to automatically restore service.

**Q. WHAT IS AN AUTOMATED OVERHEAD SWITCH?**

A. Switches are overhead remote supervisory sectionalizing and switching devices. When a fault occurs, a feeder breaker senses the fault and opens. Although the overhead switches do not communicate directly with the feeder breaker, local controllers on switches on both sides of the fault would sense the loss of voltage and open, isolating the fault. However, unlike a recloser, the overhead switches will not have the capability of reclosing to determine whether there is a permanent fault. Instead, overhead switches rely on the feeder breakers for the reclosing functionality.

Although automated overhead switches lack the reclosing functionality, they utilize a compact form factor that makes them a better choice for space-constrained locations compared to reclosers.

**Q. WHAT ARE AUTOMATED SWITCH CABINETS?**

A. Automated switch cabinets are pad mounted sectionalizing and switching devices. They are motor-operated, remote-controlled devices that are expected to be utilized for underground feeder installations. They will perform functions similar to the automated overhead switches for underground feeders.

**Q. HOW WILL FLISR FUNCTIONALITY IMPROVE THE CURRENT SITUATION?**

A. FLISR components (described above) will divide the distribution feeders approximately into thirds with generally fewer than 1,000 customers in each section, with intelligent switches in place to tie each of those sections to another feeder. Existing reclosers and intelligent devices will be integrated into the FLISR scheme. If an existing device is in the correct location to employ FLISR functionality, this will obviate the need for a new device. Other existing devices will enhance FLISR’s capabilities by enabling greater granularity in switching arrangements through having more precise voltage, current, and power information.

Once a feeder is enabled with FLISR, the system—in coordination with ADMS and FAN functionality—will automatically restore service to two-thirds of the customers on a feeder (or 1,163 customers on average) within minutes of the fault, and the other one-third of customers on the feeder (or 582 customers on average) may experience shorter service restoration times than the average of 68.3 minutes today due to the availability of more precise information regarding the location of the fault. Today, finding a fault location can involve patrolling the length of the entire feeder without knowledge of the general location. FLP will provide the general location of the faulted section reducing the area needed to be patrolled and will in many cases allow for shorter outage durations.

**Q. CAN YOU DESCRIBE IN MORE DETAIL HOW FLISR OPERATES?**

A. Yes, in the event of a fault, the FLISR protective devices will reclose or sectionalize the feeder as they currently do to isolate the fault. Once this occurs, data will be sent from those intelligent field devices to ADMS. ADMS will automatically run the FLISR application, which will locate the device closest to the fault and generate a switching plan to restore service to other customers, taking into account not only device and feeder loading, but surrounding substation loading as well. ADMS will then execute the proposed switching plan and notify the operator of the need to send a crew to the isolated section to manually investigate the fault event. This process is expected to take less than five minutes from the occurrence of an outage to operator notification. ADMS will also be able to run the FLP algorithm and predict which segment within a FLISR section the fault exists, which will reduce expected patrol times by crews.

**Q. CAN YOU DESCRIBE IN MORE DETAIL HOW FLP OPERATES AND HOW IT WILL IMPROVE DISTRIBUTION GRID PERFORMANCE?**

Yes, Public Service is proposing to install up to two sets of three-phase advanced line power sensors along each feeder targeted for FLP deployment. One set will be installed on the feeder side of the substation, and another set could be installed down the line. Existing remote fault indicators and new intelligent device telemetry will be incorporated into the FLP deployment. If an existing device is in the correct location to employ FLP functionality, this will obviate the need for a new device. Other existing devices will enhance FLP's capabilities by providing additional data to improve FLP algorithm performance.

Feeders enabled only with FLP will operate in a slightly different manner from FLISR-enabled feeders. Should a fault occur, FLP devices upstream of the fault will capture an event occurring and will communicate relevant measurements during the fault (such as current, voltage, indication) to ADMS. ADMS will compare these measurements to the impedance model and will generate expected fault locations. It will then notify the operator of these locations (with a level of certainty for each location), and the operator will dispatch a crew directly to the expected faulted section (as opposed to having the patrol the entire feeder line, as in the current situation) to isolate the faulted section. This process is expected to reduce the patrol time per fault by providing a general location of the faulted section and reducing the area needed to be patrolled.

**Q. WILL FLISR AND FLP MAKE USE OF AMI METERS?**

A. Yes, indirectly. FLP considers outage prediction results from a separate outage prediction application in situations where multiple possible fault locations are indicated. The outage prediction application utilizes data from AMI meters. In this way, FLISR and FLP indirectly use AMI data when determining the location of an outage.

**Q. HOW WILL FLISR AND THE SENSING DEVICES INTERACT WITH ADMS?**

A. As described above, ADMS will have an impedance model of the Public Service distribution system. Real-time current, voltage, and status data will be used to run load flow and state estimation applications on that model, providing awareness of system conditions for that feeder and surrounding feeders.

ADMS will provide for remote monitoring and control of FLISR and FLP devices. When a fault occurs on a FLISR- or FLP-enabled feeder, any device that is exposed to the fault will send a signal to ADMS notifying the system of the event. Devices that are capable will also send fault current during the event. ADMS will use both of sets of data, comparing fault current data against the impedance model to generate an expected fault location. If that feeder is FLISR-enabled, ADMS will generate a switching plan to isolate the faulted section based on system conditions, and will issue commands to field devices on the feeder and adjacent feeders so that non-faulted sections can be automatically restored.

**Q. CAN YOU PROVIDE A COMPARISON TO A COMMON HOUSEHOLD SITUATION?**

A. Yes, as a comparison, most strings of Christmas lights will not function at all if any one of the lights has a problem. Identifying the problematic light that causes the entire strand not to function requires testing each individual light. However, on a string of hypothetical "smart" Christmas lights, equipped with a centralized controller (comparable to ADMS) that communicates with each individual light, the centralized controller would use the data communicated to it by each of the lights to predict the location of the problematic light(s) to within a small set of lights. This is comparable to FLP. Once the lights' centralized controller isolated the small set of lights with the problem light, it would engage a switch that would allow the remaining lights to continue to work properly while the problem light is replaced. This is comparable to FLISR functionality.

### D. Industry Adoption

**Q. IS PUBLIC SERVICE'S PROPOSAL FOR ADMS CONSISTENT WITH CURRENT TRENDS WITHIN THE ELECTRIC UTILITY INDUSTRY?**

A. Yes, an ADMS solution is currently the only comprehensive platform that can accomplish what is necessary to implement the AGIS initiative. As part of its research, the Company visited five other peer utilities across the United States, and had informational discussions with three other utilities. All had similar approaches, such that ADMS is the only comprehensive platform that can manage the interaction of IVVO, FLISR, and the integration of DERs, consistent with Public Service's proposal.

**Q. IS PUBLIC SERVICE'S PROPOSAL FOR IVVO CONSISTENT WITH CURRENT TRENDS WITHIN THE ELECTRIC UTILITY INDUSTRY?**

A. Yes. Public Service's IVVO proposal includes SVCs, a hybrid approach to traditional slower reacting 3-phase devices that will enable subtle, dynamic, and fast adjustments to voltage levels on the distribution system.

There are numerous published accounts regarding the success of IVVO-type programs. The U.S. Department of Energy indicated in its December 2012 report ("DOE VVO Report")[3] that reducing feeder voltages reduces energy consumption proportionately. Without IVVO, Public Service would rely on the current method of controlling voltage levels on the distribution system. However, recent technological advances in sensors, communications, and information processing and control technologies have made it possible to monitor and control voltages throughout the distribution system using intelligent field devices.

As noted in the DOE VVO Report, 26 utilities that received smart grid investment grants ("SGIG") implemented advanced VAr optimization technologies,[4] including peer investor-owned utilities such as Consolidated Edison Company of New York; Florida Power & Light Company, a subsidiary of NextEra Energy; PECO Energy Company, a subsidiary of Exelon Corporation; and the utility operating company subsidiaries of Southern Company.

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[3] United States Department of Energy, Application of Automated Controls for Voltage and Reactive Power Management – Initial Results (December 2012) ("DOE VVO Report"), *available at* https://www.smartgrid.gov/files/VVO_Report_-_Final.pdf.

[4] Public Service notes that the figure of 26 projects may be understated, as it appears that DOE counted each holding company family as one project.

The DOE VVO Report recognized the following benefits from IVVO-projects:

- Deferred capital expenditures and improved capital asset utilization;
- Reduced electricity generation and environmental impacts; and
- More efficient utility operations, greater flexibility to address resiliency, and more opportunities to keep rates affordable.[5]

These benefits are consistent with recent goals articulated by regulators, utilities, customers and consumers, and stakeholder groups.

Although numerous utilities have begun to implement IVVO-type functions, the SVC device is an industry-leading technology. Public Service would be an early adopter of this technology.

**Q. WHY IS IT A PRUDENT COURSE OF ACTION FOR THE COMPANY TO BE AN EARLY ADOPTER OF THIS TECHNOLOGY?**

A. As described in more detail by Company witness Mr. Lee, the Company envisions the grid of the future to be a safe, more efficient, more reliable system that enables more customer choice by allowing customers to adopt new products, services, and technologies. SVCs provide grid edge support in manner that traditional voltage regulation devices cannot, providing fast and variable voltage support enabling customers to adopt new products and technologies safely, efficiently, and reliably. In addition, as described in more detail below in the benefits section (Part IV.A), it is anticipated that the deployment of SVCs will

[5] DOE VVO Report at ii.

increase the energy savings up to 3% and in some instances even higher. SVCs will support efficiency and voltage optimization at the edge of the grid, greater energy and peak demand savings, higher penetrations of DERs, and greater customer flexibility to adopt new products and technologies. The numerous benefits of SVCs outweigh the risks associated with being an early adopter of this technology.

**Q. IS PUBLIC SERVICE'S PROPOSAL FOR FLISR CONSISTENT WITH CURRENT TRENDS WITHIN THE ELECTRIC UTILITY INDUSTRY?**

A. Yes, FLISR includes automatic sectionalizing and restoration, and automatic circuit reconfiguration. These applications will accomplish distribution automation operations by coordinating operation of field devices, software, and dedicated communication networks to automatically determine the location of a fault, and rapidly reconfigure the flow of electricity so that some or all of the customers can avoid sustained outages. A December 2014 DOE Report summarized the findings of seven FLISR projects that received SGIG funding.[6] The participating utilities included five utility operating companies (in five utility company families), including CenterPoint Energy (headquartered in Houston, Texas).[7] Many more utilities plan to update existing feeder circuits outside of the substation with FLISR technology upgrades.

[6] United States Department of Energy, Fault Location, Isolation, and Service Restoration Technologies Reduce Outage Impact and Duration (December 2014), *available at* https://www.smartgrid.gov/files/B5_draft_report-12-18-2014.pdf.

[7] It has been reported that CenterPoint's FLISR program has prevented more than 102 million customer minutes out in more than 1000 outage events from 2011 to 2015. *See* Jeff St. John, How CenterPoint's Integrated Smart Grid is Paying Off, Greentech Media (Apr. 16, 2015).

**Q. WHY IS IT IMPORTANT TO IMPLEMENT THESE TECHNOLOGIES NOW?**

A. Although Public Service has deployed some automation with remote monitoring and control of the distribution system, none of the control systems the Company has today provide integrated capabilities for distribution operation that are now available with ADMS. The Company's ability to support both existing and new electronic field devices is being strained because of limitations with existing deployed technologies.

As discussed above, a more intelligent distribution system will be able to better meet customers' energy needs, while also integrating new sources of energy and delivering power over a network that is increasingly interoperable, efficient, and resilient. Public Service's distribution grid is in need of operational improvements that can be achieved through new technologies and devices such as AMI, IVVO, and FLISR. Intelligent field devices will also provide for improvements in reliability and reductions in peak demand and electricity consumption through the use of advanced applications like IVVO.

The combination of infrastructure improvements and technologies that are part of the AGIS initiative will help the grid operate optimally and will facilitate the system's absorption of new and dynamic distributed energy resources, the level of which is expected to continue to increase.

## E. Information Technology and Cybersecurity

**Q. WILL ADDITIONAL INFORMATION TECHNOLOGY INTEGRATION BE NEEDED THE CPCN PROJECTS TO FUNCTION PROPERLY?**

A. Yes. Company witness Mr. David C. Harkness explains how the CPCN Projects will be integrated with the Company's new and existing applications through information technology ("IT"). IT integration and cyber security will be critical aspect of the AGIS initiative, as they will ultimately interconnect and protect the components of AGIS and existing Company applications.

## III. IMPLEMENTATION

**Q. PLEASE PROVIDE AN OVERVIEW OF THE IMPLEMENTATION OF THE AGIS SYSTEMS DISCUSSED IN YOUR TESTIMONY.**

A. During the initial stages of the deployment of the AGIS systems, all of the systems will be deployed concurrently. ADMS and the FAN are the two foundational systems that are required to implement FLISR, FLP, and IVVO. Without ADMS, the field devices would operate in a similar manner to how they operate today, based on local conditions and with little awareness of the rest of the system. Without the FAN, the field devices would not have a means to communicate with ADMS and their head-end systems and similarly would operate in the same manner to how they operate today. Company witness Mr. Wendall A. Reimer goes into more detail regarding the implementation of FAN.

For ADMS, Public Service began the design and implementation of this program in the second quarter of 2016. Because ADMS is a foundational system that will control the advanced applications, ADMS is a critical path that must be functional upon deployment of the field devices. As described in more detail below, ADMS is planned to be operational on a limited number of feeders in 2019 and expanded to the other feeders on rolling basis.

The FLISR and FLP devices are on a seven-year deployment schedule that also began earlier this year. The deployment will be prioritized by the historical reliability performance of the feeders, starting with the worst performing feeders. Deployment of devices will be in clusters of three-to-five feeders to gain the operational and reliability benefits in a localized area. Upon ADMS being operational, the FLISR devices will be commissioned into ADMS and the full functionality of FLISR will be enabled.

Implementation of IVVO is on a five-year deployment schedule and, pending approval, is expected to begin in 2017. The deployment will be prioritized by consideration of demand and energy, whether feeder lines and associated facilities are underground or overhead, and the location of existing capacitors. The areas with the greatest demand and energy will be prioritized first as they offer the greatest opportunity for demand and energy savings; the areas with largest amount of overhead feeders will be prioritized as installing devices on an overhead system is easier and more cost effective; and locations with existing capacitors that can be utilized will receive higher priority for participation. Deployment of devices will be on feeders grouped by substation to gain the efficiency benefits in a localized area. Upon ADMS being operational, the IVVO devices will be commissioned into ADMS and the full functionality of IVVO will be enabled.

**Q. PLEASE DESCRIBE THE IMPLEMENTATION OF ADMS IN MORE DETAIL.**

A. Public Service expects to begin detailed design and implementation of ADMS in 2016. Implementation of the ADMS application will consist of installation, testing and verification of the functionality of the core applications of ADMS (which are described above in Section II(A)) and the advanced applications like IVVO, FLISR, and FLP. It may take some time for ADMS to be integrated with all of the Company's systems and applications. ADMS will enable the functionality of advanced applications; however, the intelligent devices must be installed and operational in order to interact with ADMS. Other existing devices that lack advanced communication or control capabilities will be unable to interact with ADMS.

In the first stage of ADMS project implementation, the Company will test and verify the core and advanced functionality on an initial, representative sample of approximately 20 feeders where ADMS will be operational. This will include integration of ADMS with GIS and the FAN. Public Service expects to conduct the initial, limited implementation of ADMS during 2019.

When the Company has determined that ADMS is properly functioning on the initial set of feeders, the core and advanced functionality of ADMS will then be deployed to the other Public Service feeders on a rolling basis.

The Direct Testimony of Company witness Mr. Harkness provides more detail on the integration of ADMS.

**Q. WILL THE IVVO AND FLISR DEVICES BE DEPLOYED THROUGH PUBLIC SERVICE'S ENTIRE SERVICE TERRITORY?**

A. No, Public Service is pursuing a selective deployment of these devices.

**Q. WHERE AND WHEN WILL THE IVVO DEVICES BE DEPLOYED?**

A. Public Service will deploy intelligent field devices to implement IVVO on feeders within the Denver metropolitan area. Approximately 67% of Public Service's customers are located in the Denver metropolitan area and these customers are served by approximately 60% of the Company's feeders (or 472 feeder lines). Therefore, the Company can provide the energy savings benefit of these technologies to approximately 67% of its customers by deploying the devices on only 60% of its system. Specifically, Public Service plans to install new capacitors on all 472 of these feeders. The Company will also strategically install approximately 4,350 SVC devices on a subset of those 472 feeders. The five-year deployment, expected to start in 2017, will include 472 of the nearly 800 feeders on Public Service's distribution system.

Public Service is proposing the selective deployment of IVVO because two-thirds of the Company's customers can directly benefit from IVVO while the Company will only deploy the intelligent field devices on 60% of the system. In addition, the portions of the Public Service distribution system where IVVO will not be deployed are more rural, meaning that the feeders are longer, which increases the voltage drop along the lines. As such, more non-standard equipment would likely need to be replaced for devices on those feeders to be integrated with the FAN and ADMS. Also, because the customers are more spread out, the cost and complexity of getting communications to devices would increase accordingly. All of these reasons factored into the decision to propose a selective deployment that would maximize the benefits and limit the cost and complexity of deploying IVVO.

Public Service is proposing the selective deployment of SVCs because SVCs are a relatively new product to the electric utility industry. In addition, the SVCs do not have a mature underground product, so the Company's current focus will be placing the devices on overhead systems until the underground product becomes more mature. Public Service intends to strategically place the devices to maximize their benefit and limit the placement of devices to areas that will enable end-of-line voltage support.

**Q. WILL PUBLIC SERVICE EXPAND THE DEPLOYMENT OF IVVO TO OTHER AREAS?**

A. As described above, the deployment area was selected as the most reasonable area to maximize the benefits and limit the risk of deploying IVVO on a system level. The rural areas have a higher level of cost and complexity and the Denver metropolitan area was selected as a reasonable deployment that minimized the cost and maximized benefits for the customers and the Company. As the Company proves out the benefits and functionality of IVVO and develops a higher level of expertise, the Company will consider implementing IVVO in other areas outside of the Denver metropolitan area in the future.

**Q. WHERE AND WHEN WILL THE FLISR AND FLP DEVICES BE DEPLOYED?**

A. Public Service will deploy FLISR devices for automatic service restoration on feeders within the Denver metropolitan area as well as certain other urban areas. The feeders in the Denver metropolitan area and other more urban areas generally are shorter, have more robust interconnections to other feeders and substations, and have higher customer counts than their rural counterparts. Thus, these feeders will realize a greater benefit for the costs required to implement FLISR.

Public Service is pursuing a selective deployment of FLISR devices and is only deploying FLISR on feeders that the Company identified as having the greatest potential for improved reliability. The large majority of the feeders on the

Public Service system have very few sustained outages and there would be minimal to no benefit to deploying FLISR on these feeders.  Instead, Public Service will deploy the FLISR devices on its historically “worst performing” feeders in order to improve their reliability and minimize sustained outages.

The Company will deploy devices that provide FLP functionality throughout the entire service territory. The seven year deployment of FLISR and FLP devices is expected to begin in 2016.

# IV. BENEFITS AND COSTS

## A. Benefits

**Q. HAS PUBLIC SERVICE IDENTIFIED BENEFITS THAT WILL BE GAINED FROM IVVO AND THE OTHER COMPONENTS OF THE AGIS INITIATIVE YOU HAVE DISCUSSED?**

A. Yes. Public Service has identified a range of such benefits. I will describe benefits that could be quantified, including avoided energy (and associated fuel savings) and avoided capital investment (including generation capacity, and transmission and distribution) resulting from the deployment of IVVO. I also describe qualitative benefits that were not quantified by the Company, but will accrue to both Public Service and its customers resulting from the deployment of IVVO and other components of the AGIS initiative.

### 1. Quantifiable Benefits from IVVO

**Q. WILL THERE BE QUANTIFIABLE FINANCIAL BENEFITS THROUGH PUBLIC SERVICE'S IMPLEMENTATION OF IVVO TECHNOLOGY?**

A. Yes, Public Service anticipates quantifiable financial benefits from the deployment of the IVVO technology will begin to be realized in 2019. I will discuss three areas of potential benefit for IVVO:

- Avoided energy (energy fuel savings);
- Avoided line losses (energy fuel savings); and
- Avoided capacity costs (generation, transmission, and distribution).

These financial benefits are summarized in Attachment CSN-1. These inputs were used in the cost-benefit analysis discussed in the Direct Testimony of Company witness Mr. Samuel J. Hancock.

**Q. PLEASE EXPLAIN THE ESTIMATED ELECTRIC ENERGY SAVINGS PUBLIC SERVICE ANTICIPATES THROUGH THE IMPLEMENTATION OF IVVO TECHNOLOGY.**

A. Public Service expects to experience a reduction in energy consumption through the deployment of IVVO. This will, in turn, result in savings through the avoidance of energy production or procurement by the Company, and associated fuel savings.

**Q. PLEASE EXPLAIN HOW THE PROJECTED LEVEL OF ENERGY SAVINGS WAS DEVELOPED.**

A. Public Service anticipates enabling energy savings through ADMS controlling the Company's traditional devices (e.g., capacitors and LTCs), as further enhanced by the use of SVCs. On feeders where the capacitors will be deployed in conjunction with the SVCs, the energy savings have been projected to be greater than the reduction experienced on the two pilot projects run on Public Service's system—as high as 3%. The increased savings will be the result of the deployment of the SVCs at strategic locations, in addition to the capacitors. However, because the Company will not deploy intelligent field devices to implement IVVO across its entire system, the projected system-wide energy savings have been adjusted to reflect the plan's deployment. In the future, as additional IVVO devices (including traditional devices as well as SVCs) are deployed across Public Service's system, energy savings could be as high as 3%-5% on the best-performing feeders where the IVVO technology is deployed.

Public Service estimates that the average energy savings that will be achieved upon deployment of IVVO with the SVCs will be 2.06% on each feeder where the IVVO intelligent field devices will be installed. Energy savings will start to be realized in quantifiable amounts when ADMS is operational, which is anticipated to be in 2019. The percentage of energy savings achieved by IVVO will erode over time as newer more efficient devices have less energy variation over different voltage ranges. The energy savings percentage is expected to be 1.83% (per feeder where IVVO is deployed) in 2022.

**Q. HOW WAS THE 2.06 PERCENT ENERGY SAVINGS LEVEL ESTIMATED?**

A. The value of 2.06% was estimated through several steps, and is based on an expected voltage reduction level of 2.86% as supported by the results of the Company's participation in pilot projects and other industry studies. The starting point was the Company's projected per-feeder energy savings of 1.8% from a deployment of capacitors and LTCs (but not SVCs). This figure was based on the 2.0% energy savings from Public Service's two pilot projects, and is consistent with energy savings levels in EPRI's Green Circuit Program, which collected data from multiple projects including Public Service's two pilots. Because of required maintenance and field switching that occurs during normal operation of the grid, there will be times when the system will not operate optimally or must be disabled. To account for these factors, the 2.0% level was reduced by 10% to yield a net benefit of 1.0%.

The Company next had to estimate the additional savings that would be achieved through the deployment of SVCs. Based on Public Service's experience with its pilot projects, Public Service projected that there would be a cumulative energy savings of 3.0% per feeder through the IVVO deployment, including SVCs. Thus, the additional savings achieved through the deployment of SVCs was projected to be 1.0% [3.0% - 2.0% = 1.0%]. The 1.0% additional savings was also reduced by 10% to account for maintenance and field switching to yield a net additional benefit from SVC deployment of 0.9% per feeder.

As I mentioned above, the SVC devices will not be installed on every one of the 472 feeders where IVVO will be deployed. The Company determined that because this technology is industry-leading and has not yet been deployed across a large utility distribution system like Public Service's, it would be prudent to perform a more limited deployment of this advanced technology at this time. The Company plans to install approximately 4,350 SVC devices at strategic locations among the 472 feeders where IVVO will be implemented. Because the Company projected that a full deployment of the SVCs on all 472 feeders would have required 15,000 such devices, the Company adjusted its expected additional energy savings to reflect the proportion of devices that will be installed on the feeders (4,350). This can be expressed as follows:

$$\text{Additional energy savings rate (per feeder)} * \frac{\text{Number of SVCs installed}}{\text{Number of SVCs needed for hypothetical deployment on 472 feeders}}$$

And, numerically:

$$0.9 \text{ percent} * \frac{4350}{15{,}000}$$

Thus, the additional energy savings rate from the deployment of SVCs was adjusted to 0.26%. This figure represents projected average additional energy savings per feeder on the 472 feeders where IVVO will be deployed.

The Company then added the 1.80% energy savings per feeder from deployment without SVCs to the 0.26% average additional energy savings per feeder to get 2.06% [1.80% + 0.26% = 2.06%]. 2.06% represents the projected average energy savings per feeder on the 472 feeders where IVVO will be deployed. As I stated above, the energy savings percentage will erode over time. Public Service projects that the percentage will be 1.83% in 2022.

**Q. WHAT DOES THE COMPANY PROJECT WILL BE THE ACTUAL AMOUNT OF ENERGY SAVED THROUGH THE IMPLEMENTATION OF IVVO?**

A. The projected energy savings are expected to be approximately 70.9 GWh in 2019—the first year where energy savings will be realized at quantifiable levels. The energy savings are expected to rise steadily each year as IVVO continues to be implemented, with projected energy savings of 164.5 GWh, 254.6 GWh, and 339.9 GWh in 2020, 2021, and 2022, respectively.

**Q. HOW WERE THESE ENERGY SAVINGS LEVELS CALCULATED?**

A. Because IVVO is anticipated to be implemented on approximately 472 feeders, rather than on the entire system, Public Service determined the ratio of customers (as a proxy for consumption) that will experience the benefits from IVVO. As discussed above, Public Service is deploying IVVO on the feeders serving more densely populated areas. Although the IVVO devices will only be deployed on approximately 60% of the Company's feeders, it will provide benefits to approximately 67% of Public Service's customers.

Therefore, Public Service applied the projected energy savings percentage to 67% of the Company's projected retail demand to determine the amount of energy savings in GWh each year. For the years prior to 2022 (the first year in which IVVO will be fully implemented), the Company adjusted the projected GWh saved to reflect the rollout percentage for that year.

**Q. DOES PUBLIC SERVICE ANTICIPATE OTHER ENERGY SAVINGS THAT ARE NOT ON THE CUSTOMER SIDE OF THE METER?**

A. Yes. The voltage optimization anticipated from IVVO is also expected to reduce the amount of distribution losses experienced on the distribution system. The reduction in losses will save approximately 1.8 GWh in 2019, rising to approximately 9.2 GWh in 2022. The energy savings from reduced distribution line losses will account for the remaining savings benefits—those that do not occur on the customer side of the meter.

**Q. IS THE REDUCTION IN ENERGY CONSUMPTION LIKELY TO RESULT IN OTHER SYSTEM BENEFITS?**

A. Yes, Public Service is projecting that IVVO will reduce the system's peak demand by 1.15% in the areas it is deployed. Once fully deployed, the 1.15% will amount to an annual demand reduction of approximately 44.5 MW in 2022. The demand reduction will enable the Company to defer generation investments, as well as transmission and distribution investments.

**Q. IS IT POSSIBLE TO ESTIMATE THE FINANCIAL BENEFITS FROM THE ENERGY AND DEMAND REDUCTION DESCRIBED ABOVE?**

A. Yes. As noted in Attachment CSN-1 to my testimony, the benefits described above are expected to provide operations and maintenance (O&M) benefits, including fuel savings resulting from a reduction in energy consumption and the reduction in energy losses.

Public Service also anticipates financial benefits from the deferral of capital investments. As with any demand-side management program, the financial value of demand reduction is based on deferred MW of generation. The financial benefits of the deferred capital costs from the avoided generation are set forth in Attachment CSN-1.

These inputs were used in the cost-benefit analysis discussed in the Direct Testimony of Company witness Mr. Hancock.

2. Qualitative Benefits from IVVO

**Q. WILL THE ELECTRIC ENERGY SAVINGS DESCRIBED ABOVE RESULT IN QUALITATIVE BENEFITS FOR CUSTOMERS?**

A. Yes. For the customers located on feeders where IVVO is deployed, they will benefit by reducing their usage and demand. IVVO is different from other DSM programs in that the Company makes the investment on the utility side of the meter, while the majority of the benefits that will be derived from IVVO, as a result of optimizing voltage on a year-round basis, will occur on the customer side of the meter—that is, the reduction in customers' energy consumption and demand. Customers will directly benefit from IVVO because the voltage management will enable their end-use devices to consume less energy without having to take any action, change any use or behavior, or make any investment. The reduced demand and energy consumption on a per customer basis can have a lot of variability. As shown in Figures CSN-6 through CSN-9, the reductions are dependent on the voltage, different end-use devices, and how customers use the different end-use devices. These factors can have a great deal of variability on an individual customer basis, making it challenging to quantify the benefits for each individual customer.

Under circumstances that are otherwise the same, Public Service expects that this would also lead to electric bill savings for customers located on feeders where IVVO is deployed. However, customer bill savings were excluded from the cost-benefit analysis because those benefits would not be experienced by all customers - only the subset of customers located on feeders where IVVO is deployed. As explained in the testimony of Company witness Mr. Hancock, only those benefits experienced by all customers were quantified.

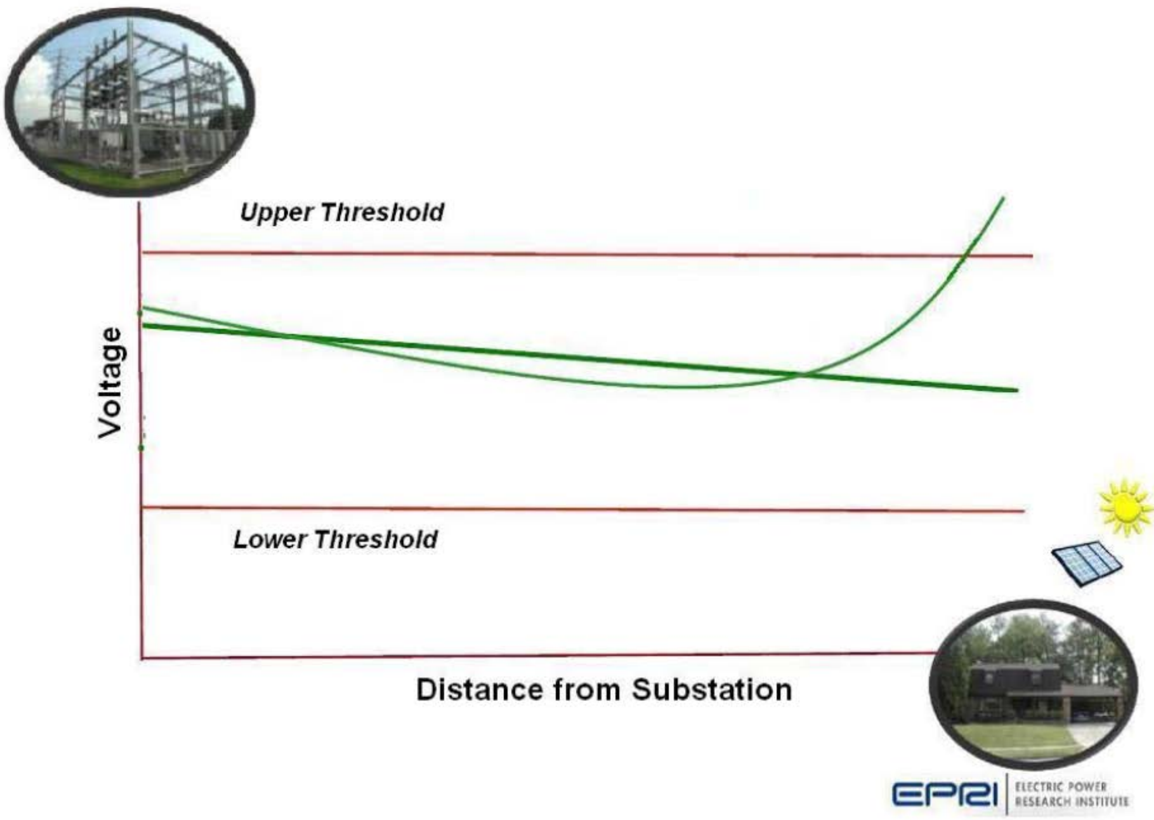
**Q. WILL THE ENERGY SAVINGS FROM IVVO LEAD TO OTHER BENEFITS?**

A. Yes. There will be environmental benefits associated with the increased energy efficiency. Improved energy efficiency can result in reduced demand for electric generation and thus a reduction in carbon emissions caused by certain types of generation. The reduction in carbon emissions, in turn, will provide environmental and societal benefits.

**Q. IS THE VOLTAGE REDUCTION EXPECTED TO INCREASE THE SYSTEM'S CAPACITY TO HOST DISTRIBUTED ENERGY RESOURCES?**

A. Yes. DERs like solar increase the voltage on the edge of the grid as illustrated by the curved line in Figure CSN-10 below. By increasing the voltage at the end of the feeder, solar DERs can impact the system and other customers by causing over-voltage issues because voltages on the feeder may be above the ANSI C84.1 range. By lowering the voltage and reducing any potential over-voltage impacts from solar DERs, IVVO will support the ability of additional solar to be hosted on the system, enabling continued customer flexibility.

**Figure CSN-10**




3. <u>Other Benefits</u>

**Q. WILL THE TECHNOLOGIES DISCUSSED ABOVE CONTRIBUTE TO GRID VISIBILITY AND CONTROL?**

A. Yes, FLISR, FLP, IVVO, and ADMS will make the grid more accessible to operators, providing visibility to areas that previously had none. The devices will communicate information about the grid from the locations where they are installed. In addition, even in areas that previously had communications capabilities, deployment of the FAN will provide a more robust communications network and enhanced visibility of the distribution system to the Company, allowing for greater uptime and lower latency.

**Q. WILL THESE TECHNOLOGIES PROVIDE OTHER OPERATIONAL BENEFITS?**

A. Yes. By improving grid visibility and centralizing automated restoration functions in the ADMS, operators and line crews will be exposed to a standard type of automated device operation across the Company's system, rather than the current siloed approach to automation or the creation of "islands of automation."

**Q. WILL THESE TECHNOLOGIES PROVIDE RELIABILITY BENEFITS?**

A. Yes, as described in more detail earlier in my testimony, greater system reliability will be the main benefit of FLISR and FLP. Automated restoration will cut down customer minutes out ("CMO") for a significant number of customers located on FLISR-enabled feeders. FLP will also reduce CMOs through more effective identification of fault events and improved dispatching of crews for restoration. FLISR and FLP are expected to generate a total value of approximately $323 million through 2035, primarily realized by Public Service's customers through reduction of CMOs.

**Q. CAN YOU DESCRIBE IN MORE DETAIL CMOS AND RELIABILITY BENEFITS?**

A. Yes. Electric power outages and blackouts cost the United States about $80 billion annually, according to a 2006 study by Lawrence Berkeley National Laboratory. The 2015 update to the study provides economic impact data per event based on the customer class (i.e., medium and large Commercial & Industrial ("C&I"), Small C&I, Residential) and the length of the outage.[8]

Based on the 2015 study and the updated economic impacts to customers, Public Service valued the cost per CMO of a mainline outage at approximately $0.91. The Company then calculated anticipated benefits from FLISR using the cost per CMO.[9]

**Q. ARE THERE OTHER BENEFITS THAT WILL BE ENABLED BY ADMS?**

A. Yes. As discussed above, ADMS capabilities will enable several benefits to be realized: reduced SAIDI by reducing outage restoration time once an outage has occurred, improved customer experience by reducing the number of sustained outages experienced by customers, improved power quality, reduced voltage levels and demand, increased hosting capacity and integration of distributed energy resources including micro-grids, reduced risk of human error events, and improved planning by providing efficient access to historical grid power flow data, historical grid topology data, and contingency analysis capabilities utilizing the current operational model representing the distribution grid.

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[8] *Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States*, available at https://emp.lbl.gov/sites/all/files/value-of-service-reliability-final.pdf.pdf. For instance, a one hour outage would have an economic impact of $17,804 on a medium or large C&I customer, $647 on a small C&I customer, and $5.10 on a residential customer.

[9] For instance, the average time to restore a feeder level fault is 68.3 minutes. Such a fault affects all customers on that feeder (1,745 on average), resulting in 119,184 CMOs (68.3 minutes * 1745 customers) or an economic impact of $108,457 (119,184 CMOs * $0.91). FLISR will automatically restore service to two-thirds of the customers on a feeder (or 1,163 customers on average) within minutes of the fault, reducing the CMOs to 39,728 or an economic benefit of $72,305.

**C. Costs**

**Q. WHAT WILL BE THE PRINCIPAL COSTS ASSOCIATED WITH THE INSTALLATION AND DEPLOYMENT OF THE IVVO TECHNOLOGY?**

A. As noted in Attachment CSN-2, the principal costs of implementing IVVO will be related to the advanced application's assets and communications—specifically, the overhead and underground assets (materials) and their installation (labor). As described above in Section II.B, many of the devices involved in the IVVO deployment are not new to the Company. As such, the Company was able to use historical costs to develop the cost estimates to implement the IVVO solution proposed here. With respect to the new SVC devices, Public Service has already engaged in a limited pilot installation of these devices on feeders at the Englewood substation, as discussed above; therefore, the Company was able to use historical costs for these devices as well. For installation, the Company will use primarily contract labor. The projected labor and installation costs were developed using contractor wage scales. These inputs were used in the cost-benefit analysis discussed in the Direct Testimony of Company witness Mr. Hancock.

**Q. IS PUBLIC SERVICE ASSIGNING A CONTINGENCY AMOUNT FOR THE IVVO TECHNOLOGY ASSETS?**

A. Yes. As noted in Attachment CSN-2, Public Service has developed contingency amounts for the IVVO advanced application assets. Because the cost projections for devices and installation were developed based on historical costs, the contingency amounts for those assets are relatively small. The Company has accurate cost information with respect to field devices, particularly those that are already on the system, and utilized a 10% contingency. However, for elements such as substation design, a 30% contingency level is assigned due to the greater degree of uncertainty related to the unique nature of a facility. Similarly, Public Service assigned a 30% contingency for other costs, including systems integration and vendor management, because the cost estimates were not based on historical information.

Among the factors that the Company considered in the development of the contingency were the costs associated with integration efforts, as the Company has not undertaken a project like IVVO on the scale it proposes to here, and the integration of IVVO with ADMS will be a new undertaking for the Company. In addition, costs will vary based on differences in geographical locations and land conditions, such as the costs for permitting, easement acquisition, and installation of poles and structures. These inputs were used in the cost-benefit analysis discussed in the Direct Testimony of Company witness Mr. Hancock.

**Q. ARE THERE O&M COSTS ASSOCIATED WITH THE IVVO ASSETS?**

A. Yes, as noted in Attachment CSN-2, O&M costs will include costs related to capital support, asset and device support, and device replacement. The Company developed the costs based on its experience with prior installations and the anticipated level of support needed to provide on-going asset support, device replacement costs for minor components like supply batteries, and on-going support to troubleshoot any communication and device operational issues.

These inputs were used in the cost-benefit analysis discussed in the Direct Testimony of Company witness Mr. Hancock.

**Q. IS PUBLIC SERVICE ASSIGNING A CONTINGENCY AMOUNT FOR THESE O&M COSTS ASSOCIATED WITH THE IVVO ASSETS?**

A. Yes. As noted in Attachment CSN-2, Public Service has developed a contingency amount for the IVVO assets O&M costs. Similar to the contingency amount for capital expenditures, the O&M contingency captures costs that will vary based on differences in geographical locations and land conditions, such as the costs for permitting, easement acquisition, and installation of poles and structures. These inputs were used in the cost-benefit analysis discussed in the Direct Testimony of Company witness Mr. Hancock.

**Q. WILL THERE BE OTHER CAPITAL COSTS ASSOCIATED WITH THE IVVO TECHNOLOGY?**

A. Yes, as noted in Attachment CSN-2, there are operations and personnel costs associated with the overhead and underground assets and the ADMS-IVVO integration. Public Service will use Company personnel to perform commissioning work to ensure that the IVVO devices will be able to communicate with the FAN. There will also be communications operations costs and costs for external resources. These external resources will work primarily on the engineering work involved at the Company's substations, including the replacement of local device controllers so that they will be able to communicate with ADMS. There may also be further labor costs for ancillary support related to commissioning or communications. The Company developed its cost projections for internal resources using historical wage and labor costs, and for external resources using contractor wage scales. These inputs were used in the cost-benefit analysis discussed in the Direct Testimony of Company witness Mr. Hancock.

**Q. IS PUBLIC SERVICE ASSIGNING A CONTINGENCY AMOUNT FOR THESE CAPITAL COSTS?**

A. Yes. As noted in Attachment CSN-2, Public Service has developed a contingency amount for the ADMS-IVVO integration costs as well as for personnel and labor costs. The Company developed the 30% contingency level based on the anticipated labor that may be required for the integration. In light of the fact that the Company has not previously undertaken a project like the one proposed, a 30% contingency is reasonable given the Company does not have historical integration costs. These inputs were used in the cost-benefit analysis discussed in the Direct Testimony of Company witness Mr. Hancock.

**Q. WILL THERE BE OTHER O&M COST ITEMS ASSOCIATED WITH IVVO?**

A. As noted in Attachment CSN-2, O&M costs will also include costs related to network communications, vendor costs, and training. Similar to the development of other cost projections, the Company relied on historical cost information to develop its cost estimates for O&M costs related to communications, vendor costs, and training. The Company also has information available based on historical device maintenance and installation. These inputs were used in the cost-benefit analysis discussed in the Direct Testimony of Company witness Mr. Hancock.

## V. ALTERNATIVES CONSIDERED

**Q. DID PUBLIC SERVICE CONSIDER ALTERNATIVES TO IVVO AS PROPOSED IN THIS PROCEEDING?**

A. Yes. The primary alternative to implementing IVVO was to maintain the status quo and do nothing. Another option would have been to pursue demand-side management ("DSM") programs instead of IVVO. In addition, the Company could have chosen to implement IVVO without the AMI. Finally, Public Service could implement IVVO without the SVC devices.

**Q. WHAT WOULD BE THE CONSEQUENCE OF NOT IMPLEMENTING IVVO?**

A. By maintaining the status quo and not implementing IVVO at this time, the Company would be foregoing the substantial energy savings that this grid-side efficiency measure will provide. Not offering IVVO would also result in the Company's need to augment energy supply infrastructure sooner to meet growing demand.

**Q. PLEASE EXPLAIN WHY THE COMPANY IS PURSUING IVVO OVER THE ALTERNATIVE OF INCREASING DSM PROGRAMS.**

A. IVVO is a more effective and efficient way to lower voltage on the electric grid because the application affects the entire system and benefits all customers, as opposed to relying on a subset of customers who voluntarily act to lower voltage at peak periods. It can be likened to a "wholesale level" of DSM. As described above in more detail, by having the ability to monitor voltage across the entire grid, Public Service can lower voltage on feeders across its system, which will have a savings and benefit impact for all end-use customers.

**Q. PLEASE EXPLAIN WHY THE COMPANY IS NOT IMPLEMENTING IVVO WITHOUT THE AMI.**

A. IVVO benefits from the implementation of AMI because the voltage sensing function provided by AMI meters will provide much more granular and actionable voltage data that will make IVVO more effective. Even more importantly, and as explained in the Direct Testimony of Mr. Borchardt, Public Service determined that it would implement AMI because of the benefits that technology will directly provide the Company and its customers.

**Q. PLEASE EXPLAIN WHY THE COMPANY HAS CHOSEN TO IMPLEMENT IVVO WITH THE SVCS.**

A. While IVVO could be implemented without any SVC devices, the SVCs will enable greater voltage reduction where deployed, thereby resulting in greater energy savings. In addition, the SVCs involved in the Company's proposed IVVO solution will increase the system's capacity to host renewables on the distribution system. SVCs will provide fast, variable voltage support that will help stabilize and regulate the voltage at the edge of the grid, near customers and DERs. Solar resources, in particular, are variable, intermittent, and non-coincident with peak demand, requiring more localized voltage support that is faster-acting than traditional utility devices. SVCs, as part of the IVVO solution, will help provide fast, variable voltage support limiting the impacts from solar and increasing the hosting capacity. This will enable the Public Service to continue to offer flexible options to our customers, which we believe our customers want.

However, as explained above, Public Service is industry-leading in the use of these intelligent devices. Therefore, the Company is prudently pursuing a limited deployment of the SVCs given this early stage in the devices' commercial use. By installing these devices along feeders that most need additional voltage support, the Company intends to efficiently deploy this beneficial technology.

**Q. DOES THIS CONCLUDE YOUR TESTIMONY?**

A. Yes, it does.

## Statement of Qualifications

### Chad S. Nickell

I am the Manager of Distribution System Planning and Strategy South for Xcel Energy. My role is to provide strategic direction for building a five-year distribution plan for ensuring a reliable and cost effective electric distribution system. My key responsibilities include developing and leading a system advancements and renewal strategy and managing the current year and five-year distribution capital budget for Public Service and Southwestern Public Service Company, one of the other Xcel Energy Operating Companies.

I have over six years of experience in the utility industry; and joined Public Service Company of Colorado in 2008 as a Distribution System Planning Engineer. I graduated from the University of Colorado, Boulder in May 2004 where I earned a Bachelor of Science degree in Electrical Engineering.