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Ameren Illinois Company

Voltage Optimization Evaluation Plan
2018-2021 Plan Period

FINAL

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Opinion Dynamics

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1. Introduction

This document outlines the multi-year evaluation plan for Ameren Illinois Company (AIC)'s Voltage Optimization (VO) program from 2018 through 2021. In addition, this document includes the detailed 2018 evaluation plan for VO. The overarching evaluation objectives for these efforts are to calculate the energy use reductions attributable to VO and support the successful implementation of the VO program. Note, we will provide additional detailed evaluation plans for each year.

1.1 Voltage Optimization Initiative

Voltage optimization (VO) is a form of energy efficiency technology implemented by electric utilities at the distribution substation or circuit level that optimizes voltage levels along distribution circuits to reduce electricity usage. There are two main VO technologies: Conservation Voltage Reduction (CVR) and Volt-Var Optimization (VVO). CVR reduces customer energy consumption by reducing line voltage and VVO improves the power factor to reduce line losses. Once implemented, VO technologies are intended to operate 24 hours a day, 365 days a year. AIC will implement hardware and software solutions using VO technologies.

AIC plans to launch its VO program in 2018 leveraging experience gained from a 2012 VO Pilot Project. As part of 2018 implementation activities, AIC plans to install hardware, software, and communications components[1] on a subset of 1,047 eligible feeders[2] on a phased basis, with 19 circuits deployed in 2018 and culminating in 182[3] circuits deployed by 2024. Table 1 provides AIC's implementation plan and savings goals for the VO program.

Table 1. VO Program Implementation Plan

Year Ending	2018	2019	2020	2021	2022	2023	2024	2025
Estimated Cumulative Persisting Annual Savings (MWh)	0	7,650	59,994	128,433	201,725	275,006	348,287	421,568
% Annual Cumulative Persisting Savings	0%	0.03%	0.21%	0.46%	0.72%	0.98%	1.25%	1.50%
Estimated Incremental # of Circuits Deployed	19	130	170	182	182	182	182	0
Estimated Incremental Construction Cost (Capital Cost)	$2M	$14M	$18M	$19M	$19M	$19M	$19M	$0
Estimated Incremental Total Investment Cost (Construction Capital, Construction O&M, Upfront Capital)	$5M	$17M	$20M	$20M	$20M	$20M	$20M	$0

Source: Ameren Illinois Voltage Optimization Plan, October 2017.

[1] Ameren Illinois identified multiple technology upgrades required to successfully deploy a VO program. These technology upgrades have hardware, software and communication components.

[2] AIC staff used voltage level as the primary criteria for establishing the initial pool of potential candidate circuits and excluded circuits served by voltage levels > 20 kV or that serve only exempt customers (a customer whose highest 15-minute demand is at or greater than 10 MW).

[3] The number of circuits planned for VO deployment was determined based on calculated assumptions, industry results, and past AIC VO pilot results. The actual number of feeders with VO could increase based on deployment results.

The energy savings goals for the program were calculated using an algorithmic approach with assumptions from the pilot program, as well as industry literature. Key assumptions include an expected 3% voltage reduction across VO circuits and a corresponding usage reduction of 2.4%, which results in an assumed 0.8 CVR factor (please note that all input variables will be explained in further detail in the following sections).

1.2 Multi-Year Evaluation Approach

Research Objectives

The VO evaluation team seeks to address the following research questions:

1. What are the estimated energy savings from VO?
2. What are the estimated demand savings from VO?
3. What, if any, modifications are needed to the algorithm approach or its underlying parameter assumptions?

The process evaluation for this program will be limited to annual interviews with program staff, which will aid the evaluation team's understanding of the status of the program at the start of each evaluation year and inform the team of key developments made as the program has matured.

Methodology

The energy savings associated with VO are mainly due to end-use load reductions resulting from a reduction in distribution voltage. Generally, the larger the reduction in line voltage, the larger the end-use energy savings. The relationship between voltage and usage due to VO, commonly expressed in the industry as a Conversation Voltage Reduction Factor (CVR_f), is one of the primary methods of demonstrating the efficacy of VO:

$$CVRf = \frac{\%\ Change\ in\ Usage}{\%\ Change\ in\ Voltage}$$

Through AIC's pilot study and a survey of the literature, AIC estimated that VO will lead to a 3% voltage reduction and a corresponding 2.4% usage reduction on circuits in AIC's territory. Based on these results, a CVR_f of 0.80 is applied to AIC circuits.

Annual Impact Evaluation

The primary method for calculating energy savings due to VO from 2019 to 2020 is the following algorithm, which uses AIC's calculated CVR_f as a key input:

Equation 1. VO Savings Algorithm

$$Annual\ Energy\ Savings = Annual\ Energy\ Use_{\ 2014-2016} \cdot CVR_f \cdot \%\Delta V$$

Where:

- $Annual\ Energy\ Use$ = The average annual customer energy use over the 2014-2016 timeframe excluding the exempt customers
- CVR_f = The estimate of the conservation voltage reduction factor (initially assumed to be 0.80)

- $\%\Delta V$ = The percent change in voltage resulting from VO implementation relative to the pre-installation baseline, calculated with one full year of actual pre- and post-voltage using a regression model to control for exogenous factors that may contribute to changes in voltage (e.g., weather) for each circuit. The calculation of energy savings due to VO in 2021 will be based on the results of IL-TRM research outlined below and pursuant to the terms of the stipulated agreement. The research may provide updated assumptions for variables currently included in the VO Savings Algorithm or provide an alternative approach to estimating VO savings moving forward.

IL-TRM Research (On/Off Testing)

We will verify the CVR_f and the algorithm approach as an energy savings evaluation method by implementing an "on/off" experimental approach on a representative sample of circuits in Ameren's territory and comparing the results to the algorithm approach described above. If the energy savings results from the algorithm approach and on/off methodology diverge substantially, we may suggest an alternative method, or changes to parameter assumptions within the algorithm (such as the CVR_f). Any changes to the methodology will be made prospectively pursuant to the stipulated agreement.

In 2018, we will work with AIC to select a statistically representative sample of distribution feeders on which to implement on/off testing. We will select from the pool of potential circuits that already have VO implemented or are planned for VO implementation in 2018 or 2019. The circuits selected for on/off testing will adhere to a set alternating VO on and VO off schedule starting on a rolling basis dependent on the date of VO implementation. Each circuit will operate on the prescribed on/off schedule for at least three complete seasons (summer, winter, and either spring or autumn) to ensure that data is obtained for each circuit across seasons that have substantially varying load.

AIC will provide voltage, real power, and reactive power data collected at the 60-minute interval level for the on/off circuits. We will use this data to calculate the impacts of VO using regression models. The selected regression models will be applied to sample feeders that have sufficient test data and the model results will be used to develop seasonal and annualized impact estimates.[4] See Equation 2 for an example of the potential regression model specification. The final model specification is subject to change contingent on the data and other factors.

Equation 2. Example VO Load and Voltage Model

$$X_{it} = \beta_{weekend} * Weekend_t + \beta_{CDH} * CDH_t + \beta_{HDH} * HDH_t + \sum_{h=1}^{23} \beta_{Hour} * Hour_{ht} + \sum_{h=1}^{23} \beta_{Hour\ Weekend} * Hour_{ht} * Weekend_t + \beta_{VO} * VO_t + \beta_{VO\ Weekend} * VO_t * Weekend_t + \sum_{h=1}^{23} \beta_{Hour\ VO\ Weekend} * Hour_{ht} * VO_t * Weekend_t + \beta_0 + \varepsilon_{it}$$

[4] If insufficient test data are available to permit Opinion Dynamics to develop reliable statistical estimates of VO impacts for some sample feeders on which VO has been commissioned in 2018 or 2019, we will base our savings estimates on the best information available at the time. This may include empirical estimates developed from other AIC VO feeders, or empirical estimates developed in other jurisdictions that are available in the published literature.

Where:

- X_{it} = Load measured at the customer service points[5] on feeder i at time t measured as either real power (MW), reactive power (|MVAR|), or voltage (V)
- $Weekend_t$ = Indicator variable for weekend (weekend = 1) or weekday (weekday = 0)
- CDH_t = The number of cooling degree-hours at time t
- HDH_t = The number of heating degree-hours at time t
- $Hour_{ht}$ = Set of 23 indicator variables for hour of the day at time t
- VO_t = Set of indicator variables on feeder i in time t during test period p for VO status where VO status can be fully enabled (VO = 1), fully disabled (VO = 0), or in transition between control states (0 < VO < 1)
- βs = Coefficients on parameters that are estimated by fitting the model to the experimental data
- β_0 = Intercept term
- ε_{it} = The variation in load on feeder i at time t and day type j during test period p that is not captured by the model

The estimated VO impacts on each sample feeder will be derived by fitting the regression model using all the experimental data in each seasonal on/off test period to obtain unbiased estimates of the model coefficients for that feeder in that period. The fitted models will then be used to simulate the load and voltage profiles for each sample feeder in that season under two scenarios: one assuming VO controls are fully engaged (VO = 1) and the other assuming baseline controls (VO = 0). The difference between the two circuit statuses is the measured impacts of VO on voltage and energy usage on each sample feeder during each season. The demand impacts will be calculated using the same method except only the peak demand time periods, as defined by AIC,[6] will be used in the regression model and subsequent simulation.

The aggregation of the energy impacts across seasons for a given feeder is the annualized impact for that feeder.[7] Aggregating across feeders will yield the aggregate impact for a given period. To express these impacts in percentage terms, the estimated impacts for each feeder will be divided by the corresponding simulated usage, load or voltage value under the baseline (VO = 0) scenario. The experimental CVR_f values for each sample feeder is the ratio of the percentage usage or load reduction to the percentage voltage reduction.

We will use the results of the on/off testing experiment to develop estimates of the distribution of VO impacts across all AIC VO implemented circuits, validate the algorithmic approach, and assess the accuracy of the

[5] Interval voltage measurements on each feeder will consist of the load-weighted mean voltage readings (on a common 120V nominal basis) from a representative sample of all reporting AMI meters, where available, served by the feeder. Voltage readings at customer service points are preferred for measuring VO voltage reductions because the bulk of VO energy savings are expected to occur behind customers' meters, the result of more efficient operation of customer loads, if not available, SCADA voltage values will be used. Thus, the voltage reductions delivered to customer service points are the relevant statistic for measuring VO impacts.

[6] We will define the peak period after consultation with AIC, but anticipate that it will reflect system peak periods.

deemed CVR_f of 0.8. Following the completion of the study, and pursuant to the terms of the stipulated agreement, we will share results and recommendations for IL-TRM updates, if any, in a workpaper developed in coordination with the ComEd evaluation team. We will also attend IL-TRM stakeholder meetings and engage key parties to ensure that the evaluation delivers robust and useful information to practitioners.

Evaluation Tasks

Table 2 shows the proposed tasks for the VO evaluation over the next 4-year period.

Table 2. Voltage Optimization Evaluation Activities – Four Year Plan

Evaluation Timing	Objective	Activity	2018	2019	2020	2021
Annual	Verify and calculate annual energy savings	Program Manager Interviews	✓	✓	✓	✓
		Tracking System Review	✓	✓	✓	✓
		Confirm Operation of VO by Calculating the Change in Voltage		✓	✓	✓
		Mid-Year Data Review Memo	✓	✓	✓	✓
		Estimate Savings by Applying Energy Savings Algorithm*		✓	✓	✓**
Phased	Estimate parameters associated with VO savings algorithm	Select Feeders for 2021 TRM Update and On/Off Testing	✓			
		Selection of Feeders for 2023 TRM Update			✓	
		Regression Analysis to Confirm Algorithm Assumptions		On/Off Testing Occurs	✓	✓
**Savings estimates for 2021 will be based on the updated 2021 IL-TRM pursuant to the stipulated agreement, which will be informed by the on/off testing.						

We proposed the evaluation activities included in Table 2 to address these primary research objectives:

- Verify and calculate energy savings attributable to the program annually using an algorithmic approach. Activities include:
  - **2019-2021:** Verify the installation and operation of VO-implemented circuits annually. This will include acquiring and analyzing the relevant distribution system data (SCADA, AMI, or non-SCADA enabled field device data), reviewing AIC's data evaluation and management tracking system, and performing a regression to calculate the change in voltage resulting from VO deployment relative to pre-period voltage. We will also verify that the circuits deployed and verified in previous years are still in operation each year.
  - **2019-2020:** Calculate annual and cumulative persisting annual energy savings (CPAS) using the algorithm approach annually. This will include inputting our calculated percentage reduction in

voltage on VO circuits and applying the relevant CVR factor and pre-period energy usage.[8] These results, along with the on/off testing findings, will inform the development of the 2021 IL-TRM.

- **2021:** Calculate annual savings and CPAS using the updated IL-TRM pursuant to the stipulated agreement, which will be informed by the on/off testing.

- Estimate parameters associated with algorithmic approach to inform IL-TRM updates by using an on/off testing approach. Activities include:
  - **2018**: Select a representative sample of circuits in AIC's service territory on which to implement on/off testing, and develop the on/off testing schedule for implementation in 2019. The on/off testing will be implemented on a rolling basis as VO is deployed.
  - **2019-2020** Calculate the energy and demand savings attributable to VO using regression analysis on the data collected from the on/off testing to confirm the accuracy of the algorithm. Some of the relevant variables that will be considered for inclusion in the regression analysis are season, time of day, day-type, customer load type, feeder length, and distributed energy generation penetration. Energy and demand savings will be calculated based on the on/off methodology starting in 2019 and the results will inform the development of the 2021 IL-TRM.
  - **2020:** Select a sample of circuits for a second round of on/off testing (to be completed in 2021), with results submitted for inclusion in the 2023 IL-TRM Update Process. Lessons learned from the first round of sampling and on/off testing conducted in 2019 and 2020 will inform the second wave of this research.[9]

1.3 2018 Detailed Evaluation Plan

To achieve our research objectives, we will complete a series of evaluation tasks in 2018 as outlined in Table 3.

Table 3. Summary of VO Program Evaluation Activities for 2018

Activity	Impact	Process	Forward Looking	Description
Program Manager Interviews	✓	✓		Interviews with program manager and associated staff to understand evaluation objectives, data available, and support on/off testing deployment
Select Circuits for On/Off Testing			✓	Includes reviewing circuit characteristics, pilot estimates, and developing a sampling design to support estimating parameters included in the algorithm. Deliverables will include a description of the sample design and list of selected circuits
Mid-Year Data Review	✓			Includes Tracking System Review

[8] Per the Voltage Optimization Plan Settlement Stipulation (ICC Docket No. 18-0211), A CVR factor of 0.80 will apply to 2019 and 2020 claimed savings for the first 165 circuits that have VO installed. If more than 165 circuits have VO installed by the end of 2019, the additional circuits will be evaluated using updated CVR factors and/or evaluation methodologies.

Activity	Impact	Process	Forward Looking	Description
Ongoing Statewide Coordination Meetings for TRM Update			✓	Quarterly meetings between the ComEd and AIC evaluation teams to coordinate on/off testing across the two projects and plan for the IL-TRM update in 2021.

We describe each of these activities in detail below.

Task 1: Program Manager Interviews

The evaluation team will meet with AIC staff, including distribution engineers, to develop a deeper understanding of AIC's VO implementation plan and deployment progress to date. In 2018, we will hold an in-person kick-off meeting with the team. The meeting will be instrumental to informing evaluation activities and timelines, and will answer critical questions regarding implementation plans, characteristics of the AIC grid and affected feeders, impact methodology, data availability, and communication plans between AIC staff and the evaluation team.

Following the in-person meeting, the evaluation team will develop a data request. The data request will address three overarching data needs: VO program plan documentation, data type and availability VO-enabled circuits, and characteristics of the 1,047 anticipated VO circuits.

Deliverable: In-person Meeting Agenda; Data Request *Deliverable Date: May-June 2018*

Task 2: Select Circuits for On/Off Testing

We will use information submitted in response to the data request to select a representative sample of circuits on which to conduct on/off testing. Given that AIC has already selected and started designing the 130 circuits for VO deployment in 2019, we will select our sample for on/off testing out of these 130 circuits. The team may also include some or all of the original 19 circuits deployed in 2018 if they are representative of the broader set of chosen circuits. Sample selection is a critical step in the on/off testing process as results from the experiment will inform updates to the IL-TRM, and as such, should be an accurate reflection of the circuits to which standardized values will apply. Though we will consider a range of variables in the sample selection process, critical considerations include the number of low income customers along the circuit, rate class, division, and type of technology implemented. Given AIC's strategic focus on serving low income customers, we will incorporate this variable in our sampling plan to reflect the overall goals of the VO program in serving this population.

After initial sample development, we will work with AIC engineers to assess the feasibility of installing VO on the selected circuits and the timeline for doing so. Depending on the needs and constraints of grid (e.g., ongoing T&D upgrades not associated with VO deployment, customer solar installation, etc.), we will work with project engineers to ensure that we have a representative sample that reflects VO deployment. After on/off testing commences, we will perform preliminary analysis and deliver interim results to AIC. We anticipate this activity to occur in Fall 2019, after the on/off testing has been underway for approximately six months.

Deliverable: Sample Memo Describing Circuits for On/Off Testing *Deliverable Date: July-August 2018*

Task 3: Mid-year Data Review

The evaluation team will conduct a comprehensive review of all data submitted in response to the data request. The data review will include a VO program data inventory, QA/QC of submitted data, and an assessment of data coverage. Because VO will not be operating on circuits in 2018, we will not perform interim analysis to calculate the change in voltage resulting from VO deployment. In addition, after reviewing data type, quality, and coverage, we will develop an impacts analysis workflow that includes a data dictionary and steps for cleaning and analyzing VO program-specific data using the algorithmic approach.

The evaluation team will document findings from the mid-year data review in an Early Feedback Memo. The memo will account for all data received, detail any data-related issues or gaps that may impact future analyses, and describe the sampling design and considerations for the on/off testing.

Deliverable: Mid-year Data Review Memo *Deliverable Date: October 2018*

Task 4: Ongoing Statewide Coordination Meetings for TRM Update

We propose to hold quarterly meetings between the Navigant team evaluating ComEd's VO program and the Opinion Dynamics evaluation team. Given the technical challenges, risks to customer reliability, and subsequent delays that the rollout of VO technology often entails, we see opportunity for the two evaluation teams to communicate about the status of each project on a regular basis. Ongoing communication will allow for consistent application of evaluation methodology, troubleshooting between the two teams, and planning for the TRM update in 2021.

Evaluation Budget and Timeline

Table 4 summarizes the timing of each evaluation activity, as well as the budget associated with each task.

Table 4. 2018 VO Initiative Evaluation Budget

Evaluation Activity	Deliverable Date	Budget
Evaluation Planning	June 2018	$19,000
Program Manager Interviews & In-Person Meeting	May 2018	$22,000
Select Circuits for On/Off Testing	July-August 2018	$18,000
Mid-Year Data Review & Memo	October 2018	$45,000
Project Management and Statewide Coordination Meetings	Ongoing	$16,000
	Total	**$120,000**

Table 5 outlines the timeline of evaluation activities planned for 2018-2020. The schedule beyond early 2020 will be defined at a later date, and adjustments will be made, as needed, as evaluation activities progress.

Table 5. Evaluation Schedule

	2018								2019												2020			
	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
STANDARD EVALUATION ACTIVITIES																								
Program Manager Interviews																								
Conduct interviews with AIC staff	X								X												X			
Mid-Year Data Review & Memo																								
ODC sends AIC data request to support mid-year data review memo		X											X											
AIC submits data in response to data request		X											X											
ODC submits questions to AIC regarding the tracking data			X											X										
ODC calculates preliminary change in voltage post VO															X	X	X							
ODC performs preliminary savings calculation on circuits undergoing on/off testing															X	X	X							
ODC sends AIC mid-year data review memo						X												X						
Impact Analysis of Energy Savings with Algorithm Approach																								
ODC sends AIC data request for end-of-year data																				X				
AIC submits data in response to data request																					X			
ODC uses algorithmic approach to calculate savings																					X	X	X	
Evaluation Reporting																								
ODC delivers evaluation plan		X							X												X			
ODC delivers draft report to AIC and SAG																							X	
AIC reviews report																							X	X
ODC delivers final report to AIC																								X
TRM-SPECIFIC RESEARCH																								
On/Off Sample Design and Sampling																								
ODC selects sample of circuits for on/off testing			X	X																				
ODC informs AIC of sample design and proposed on/off schedule				X																				
AIC and ODC discuss proposed deployment plans with AIC staff					X																			
AIC Deploys VO Solution for On/Off Testing																								
AIC deploys VO solution on selected circuits for on/off testing							X	X	X	X	X													
AIC maintains on/off schedule of VO operation on sample circuits													X	X	X	X	X	X	X	X	X	X		
ODC sends AIC data request to confirm on/off is occurring														X				X				X		
AIC submits data in response to data request														X				X				X		
Impact Analysis using Regression Approach																								
ODC delivers preliminary results of on/off testing in an intermim memo																			X	X				
ODC calculates savings from circuits undergoing on/off testing																						X	X	X

Note: The algorithm approach may be applied for the 2021 program year, but the variables may be updated subject to the results of the IL-TRM research.

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