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Voltage and Reactive Power Optimization (VVO) Pilot Summary and Potential Deployment Plans

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June 2018

PG&E has piloted but not deployed VVO

- PG&E's Voltage and Reactive Power Optimization (VVO) pilot project was approved by the CPUC in March 2013* to demonstrate the value and challenges of deploying new Smart Grid technology to deliver Conservation Voltage Reduction (CVR) and enable the continued adoption of Distributed Energy Resources (DERs)
- PG&E's VVO pilot ran from late 2013 through end of 2016**
- Lab tested then field trialed VVO software on 14 distribution circuits in and around Fresno
- Pilot VVO software vendors DVI and Utilidata were 100% focused on VVO software control systems to deliver CVR

** CPUC Decision 13-03-032 issued in March 2013*

*** Closeout report available via PG&E Advice Letter 4990-E, dated December 30, 2016*

Pilot technology selection vs. deployment strategy

Comparing pilot technology selection to the present potential deployment strategy requires understanding context of 2014 vs. 2018

2014

- PG&E about to consolidate 13 legacy to 3 new Distribution Control Centers, plans involved adoption of Distribution Management System (DMS) as electronic, real-time as-switched model

Pilot Technology

- Pilot project technology evaluated via RFI process
- Vendors selected based on likelihood of delivering best CVR savings for duration of pilot
- Used simpler solution architecture, not integrated with DMS electronic as-switched model

2018

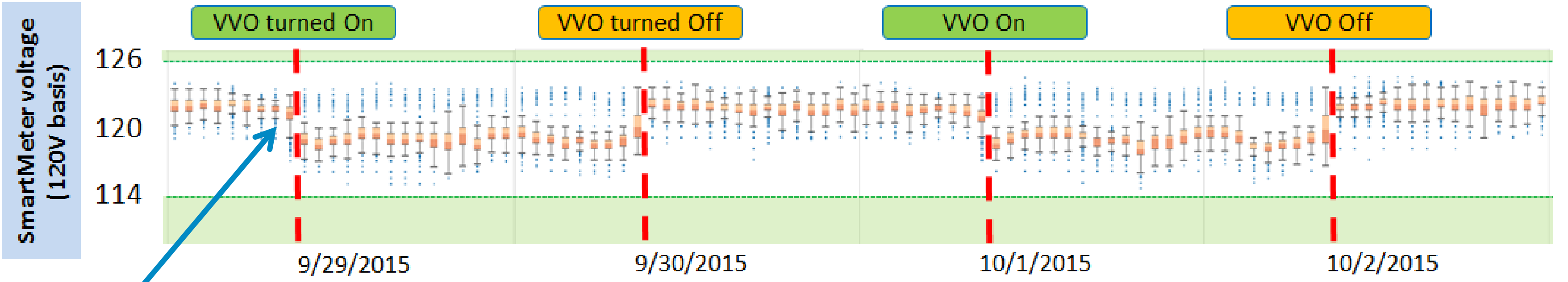
- Planning to replace Distribution SCADA, and adopt Advanced Distribution Management System (ADMS)
  - RFP in progress

Deployment Concept

- VVO would be an “advanced application” enabled by the deployment of ADMS, where SCADA is integrated with the distribution as-switched model
  - More complex solution architecture

Pilot benefits Measurement & Verification methods

Toggled VVO on & off, used regression to quantify energy savings and demand reduction



Prototype visualization & analysis tool showed voltage distribution impact from VVO being turned On and Off on alternating days

Results calculated for each bank across five seasons (Summer 2015 through Summer 2016)

1. **Some peak demand reduction results have large error bands affecting statistical significance
2. Comprehensive M&V results included in final report (Advice Letter 4990-E)

M&V shows weighted average CVRf across 12 of the piloted circuits of 0.7

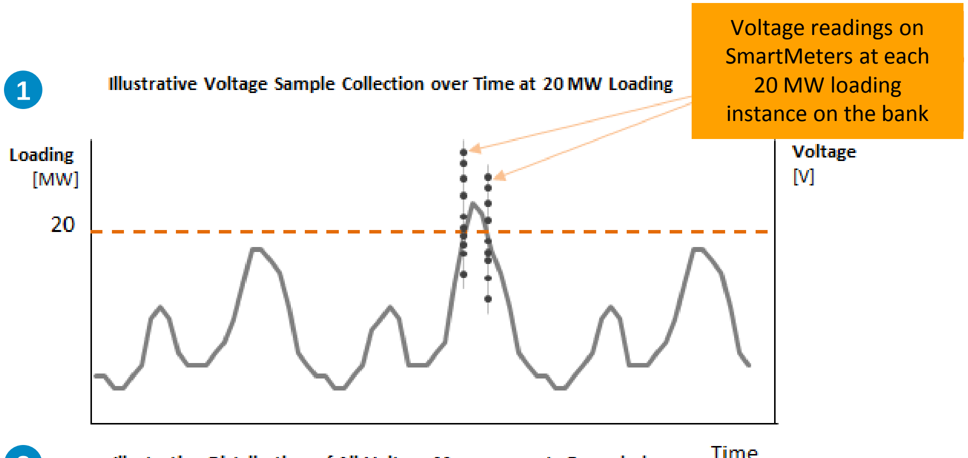
Subset of Pinedale Bk 1 M&V Results

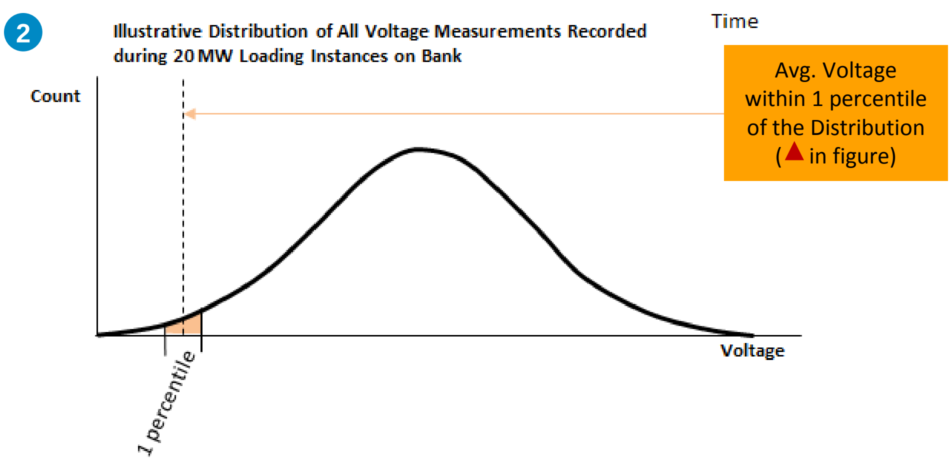
Period	Pinedale Bank	Voltage Reduction [%ΔV]	Energy Reduction [%ΔE]	Energy Conserved [MWh]	Reactive Power Reduction [%ΔQ]	Real Power Demand Reduction on CAISO 1-in-2 Peak Day Scenario [%ΔP]
Period 2 Autumn 2015	**Bank**	**1.8%**	**2.0%**	**131**	**57%**	
	P-2101	1.3%	2.3%	60	-102%	
	P-2102	2.2%	2.8%	54	88%	
	P-2103	1.7%	0.9%	17	64%	
Period 3 Winter 2016	**Bank**	**1.7%**	**0.9%**	**114**	**49%**	
	P-2101	1.4%	0.8%	45	-21%	
	P-2102	2.0%	1.1%	42	86%	
	P-2103	1.5%	0.7%	27	46%	
Period 4 Spring 2016	**Bank**	**1.6%**	**0.7%**	**57**	**51%**	
	P-2101	1.3%	0.7%	23	0%	
	P-2102	1.9%	1.3%	28	85%	
	P-2103	1.4%	0.3%	6	46%	
Period 5 Summer 2016	**Bank**	**1.2%**	**0.6%**	**101**	**49%**	**1.2%**
	P-2101	0.7%	0.1%	7	13%	0.8%**
	P-2102	1.4%	0.7%	35	74%	1.7%
	P-2103	1.4%	1.4%	60	54%	1.0%**

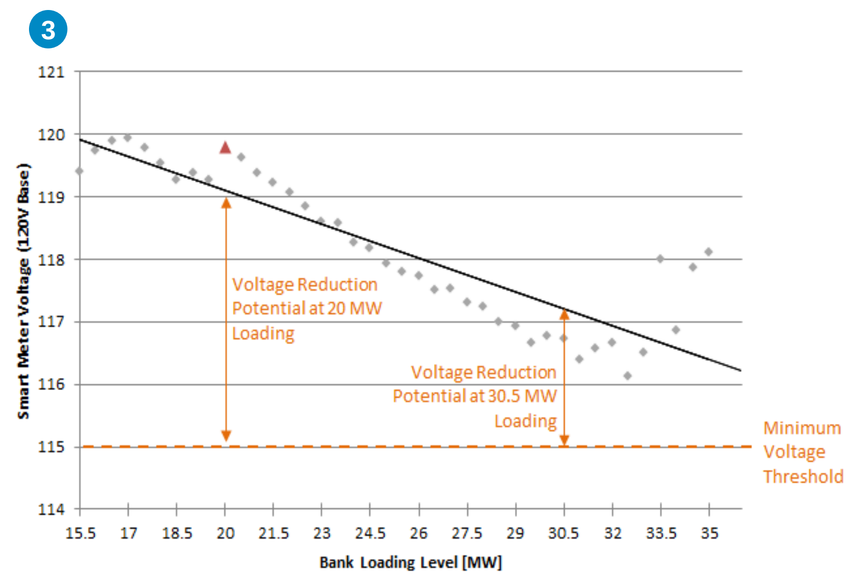
SmartMeter voltage measurements were used to forecast deployment-scale benefits (1 of 2)

Voltage data collected from non-VVO pilot circuits enabled forecasting of energy reduction savings [MWh] from VVO deployment

1. Voltages corresponding with loading
2. Voltage distributions at various loading levels analyzed
3. Lowest 1 percentile plotted against loading, allowing forecast of voltage reduction at various loadings



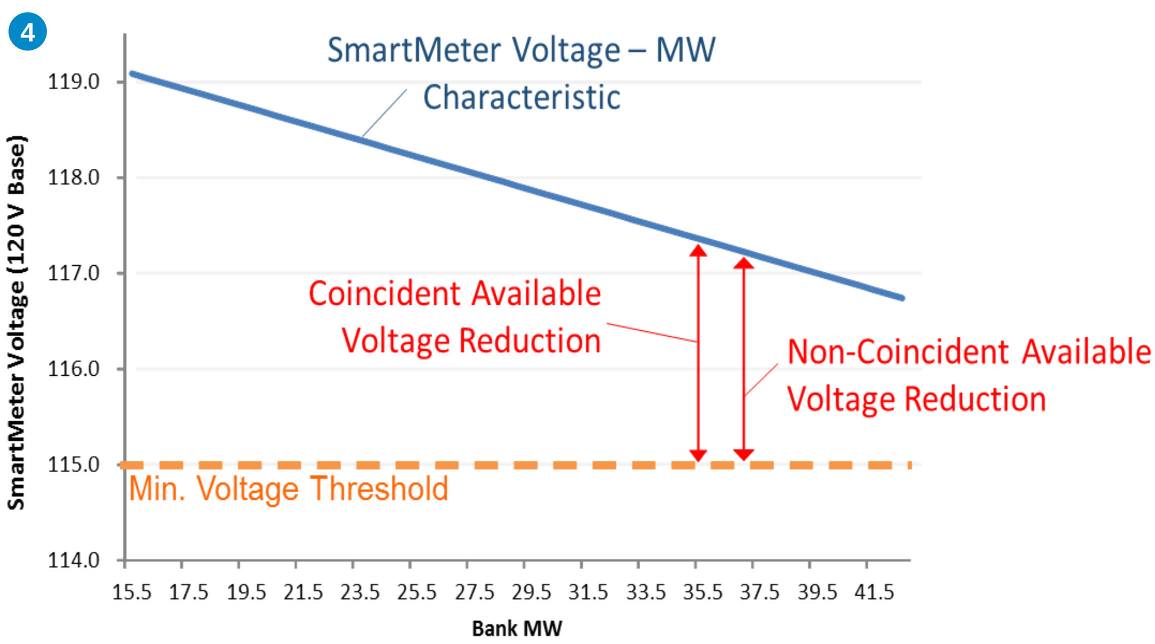




$$\%\Delta E = CVRf \times \%\Delta V$$

SmartMeter voltage measurements were used to forecast deployment-scale benefits (2 of 2)

4 Trend of allowable voltage reduction at varying load levels allows evaluating potential demand [MW] reduction during coincident CAISO peak



$$\%\Delta P = CVRf \times \%\Delta V$$

Allowable voltage reduction for energy [MWh] and peak demand [MW] savings calculated for 33 banks and extrapolated to enable forecasting the ability of VVO to deliver Conservation Voltage Reduction benefits at wide-scale.

Results of benefit forecast summarized on subsequent slide.

VVO's CVR benefits forecasted in late 2016

PG&E estimates deployment to ~170 banks (~510 out of PG&E's over 3,200 distribution circuits) has a favorable Benefit to Cost Ratio

- Two scenarios (high and low effectiveness) evaluated
- Evaluated impact of not realizing peak demand reduction benefits, B/C still favorable

Effectiveness Scenario	Discounted Lifetime Costs	Discounted Lifetime Benefits	Lifetime	Benefit-Cost Ratio	Benefit-Cost Ratio (excluding Avoided Cost of Capacity benefits)
High	$180M	$472M	20 yrs.	2.6	2.5
Low	$198M	$286M	15 yrs.	1.4	1.4

Effectiveness Scenario	CVRf	Avg. %△ in Voltage, for CAISO System Peak	Avg. %△ in Peak Demand	Avg. %△ in Voltage, for Energy	Avg. %△ in Energy Consumed
High	0.8	1.6%	1.04%	3.05%	1.97%
Low	0.6	1.6%	0.81%	3.05%	1.53%

Assumption	High Effectiveness Scenario	Low Effectiveness Scenario
CVR factor	0.8 in year 1, deflates on average 1% per year for remaining useful life	0.6 in year 1, deflates on average 1% per year for remaining useful life
Useful Lifetime	20 years	15 years
Source of Avoided Cost Forecasts	Energy and Environmental Economists (E3)	Energy and Environmental Economists (E3)

Note: tables shown are included in PG&E's final report contained in Advice Letter 4990-E