PUBLIC UTILITIES COMMISSION
505 VAN NESS AVENUE
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December 9, 2014

Advice Letter 4528-E

Meredith Allen
Senior Director, Regulatory Relations
Pacific Gas and Electric Company
77 Beale Street, Mail Code B10C
P.O. Box 770000
San Francisco, California 94177

SUBJECT: Smart Grid Voltage and Reactive Power Optimization Pilot Project - Phase 1 Status Report, Pursuant to D.13-03-032

Dear Ms. Allen:

Advice Letter 4528-E is effective as of December 1, 2014.

Sincerely,

Edward Randolph

Edward Randolph
Director, Energy Division

Pacific Gas and Electric Company®

Meredith Allen
Senior Director
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October 31, 2014

Advice 4528-E
(Pacific Gas and Electric Company ID U 39 E)

Public Utilities Commission of the State of California

Subject: Smart Grid Voltage and Reactive Power Optimization Pilot Project - Phase 1 Status Report, Pursuant to Decision 13-03-032

Purpose

The purpose of this advice letter is to comply with Ordering Paragraph (OP) 9 of Decision (D.) 13-03-032, *Decision Granting, in Part, and Denying, in Part, Pacific Gas and Electric Company's Application for Smart Grid Pilot Deployment Project*, which directs Pacific Gas and Electric Company (PG&E) to submit a status report via a Tier 2 Advice Letter within 14 days of the completion of each phase of each approved Smart Grid pilot. The Smart Grid Voltage and Reactive Optimization Pilot Project (VVO Pilot) has completed the key objectives of Phase I as described in Advice Letter 4227-E.[1] Therefore, PG&E submits this status report for review and approval to commence Phase 2 of the VVO Pilot.

Background

On November 21, 2011, PG&E filed Application (A.) 11-11-017 requesting authorization to recover costs for implementing six Smart Grid Deployment Pilot Projects over four years. The Smart Grid Deployment Pilot Projects seek to advance the modernization of PG&E's electric grid consistent with California's energy policies as described in Senate Bill (SB) 17 and PG&E's Smart Grid Deployment Plan which was filed on June 30, 2011, and approved on July 25, 2013.

On March 27, 2013, in D.13-03-032, the California Public Utilities Commission (Commission or CPUC) approved four of the Smart Grid Pilot projects proposed by PG&E in its November 2011 application: (1) the Smart Grid Line Sensor Pilot Project, (2) the Smart Grid Voltage and Reactive Power Optimization Pilot Project,

[1] PG&E's Advice Letter 4227-E, *Smart Grid Pilot Deployment Projects Implementation Plan, Pursuant to D.13-03-032*, submitted for filing on May 22, 2013, and approved effective June 21, 2013, by the CPUC's Energy Division.

(3) the Smart Grid Detect and Locate Distribution Line Outages and Faulted Circuit Conditions Pilot Project, and (4) the Smart Grid Short Term Demand Forecast Pilot Project. OP 9 of D.13-03-032 states:

> "Within 14 days of the completion of each phase of each approved pilot, PG&E shall submit a status report via a Tier 2 Advice Letter to Commission staff. Each status report must include a) details of the activities occurring in the phase; b) a detailed breakdown of the costs of those activities; c) the results of the phase including evaluation and measurements of pre-selected metrics to portray the success or failure of the pilot phase; and d) a recommendation and rationalization of whether the pilot should advance to its next phase. PG&E should ensure that status reports are detailed, both quantitatively and qualitatively. Funding for subsequent phases, although approved in this decision, may not be spent by PG&E until the Advice Letter for the current phase is submitted and approved."

Discussion

PG&E has achieved its key VVO Pilot Phase 1 goals and objectives, as described below and in Attachment 1, and is ready to proceed to Phase 2. Specifically, PG&E has completed testing of the specific Volt/Var optimization system and has demonstrated that the VVO pilot is ready for a field trial on up to 12 feeders on PG&E's electric distribution system. PG&E submits this Advice Letter upon completion of the key Phase 1 objectives in order to allow for timely CPUC evaluation of the Phase 1 work and transition of work to Phase 2 to meet seasonal operational clearance windows and capture VVO benefits results for the summer of 2015. The summer 2015 benefits results are a key element of the analysis PG&E will perform to prepare a post-pilot VVO deployment recommendation. PG&E will commence Phase 2 activities upon CPUC approval of this advice letter.

Overview of the Smart Grid Voltage and Reactive Optimization Pilot Project

Through its VVO Pilot project, PG&E will determine how it can optimize the operating voltage and reactive power on its distribution system, which will result in reduced customer energy usage and reduced utility system losses for the benefit of its customers. Specifically, this project seeks to (1) enhance grid system monitoring and control, (2) manage grid system voltage and losses, and (3) support increased penetration of distributed renewable resources.

VVO offers three potential direct benefits:

> Reduced Energy Use – Operation of distribution circuits at the lower end of the acceptable voltage range is expected to reduce customer energy use and correspondingly reduce power/energy procurement costs. The benefits

of the reduction in energy use would accrue directly to customers, thereby improving overall cost effectiveness.

Reduced Peak Demand – Similar to the reduction in energy use, there is potential for a reduction in peak demand due to the deployment of VVO. Reduction in peak demand would reduce capacity procurement costs and, as with the reduced energy use, the benefits would accrue directly to customers.

Reduced System Losses – The reduction in energy use and peak demand would incrementally reduce losses directly improving the efficiency of PG&E's distribution system.

PG&E is assessing VVO capabilities in each of the above areas as part of the pilot evaluation of commercially available systems and components. The pilot evaluations will be used to establish feeder characteristics that support benefit realization and project benefits associated with a large scale deployment of VVO.

VVO Pilot Phase 1 – Analysis and Laboratory Test Results

The analysis and laboratory test phase involved: (1) assessing commercially available Volt/VAR Optimization system products, reviewing the manufacturer's specifications and capabilities relative to PG&E's performance requirements and integrating with existing systems as well as evaluating vendor performance and viability; (2) benchmarking with other utilities to assess industry experience with the technology provided by various vendors to assess operating performance and benefits and new innovations developed through actual field usage; and (3) testing a small subset of Volt/VAR Optimization systems that have a high probability of successful integration into PG&E's system, providing accurate and necessary results and being used by operators and engineers to change system operations practices to achieve the targeted benefits.

As described in further detail in Attachment 1, PG&E has successfully completed the key objectives of Phase 1 and recommends moving to Phase 2. It is important that PG&E begin the Phase 2 activities on December 1, 2014, to meet seasonal substation operational clearance windows and ensure a timely ability to order, deploy, and install all equipment and systems necessary to capture VVO results for the summer of 2015. Commencing Phase 2 activities after December 1, 2014, will impact the critical path of this pilot project, increasing the risk of missing these key schedule milestones. PG&E will continue with supplemental vendor testing, including piloting a second Volt/Var optimization system vendor product. PG&E believes all authorized activities under Phase I will be completed in December 2014.

VVO Pilot Phase 2 – Field Trial

In Phase 2, PG&E will install and performance test the Volt/VAR Optimization system or systems identified in Phase 1 on up to 12 of PG&E's actual distribution circuits and use SmartMeter voltage data to enhance VVO performance. Phase 2 will provide actual measured field benefit information to be used in determining the cost-effectiveness of a wider scale deployment of a Volt/Var Optimization system. PG&E plans to apply Phase 1 budget underruns to Phase 2, allowing PG&E to invest in improvements to VVO solutions and distribution system infrastructure that have promise of enhancing the value of VVO. In addition, this can increase knowledge of efficiently deploying and operating VVO.

Protests

Anyone wishing to protest this filing may do so by letter sent via U.S. mail, facsimile or E-mail, no later than November 20, 2014, which is 20 days after the date of this filing. Protests must be submitted to:

CPUC Energy Division
ED Tariff Unit
505 Van Ness Avenue, 4th Floor
San Francisco, California 94102

Facsimile: (415) 703-2200
E-mail: EDTariffUnit@cpuc.ca.gov

Copies of protests also should be mailed to the attention of the Director, Energy Division, Room 4004, at the address shown above.

The protest shall also be sent to PG&E either via E-mail or U.S. mail (and by facsimile, if possible) at the address shown below on the same date it is mailed or delivered to the Commission:

Meredith Allen
Senior Director, Regulatory Relations
Pacific Gas and Electric Company
77 Beale Street, Mail Code B10C
P.O. Box 770000
San Francisco, California 94177

Facsimile: (415) 973-7226
E-mail: PGETariffs@pge.com

Any person (including individuals, groups, or organizations) may protest or respond to an advice letter (General Order 96-B, Section 7.4). The protest shall contain the following information: specification of the advice letter protested; grounds for the protest; supporting factual information or legal argument; name, telephone number, postal address, and (where appropriate) e-mail address of the protestant; and statement that the protest was sent to the utility no later than the day on which the protest was submitted to the reviewing Industry Division (General Order 96-B, Section 3.11).

Effective Date

PG&E requests that this Tier 2 advice filing become effective on regular notice, **November 30, 2014**, which is 30 calendar days after the date of filing.

Notice

In accordance with General Order 96-B, Section IV, a copy of this advice letter is being sent electronically and via U.S. mail to parties shown on the attached list and the service list for A.11-11-017. Address changes to the General Order 96-B service list should be directed to PG&E at email address PGETariffs@pge.com. For changes to any other service list, please contact the Commission's Process Office at (415) 703-2021 or at Process_Office@cpuc.ca.gov. Send all electronic approvals to PGETariffs@pge.com. Advice letter filings can also be accessed electronically at: http://www.pge.com/tariffs.

/S/

Meredith Allen
Senior Director, Regulatory Relations

Attachments

cc: Service List A.11-11-017

CALIFORNIA PUBLIC UTILITIES COMMISSION

ADVICE LETTER FILING SUMMARY
ENERGY UTILITY

MUST BE COMPLETED BY UTILITY (Attach additional pages as needed)

Company name/CPUC Utility No. **Pacific Gas and Electric Company (ID U39 E)**

Utility type:	Contact Person: **Shirley Wong**
☑ ELC ☐ GAS	Phone #: **(415) 972-5505**
☐ PLC ☐ HEAT ☐ WATER	E-mail: **slwb@pge.com and PGETariffs@pge.com**

EXPLANATION OF UTILITY TYPE

ELC = Electric GAS = Gas ☐
PLC = Pipeline HEAT = Heat WATER = Water

(Date Filed/ Received Stamp by CPUC)

Advice Letter (AL) #: **4528-E** **Tier: 2**

Subject of AL: **Smart Grid Voltage and Reactive Power Optimization Pilot Project - Phase 1 Status Report, Pursuant to Decision 13-03-032**

Keywords (choose from CPUC listing): **Compliance**

AL filing type: ☐ Monthly ☐ Quarterly ☐ Annual ☑ One-Time ☐ Other _____

If AL filed in compliance with a Commission order, indicate relevant Decision/Resolution #: **Decision 13-03-032**

Does AL replace a withdrawn or rejected AL? If so, identify the prior AL: No

Summarize differences between the AL and the prior withdrawn or rejected AL:

Is AL requesting confidential treatment? If so, what information is the utility seeking confidential treatment for: No

Confidential information will be made available to those who have executed a nondisclosure agreement: N/A

Name(s) and contact information of the person(s) who will provide the nondisclosure agreement and access to the confidential information: _____

Resolution Required? ☐ Yes ☑No

Requested effective date: **November 30, 2014** No. of tariff sheets: N/A

Estimated system annual revenue effect (%): N/A

Estimated system average rate effect (%): N/A

When rates are affected by AL, include attachment in AL showing average rate effects on customer classes (residential, small commercial, large C/I, agricultural, lighting).

Tariff schedules affected: N/A

Service affected and changes proposed: N/A

Protests, dispositions, and all other correspondence regarding this AL are due no later than 20 days after the date of this filing, unless otherwise authorized by the Commission, and shall be sent to:

CPUC, Energy Division
ED Tariff Unit
505 Van Ness Ave., 4th Floor
San Francisco, CA 94102
E-mail: EDTariffUnit@cpuc.ca.gov

Pacific Gas and Electric Company
Attn: Meredith Allen, Senior Director, Regulatory Relations
77 Beale Street, Mail Code B10C
P.O. Box 770000
San Francisco, CA 94177
E-mail: PGETariffs@pge.com

ATTACHMENT 1

Pacific Gas and Electric Company

Smart Grid Voltage and Reactive Power (Volt/Var) Optimization Pilot Project Completion of Phase 1 Key Objectives Report

Advice 4528-E

October 31, 2014

Attachment 1

Pacific Gas and Electric Company

Smart Grid Voltage and Reactive Power (Volt/Var) Optimization Pilot Project
Completion of Phase 1 Key Objectives Report
October 31, 2014

This status report summarizes the completion of Phase 1 Key Objectives of the Smart Grid Voltage and Reactive Power (Volt/Var) Optimization (VVO) Pilot Project. The details presented in this Report that indicate a viable Volt/Var Optimization system has been identified with the tested capability to reduce customer energy usage and utility system losses by managing the distribution voltage and devices from the substation to the customer's service point.

Therefore, PG&E recommends and requests timely approval to proceed with the Phase 2 Field Demonstration as described in AL 4227-E.

Table of Contents:

1. Goals and Objectives

The goal of the VVO Pilot Project is to evaluate the ability of a Volt/Var system to reduce customer energy use and reduce utility system losses by managing the distribution voltage and devices from the substation to the customer service point. PG&E was authorized to perform tasks in Phase 1 to meet these specific objectives and goals[1]:

[1] AL 4227-E, Page 17.

- PG&E will assess the Volt/VAR optimization systems available in the industry in production and/or being used by other utilities to identify solutions that will meet PG&E's needs
- PG&E will analyze and identify the technology requirements necessary to support Volt/VAR optimization system implementation
- In a laboratory environment, test the selected Volt/VAR optimization systems and devices and identify the specific solution and supporting technologies to use for the field pilot. The laboratory testing will include a benefits assessment that will be used to support a recommendation to proceed to Phase 2 (the field trial stage of the pilot project)

PG&E has fulfilled the goals and objectives of Phase 1. Based on findings obtained in Phase 1, PG&E requests approval to proceed to Phase 2 in which PG&E will deploy automated field equipment and perform field trials of the Volt/VAR optimization system(s) on up to 12 distribution feeders in a limited number of PG&E's divisions. The Phase 2 field trial will pilot VVO on live feeders to evaluate VVO's ability to:

1. Enhance grid system monitoring and control
2. Manage grid system voltage and losses
3. Support increased penetration of distributed energy resources

2. Benchmarking with Other Utilities

PG&E conducted benchmarking interviews with American Electric Power, Arizona Public Service, National Grid, Oklahoma Gas & Electric, Kauai Island Utility Cooperative, and Central Lincoln Public Utility District to understand these utilities drivers for implementing VVO technology, and their vendor selection processes and outcomes.

The benchmarking sessions identified several key learnings from peer utilities:

- Perform end-to-end testing prior to a field pilot to work out any issues with integrating complex IT systems
- Engage the key internal subject matter experts up-front to be part of the solution design
- Enable tie in to smart meter voltage data capture
- Conditioning circuits may enhance VVO benefits
- End user change management is key to ensure VVO remains in operation during peak periods to drive benefits
- VVO implementations at different utilities have various system architectures (e.g., existing SCADA platforms may, or may not be used to communicate with and control line devices)
- SmartMeter™ voltage data is useful for evaluation of VVO performance and for optimization of VVO value

Industry statistics were also used to inform project benefits:

- Utilities have reported VVO has reduced energy consumption between 1.5 – 3%

- Typical Conservation Voltage Reduction Factor (CVRf), which is used to convert the voltage reduction into energy consumption reduction, ranges from 0.6 – 0.9.

3. Prospective Vendors: Evaluation and Selection

PG&E pursued a two-stage vendor evaluation process. The process included: 1) an initial Request for Information (RFI) to clearly understand commercially available VVO products and 2) a detailed investigation of vendors shortlisted based on the RFI. The two phases of the evaluation are described in greater detail in the subsections below.

Request for Information (RFI)

PG&E issued an RFI in November 2013 to evaluate the capabilities of available VVO products. PG&E engaged industry experts to ensure the RFI would provide information relevant for the selection of candidate vendors. The RFI focused on the following attributes of the vendor technologies:

- VVO Approach
- Abnormal Condition Impact on VVO performance
- Reporting, Analytics, and EM&V Capabilities
- System Maintenance and Support Requirements
- Application Architecture
- Network and Communications
- Security
- System Integration
- Existing Installations / Customers

Eleven VVO vendor responses to the RFI were evaluated by project stakeholders representing the PG&E Electric Operations and IT organizations. The vendor evaluation was aligned with the PG&E's sourcing policies and included consideration of supplier diversity, safety, and environmental responsibility, in addition to the technical evaluation.

Five vendor offerings were selected for additional investigation in the detailed investigation stage of the evaluation process (discussed further below).

Detailed Investigation

PG&E performed a detailed investigation of the five vendors selected at the conclusion of the RFI stage of the evaluation. This detailed investigation included:

- Vendor Demonstration of VVO Offerings
- Discussions with Utility Customers Using Vendor Solutions
- Assessment of Ability to Leverage Existing and Planned PG&E Infrastructure

- Qualitative Assessment of Potential Customer Benefits
- Review of Capability to Manage Grid Complexity
- Capability to Provide a SCADA Enhancement Path and Integration of DMS/EMS
- Preliminary Total Ownership Cost Evaluation

Two of the five vendors were selected for testing at PG&E's Applied Technology Services (ATS) laboratory in San Ramon: Dominion Voltage Inc. (DVI) and Utilidata.

4. Laboratory Test Environment

PG&E configured and enhanced the existing Distribution Test Yard (DTY) at the ATS facility to support testing of the selected vendor VVO solutions Specifically, PG&E made the following necessary changes in the DTY including:

1) Load Tap Changer (LTC) Controller Configuration: A new LTC controller configuration was developed to allow remote VVO control of the LTC controls.
2) Line Regulator Control Integration: Line regulator controls have not traditionally been SCADA connected. Integration of line regulators is necessary to facilitate VVO control and PG&E developed controller settings and corresponding SCADA entries to facilitate such remote control.

Further, PG&E developed the integration between the PG&E SCADA system and the vendor VVO applications to enable VVO control of field devices via SCADA.

PG&E also developed an IT integration and test harness architecture. The test harness was designed to dynamically simulate feeder performance, providing realistic feedback to the VVO applications under test. The test harness utilizes a CYME[2] power flow simulation using a model of one or more actual feeders planned for the field pilot. LabView[3] software and National Instruments hardware is used to "translate" the results of the CYME simulation for controller use and acquire controller state to support updated CYME simulation-based controller actions. The VVO application being tested is then able to "see" the controllers with readings reflective of the simulated circuit and determine the optimal capacitor states and LTC/regulator tap positions or settings. Finally, as the VVO application under test drives changes in capacitor, LTC, and

[2] CYME is the power systems modeling software used by PG&E distribution engineers to simulate how the distribution system behaves under different loading conditions.
[3] LabView is a graphical programming platform that is used to acquire data from test harness devices (e.g., device controllers, SmartMeters™), automate test protocol, and control test harness devices.

regulator states, an updated CYME simulation will provide revised readings to the controllers to reflect the new operating state of the system.

PG&E also developed a SmartMeter™ test architecture, unique to laboratory testing of DVI, given the more complex nature of the DVI platform. PG&E configured actual and simulated SmartMeters™, creating a system to evaluate how DVI's VVO application responds to SmartMeter™ voltage inputs.

The test profile and equipment, staff, and systems necessary dictated that only **one** VVO application could be tested at a time. Therefore, PG&E arranged the test schedule to start with Utilidata followed by the more complex DVI.

5. Laboratory Testing

Following vendor selection and enhancement to the DTY, PG&E commenced Laboratory Testing at the ATS facility in San Ramon. Laboratory testing focused on safety, operation, and systems integration efforts that would be required to implement a field deployment. Testing also provided the necessary design, field installation and operating instructions and training for the project to move from the laboratory environment to the field trial (Phase 2).

Table 1 below outlines the high level business requirements and corresponding product requirements tested within the laboratory.

Table 1: Business and Product Requirements

Business Requirement	Product Requirements
Operate Safely	• System must demonstrate an ability to operate safely for PG&E customers and work crews in any / all operating conditions
Monitor Applicable Devices	• Monitor applicable substation and distribution field devices via Supervisory Control and Data Acquisition (SCADA) • Recognize and properly account for different types of SCADA voltage measurements • Monitor applicable Advanced Metering Infrastructure (AMI) data
SCADA Control of VVO Devices	• Control substation and distribution field devices via SCADA

Integrate with Existing PG&E Systems	• Production user interface (UI) integrated into SCADA for monitoring and control • Use as-operated connectivity model in production system • Integrate with SCADA platform • VVO field devices must communicate remotely via SCADA • Integrate with PG&E's AMI to leverage data from SmartMeters™
Allow Distribution Operator / Operating Engineer Control for Configuration and Override	• Control to engage/disengage system • Support direct modification of circuit conditions • Support changes to operating mode • Allow to modify threshold settings for logic • Accessibility for Distribution Operators and Operating Engineers
Minimize Maintenance Effort to Sustain System	• Avoid unreasonable increase in total number of operations for regulating equipment • Accurately monitor health and status • Meet reliability, availability & IT security requirements • Scalable and upgradable
Provide Reporting and Playback Capabilities	• Provide playback capabilities • Standard reporting should be available for compliance • Accumulate calculated VVO savings (for M&V)
Maintain Acceptable Voltage Under All Reasonable Loading Conditions	• Maintain voltage within Rule 2 for normal and abnormal operating conditions[4] • Take action when voltages outside of Rule 2
Maintain Acceptable Power Factor (PF) Under All Reasonable Loading Conditions	• Maintain power factor (PF) within defined parameters • Take action when PF outside defined parameters
Automatically Configure Volt/Var Devices for Different Operating Modes	• Solution must be able to perform Conservation Voltage Reduction (CVR) • Solution should be able to reduce line losses
Adapt to Changing Field Conditions	• Adapt to changing circuit configurations • Adapt to changing circuit devices • Automatically work around local/manual devices • Manage communication losses to devices • Manage VVO device malfunctions
Data Error Handling	• Successfully operate in presence of errors in retrieved/measured data and model errors
Benefit Data to Support M&V	• Facilitate benefit forecasts

[4] Rule 2 is a CPUC / PG&E description of service that provides voltage requirements that include available voltages, minimum and maximum voltages, utility and customer requirements, etc.

	• Identify actions for improved benefits

A set of test cases were developed based on the business requirements and operating needs of PG&E to evaluate the functionality of the VVO vendor solutions under both normal and abnormal conditions.

PG&E developed nearly 50 test cases of varying priority. The test cases included slight vendor specific variations to account for different hardware requirements such as line voltage monitors (Utilidata) and SmartMeters™ (DVI). The tests were developed through collaboration with PG&E's stakeholders and fall into the following categories:

- Normal Operating Conditions
- Outside Voltage and Power Factor Compliance
- Field Switching
- Outages
- Loss of Communication
- Changes in Field Equipment
- Significant Load Changes / DG Impacts
- Devices Not Operating Per VVO Commands
- Data Inaccuracy
- Complex Circuits
- Emergency Modes

Test cases were given the following priorities:

- Priority 1 (critical priority): Tests that must be completed to verify that VVO will not adversely impact the safety or reliability of PG&E's distribution system. All Priority 1 tests must be completed for a vendor to be considered for Phase 2.
- Priority 2-4 (high, moderate, and low priority): Tests that evaluate the ease/challenge of human interactions with VVO and explore the sophistication of the VVO algorithms. These tests enhance understanding of the personnel and operational effort to manage VVO in an operational environment. Additionally, these tests evaluate the capacity of the solution to handle complex situations.

Successful completion of each test case includes specific, minimum requirements as well as a more qualitative analysis of certain characteristics.

6. Analysis and Laboratory Test Results

The analysis and laboratory testing successfully assessed the current state of VVO vendor offerings, tested new systems integrations at PG&E, and verified vendor claims and abilities.

Performance Data Collected:

PG&E collected detailed testing data associated with each of the test cases conducted. Data collected includes:

- Data generated by CYME has been captured for each test.
- Vendor VVO Operation Logs
  - Measurements received from field controllers via SCADA
  - Controls issued to field controllers via SCADA
  - Communication integrity (from VVO to SCADA)
- SCADA Operation Logs
  - Measurements received from field controllers
  - Controls issued to field controllers
  - Communication integrity (from SCADA to field controllers)

Technical Barriers Overcome:

PG&E has overcome a variety of technical challenges during the pilot testing that facilitate the field deployment. Several key technical barriers for which solutions were developed are outlined below.

Communication Protocols

The SCADA foundation required to implement VVO required a substantial shift in the control of voltage regulating equipment at PG&E. In order to successfully implement VVO, PG&E changed the communication protocol used to talk with devices via SCADA from the PG&E (2179) protocol to the more widely used DNP3. PG&E worked with its SCADA vendor to upgrade the system presently used on PG&E's electric distribution system to accommodate the needs of VVO vendor solutions.

Control Design Standards

Significant changes to PG&E's current standards for substation LTCs and line regulators were required to implement VVO. Substation LTCs and voltage line regulators have not traditionally been controlled via SCADA at PG&E. The new SCADA configuration developed in the DTY will be the foundation for the substation LTC controller

modifications required for VVO. Modifications piloted in the DTY will be the foundation for the future rollout of SCADA-connected line regulators.

Testing/Simulation Capabilities

The capabilities of the DTY were significantly expanded to provide enhanced monitoring and control functionality for this project as well as the evaluation of product updates from the VVO and equipment vendors.[5] Specifically, this was enabled by the use of innovative simulation techniques (through a combination of Python[6] programming through a CYME and LabView interface) to model actual PG&E feeders using actual equipment controllers. The techniques developed for this project can be expanded to future Smart Grid projects.

Integration

The integration of the VVO software into the company's testing environment provided an important test bed to resolve integration issues involving not only PG&E's internal systems, but also the VVO response to various manufacturers and types of utility line hardware and revenue meters that the VVO vendors had not previously worked with.

Technical Milestones Met:

Vendor-independent:

- SmartMeter™ voltage data collected from the meters on feeders targeted for the Phase 2 Field Trial

Utilidata:

- Utilidata AdaptiVolt v1.0 VVO application installed, configured, and integrated into the PG&E VVO test harness
- Utilidata AdaptiVolt v1.0 VVO successfully completed all Priority 1 testing, and the solution was deemed ready for Phase 2 Field Trial

DVI:

[5] Evaluating updated DVI and Utilidata VVO software and line device controller enhancements in the DTY is an example of how PG&E plans to invest underspent funds from Phase 1 to Phase 2 activities, which is discussed in detail in Section 13 of this Attachment.
[6] Python is a widely used general-purpose programming language that is being used in VVO testing to automate CYME load flow simulations

- DVI's EDGE Manager v1.4 VVO application installed, and DVI EDGE adaptor integrated with PG&E AMI test harness, which includes CYME modeling data, a test AMI head end system, and over 7,000 real and simulated meters.
- DVI testing in progress and expected to be completed in December 2014. In the event DVI does not pass the required Priority 1 test cases, Utilidata will be the lone VVO vendor that PG&E will deploy to the field during Phase 2.

Significant Knowledge Gained:

PG&E has developed significant knowledge surrounding the VVO vendor products and the integration required to achieve successful VVO operation. Major areas of knowledge improvement include:

Confirmation of Value of Laboratory Testing

Phase 1 has confirmed the value of laboratory testing as envisioned and approved in the Application and Advice Letter 4227-E. The lab testing yielded insights on resolving control compatibility and integration issues, which are expected to facilitate the field implementation. The test harness created at DTY allowed vendors and PG&E to uncover issues that may have gone unnoticed until operational issues were encountered.

VVO Product Maturity

The VVO vendors selected have VVO implementations running at other U.S. utilities. PG&E believes that these two vendors are among the most mature of those determined suitable for implementation at PG&E. However, laboratory testing has shown that VVO is still a relatively new product that often requires semi-customized installation and integration. Both vendors can still improve their products to drive additional benefits.

Field Controller Configuration

Phase 1 provided PG&E the opportunity to identify specific field controller configurations and protocols required to support the selected vendor VVO applications. In particular, the standard PG&E LTC controller implementation will require modification to support remote VVO control of the tap position. A successful configuration has been developed at the DTY test facility and tested with the vendor VVO applications.

End to End Integration

The combination of the physical configuration with the architecture and integration provided the capability to assess the ability for the VVO application to integrate with existing PG&E systems as well as verify that the logic and control of the vendor VVO approaches meets PG&E needs. The ATS testing facility continues to provide valuable experience surrounding integration and troubleshooting prior to field deployment.

Unresolved Technical Barriers:

PG&E has identified and managed defects, working with VVO vendors to resolve defects. Priority defects have been resolved by the first vendor. Any priority defects discovered during the second vendor testing will be resolved prior to field deployment. However, some lower priority defects remain open. This is expected for a meaningful and healthy testing process. Both vendors have responded to PG&E's needs and are working to resolve specific requests requiring more time for development.

There is no indication that these unresolved issues will adversely affect the safety or reliability of PG&E's distribution system as the VVO applications are focused on finely tuned voltage control, with limited or no potential to cause customer interruptions or system disruptions.

Resolution of these remaining issues is expected to provide opportunities for increased VVO operating effectiveness, rather than preventing successful VVO operation.

7. Selection of Feeders for Phase 2 Field Trials

As outlined in AL 4227-E[7], PG&E identified feeder location selection criteria and rationale for the Phase 2 Field Trial. Feeder selection criteria have been further developed in Phase 1 and applied to PG&E's feeder system to identify a population of feeders with attractive characteristics for Phase 2. Project stakeholders were consulted during feeder selection to ensure that piloting VVO technology would not adversely impact PG&E's ability to deliver safe, reliable, and affordable electrical service to customers served by the pilot feeders. Factors considered in selection of test feeders include:

Central Valley Region: Candidate feeders were located in PG&E's Central Valley Region to allow deployment of VVO in areas under the control of PG&E's most advanced Distribution Control Center.
SCADA Availability: Candidate feeders were required to be sourced from substation having SCADA.
Feeder Loading: Candidate feeders were selected to provide variation in loading.

[7] AL 4227-E, page 19

Feeder Length: Candidate feeders were selected to provide variation in feeder length.
Customer Classification: Candidate feeders were selected to provide the desired mix of customer classifications (Residential, Commercial, Industrial, and Agricultural) and location (urban, suburban, and rural).
Loading Characteristics: Candidate feeders were selected to provide variation in load factor, circuit balance, and PV/DG penetration.
Communication Coverage: Candidate circuits were required to have communication coverage from the existing PG&E communication systems to assist in managing the cost of the test circuit deployments.
No Disruptive Modifications: Chosen feeders were not expected to have disruptive work (e.g., feeder reconfiguration, circuit breaker replacement), that would require disabling VVO for a significant time during the pilot.

Most importantly, PG&E believes the best field pilot for this technology is in a situation with a limited number of operating engineers and distribution operators trained and functional on the VVO operating system. PG&E further believes that the findings on the feeders selected in the Central Valley part of the service area will provide a model for extrapolation to feeders throughout the system, given the characteristics noted above. Feeders on the following banks were selected based on application of the criteria outlined above, located in the Central Valley of PG&E's service area:

- Airways Bank 1
- Barton Bank 3
- Kingsburg Bank 3
- Mosher Bank 2
- Pinedale Bank 1
- Woodward Bank 2

Pending Commission approval of Phase 1, PG&E plans to pilot VVO technology on up to 12 of these feeders on 4 of these substation banks.

8. Benefits Assessment

VVO offers these potential direct benefits to customers:

- Reduced Energy Use and System Losses – Operation of distribution circuits at the lower end of the acceptable voltage range is expected to reduce customer energy use and correspondingly reduce power/energy procurement costs. The reduction in energy use and peak demand would incrementally reduce losses directly improving the efficiency of

PG&E's distribution system. The benefits of the reduction in energy use and system losses would accrue directly to customers, thereby improving overall cost effectiveness.

- Reduced Peak Demand – Similar to the reduction in energy use, there is potential for a reduction in peak demand due to the deployment of VVO. Reduction in peak demand would reduce capacity procurement costs and, as with the reduced energy use, the benefits would accrue directly to customers.

A forecast analysis of these benefit streams was performed for candidate Phase 2 Field deployment feeders. This benefit forecast analysis involved power flow simulation of the targeted feeders to predict the available voltage reduction. As with all forecasts, these analyses were based on a series of assumptions, in this case around operating conditions, load response to voltage changes, and secondary/service voltage drops. The analysis results shown in Table 2 indicate potential benefits of a magnitude that supports the recommendation to proceed to Phase 2 Field Trial.

Table 2: Estimated VVO Benefits for Feeders Considered for Field Trail

Feeder	Estimated Annual Energy Reduction (MWh)	% Reduction from Baseline	Estimated Coincident Peak Demand Reduction (MW)	% Reduction from Baseline
Barton 1114	927	3.2%	0.23	3.1%
Barton 1115	1105	3.7%	0.3	3.2%
Barton 1116	903	3.0%	0.2	2.7%
Airways 1101	439	1.6%	0.18	2.1%
Airways 1102	789	2.6%	0.2	2.5%
Airways 1103	740	1.8%	0.16	2.2%
Kingsburg 1112	1181	3.5%	0.23	2.3%
Kingsburg 1113	1027	2.1%	0.16	1.6%
Kingsburg 1114	866	2.6%	0.15	2.0%
Woodward 2104	1966	3.7%	0.61	4.2%
Woodward 2105	892	2.8%	0.43	4.2%

Woodward 2106	792	3.0%	0.3	6.4%
Mosher 2108	898	2.7%	0.44	4.4%

The extent to which actual conditions match (or fail to match) the assumptions in the forecast analysis may result in Phase 2 results differing from those presented. PG&E will compare the forecast analysis results and assumptions to the Measurement & Verification (M&V) results from the Phase 2 Field Trial. This comparison will be valuable to refine the benefits forecast model to support determination of the extent (if any) that a larger scale VVO deployment should be pursued as well as potentially contribute to establishing criteria for selection of feeders for future VVO deployment.

In Phase 2, PG&E will evaluate how VVO can support increased penetration of distributed energy resources.

9. Use of SmartMeter™ Data

The VVO Pilot will utilize voltage measurements from Smart Meters and other substation and line equipment with voltage sensing capabilities.

PG&E believes SmartMeter™ voltage data are an important element of a VVO implementation. SmartMeter™ data have already been used in the VVO pilot, and will continue to be an important element. For example:

- SmartMeter™ voltage data on targeted feeders have been collected since January 2014. These data have been analyzed to understand:
    - Magnitude of available voltage and energy reductions
    - Opportunities to modify feeders to enhance VVO benefits
    - Opportunities to modify specific service point locations to enhance VVO benefits
    - Required modifications to optimize SmartMeter™ polling and data availability to enable VVO
- PG&E will monitor SmartMeter™ voltage data daily on all feeders with VVO to understand operational impacts on customer voltages, and to ensure there are no unintended impacts to proper system voltage levels. The use of SmartMeter™ data will be critical during the field pilot phase for all feeders to ensure proper service levels to customers are maintained.
- SmartMeter™ voltage data will be analyzed to improve VVO performance during the field pilot in Phase 2. Voltage data will be polled to understand how effective VVO is in

flattening and reducing voltage profiles to drive Conservation Voltage Reduction and line loss reduction. In particular, SmartMeter™ voltage data will help PG&E refine assumptions about service transformer and secondary voltage drops to more accurately forecast benefits that may be associated with a broader deployment.

- Utilidata's roadmap indicates incorporating SmartMeter™ voltage data in their VVO control algorithm in 2015. PG&E will evaluate the performance of this algorithm enhancement and the potential to drive additional benefits. PG&E plans to test this algorithm in the lab and field environments once available.
- SmartMeter™ data will play a key role in understanding the impact VVO has on feeders with high levels of distributed generation.
- SmartMeter™ voltage data is expected to play a key role in determining the scale and selecting the feeders for a potential VVO deployment, should Phase 2 indicate a broader deployment would be would be beneficial to PG&E's customers.

10. VVO Pilot Project Milestones and Timeline by Phases

Table 4 provides updated project phases milestones and expected timelines for the VVO pilot. The forecasted timeline for Phase 2 is through 2016 with the major milestones and duration shown in Table 4:

Table 3: Project Milestones by Phase

Milestones	Start Date	End Date
Phase 1: July 2013 – December 2014		
• **Plan/analyze:** benchmark VVO implementations, assess and select vendors for testing, negotiate testing contract	7/1/2013	3/15/2014
• **End-to-end solution testing:** setup and test a full VVO ecosystem and test vendor solutions	10/1/2013	9/30/2014
• **Supplemental vendor testing:** setup and test second full VVO ecosystem and test vendor solutions	9/1/2014	12/31/2014
Phase 2: November 2014 – December 2016		
• **Field installation:** Install field equipment, setup and commission VVO schemes on 12 feeders	12/1/2014	6/31/2015
• **VVO IT infrastructure and software:** setup infrastructure, install VVO software, and integrate IT systems	12/1/2014	5/31/2015

• **Advanced functionality and optimization:** Test advanced functionality and optimize system to enhance performance	1/1/2015	12/31/2016

11. VVO Pilot Project Costs — Detailed Budget and Expenditures

The Phase 1 project costs to date and the forecasted costs to complete all testing, including supplemental vendor testing, are detailed in Table 6 below.

Table 4: Phase 1 Actual and Forecast Costs (figures are in thousands of $)

	2013	2014				**Total***
		Q1	Q2	Q3	Q4*	
Capital - Actual	$548	$1,287	$1,550	$2,299		**$5,684**
Capital - Forecast					$3,116	**$3,116**
Capital - Totals	$548	$1,287	$1,550	$2,299	$3,116	**$8,800**

Phase 1 costs were forecast to be approximately $10.2 million. Therefore, PG&E is presently forecasting a favorable underrun of approximately $1.4 million. This favorable underrun is primarily due to IT expenditures that assumed a higher cost estimate for systems integration of VVO vendor platforms into PG&E systems for the Phase 1 lab testing.

12. Summary and Recommendation to Proceed to Phase 2

In summary, PG&E believes it has qualified a viable VVO solution ready for field test deployment, and therefore PG&E recommends the Smart Grid Voltage and Reactive Power Optimization Pilot Project move into Phase 2, given:

1. Utility benchmarking indicates successful adoption of VVO systems across the US
2. Proven capability to implement on PG&E's systems – as demonstrated through test cases completed at the ATS facility
3. Confirmed potential benefits – as demonstrated through an engineering assessment of the benefits potential on feeders considered for Phase 2.

The work remaining in Phase 1 is completion of testing with the second VVO vendor (DVI) at PG&E's ATS lab facility. PG&E recommends moving into Phase 2 prior to the determination of whether DVI passes all Priority 1 tests. If DVI fails to pass all Priority 1 tests, then Phase 2 will proceed with Utilidata only. The funding required to complete laboratory testing DVI is

accounted for in the Phase 1 financial summary reported in this document. Phase 2 funding is not required to complete laboratory testing of DVI.

13. Plan to apply unspent Phase 1 funds to Phase 2

As of October 31, 2014, the date of this Advice Letter, PG&E forecasts a positive budget underrun for Phase 1 activities of approximately $1.4 million upon completion of the testing activities for the second VVO vendor and final planning activities for Phase 2. PG&E plans to apply any Phase 1 budget underruns in Phase 2, allowing PG&E to invest in improvements to VVO solutions and distribution system infrastructure that have promise of enhancing the value of VVO and increasing knowledge of efficiently deploying and operating VVO.

PG&E has identified key areas in which unspent Phase 1 funds could be utilized to provide additional value:

- Updates to VVO vendor offerings (i.e., software updates)
- Circuit conditioning to flatten distribution profiles, allowing further voltage reduction while remaining compliant with Rule 2. Examples of circuit condition are:
    - Balancing load on distribution feeders
    - Adding and/or relocating voltage controlling devices (i.e., line regulators and capacitors)
    - Service transformer replacement and other secondary voltage side modifications
    - Installation of solid state power electronic voltage controlling devices

PG&E has studied and believes that prudent investment in these areas will yield learning beyond that obtained from piloting VVO on additional feeders. For example, addressing customer-level voltages with new solid state power electronic devices or existing (service transformer replacement) methods can increase CVR benefits, which industry participants have claimed could double customer savings. PG&E does not recommend any revisions to the scope or plans for this pilot project as defined in the Smart Grid Pilot decision or AL 4227-E.

Internal scheduling project management critical path analysis indicates PG&E must begin the Phase 2 activities on December 1, 2014, to ensure a timely ability to order, deploy, and install all equipment and systems necessary to capture VVO results for the summer of 2015. PG&E believes the best understanding of the benefits potential for VVO is to have the system in place with measurement and evaluation fully engaged throughout the summer of 2015 for a benchmark and then the subsequent seasons for further study and potential advanced functionality.

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