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Ameren Illinois Company 2021 Voltage Optimization Program Impact Evaluation Report

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1. Executive Summary

This report presents the impact evaluation results from Ameren Illinois Company's (AIC) Voltage Optimization (VO) energy efficiency program implemented during 2021. The objective of the 2021 impact evaluation was to determine energy and peak demand savings associated with the VO Program in 2021 as well as to verify continued operation of voltage optimization for a sample of previously evaluated circuits.

1.1 Background

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. AIC's VO Program implements hardware, software, and communications solutions using VO technologies. 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.

By 2024, AIC anticipates deploying VO on 1,047 circuits.[1] Prior to the program launch, AIC identified multiple technology upgrades required to deploy the VO Program successfully. In 2017, AIC began installing VO hardware, software, and communications components on a subset of the 1,047 eligible circuits on a phased basis.[2] As defined in the AIC Voltage Optimization Plan,[3] AIC will claim savings only for VO circuits that were operational during a full calendar year. Therefore, 2021 represents the third year in which AIC is claiming energy savings for the program.

In 2021, evaluation activities included estimating energy and peak demand savings from 180 circuits that were deployed in 2020, as well as verifying the continued operation of circuits previously evaluated in 2019 and 2020.

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[1] 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 circuits with VO could fluctuate based on deployment results.

[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 kilovolt (kV) or that serve only exempt customers (a customer whose highest 15-minute demand is ≥ 10 MW). In addition, only circuits that were estimated to be cost-effective based on a TRC test were deemed eligible.

[3] Ameren Illinois Voltage Optimization Plan, filed in ICC Docket 18-0211 on January 25, 2018. Accessed at: https://www.icc.illinois.gov/downloads/public/edocket/463457.pdf.

1.2 2021 VO Program Savings

1.2.1 Annual Savings

The evaluation team estimated energy and peak demand savings for the 180 circuits that became operational in 2021. Overall, the 2021 VO Program achieved 95,431 MWh of verified net energy savings and 15.95 MW of verified net peak demand savings (Table 1).

Table 1. 2021 VO Program Annual Savings

	Energy Savings (MWh)	Demand Savings (MW)	Gas Savings (Therms)
Ex Ante Gross Savings	75,097[a]	N/A[b]	N/A
Gross Realization Rate	127%	N/A	N/A
Verified Gross Savings	95,431	15.95	N/A
NTGR	N/A	N/A	N/A
Verified Net Savings	95,431	15.95	N/A

[a] Ex ante gross savings sourced from AIC. Ex ante gross savings assume 0.80 CVR factor and 3% voltage reduction across the 180 measured circuits.
[b] There are no ex ante demand savings estimates for this program.

1.2.2 Cumulative Persisting Annual Savings

Table 2 summarizes cumulative persisting annual savings (CPAS) and the weighted average measure life (WAML) for the 2021 VO Program. The overall WAML for the VO Program is 15 years. For additional detail around CPAS and measure life, please see Section 4.1.3 of this report.

Table 2. 2021 VO Program CPAS and WAML

Evaluation Measure Category	Measure Life	First-Year Verified Gross Savings (MWh)	NTGR	CPAS - Verified Net Savings (MWh)							Lifetime Savings (MWh)
				2021	2022	2023	2024	...	2030	...	
Voltage Optimization – 2021 Cohort	15.0	95,431	N/A	95,431	95,431	95,431	95,431	...	95,431	...	1,431,469
2021 CPAS		**95,431**	**N/A**	**95,431**	**95,431**	**95,431**	**95,431**	**...**	**95,431**	**...**	**1,431,469**
Expiring 2021 CPAS				**0**	**0**	**0**	**0**	**...**	**0**	**...**	
Expired 2021 CPAS				**0**	**0**	**0**	**0**	**...**	**0**	**...**	
WAML	**15.0**										

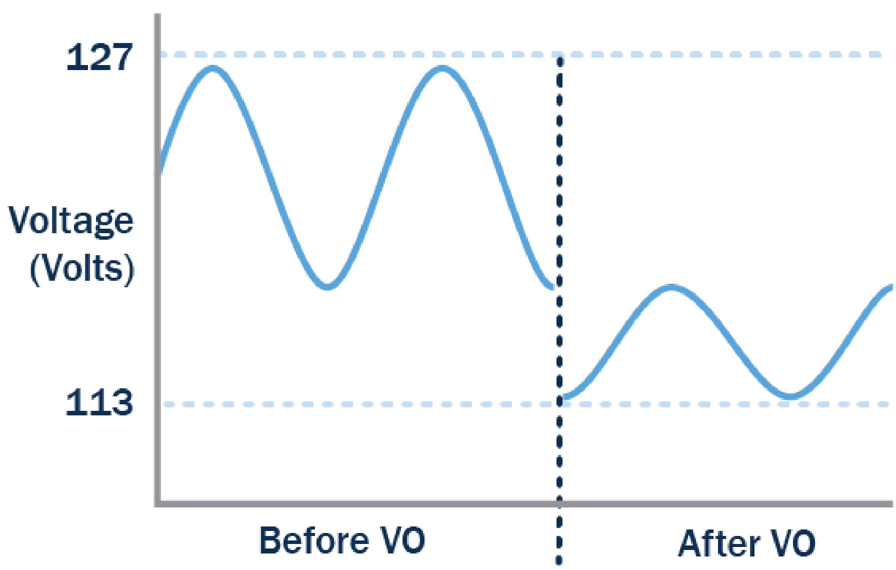
2. Overview of VO Program

Illinois Senate Bill 2814 (the Future Energy Jobs Act [FEJA]) Section 8-103(b-20)) defined voltage optimization as an energy efficiency measure. FEJA directed AIC to make a cost-effective voltage optimization investment as part of its energy efficiency portfolio.

2.1 Voltage Optimization Background

VO is a form of energy efficiency technology implemented by electric utilities at the distribution substation or circuit level. VO optimizes voltage levels along distribution circuits to reduce electricity usage by reducing power consumed by connected loads. AIC defines VO as a combination of VVO and CVR, which are implemented first to reduce the reactive power flows on a circuit,[4] and then to lower the voltage to reduce end-use customer energy consumption and utility distribution system losses. VVO optimizes capacitor bank[5] operations to improve power factor[6] and reduce system losses. CVR utilizes voltage regulators, transformer load tap changers, and capacitors to control and reduce end-user voltages, which, in turn, lowers customers' energy consumption. In other words, these technologies reduce distribution line voltage by regulating voltage in the lower portion of the allowable range. Historically, utilities have regulated voltage in the upper portion of the range to avoid low-voltage violations. Regulating voltage in the lower portion of the range does not compromise power quality. At lower voltage due to VO technologies (Figure 1), most end-uses use less energy.

Figure 1. Illustration of VO Effect on Voltage



VO technologies can operate 24 hours a day, 365 days a year. Energy savings are predominantly driven through end-use load reduction and, to a lesser extent, distribution line loss reductions. AIC's VO Program was

[4] Reactive power is measured in Volt-Amperes Reactive (VAR).
[5] Capacitor banks are groupings of several capacitors and are used to store or condition electricity (e.g., by correcting power factor).
[6] Power factor is the ratio of working power (kW) to apparent power (kVA). Higher power factors indicate higher efficiency.

developed to provide energy savings, not peak demand savings. However, there will naturally be some demand reduction on some circuits during the hours of operation of the system in a given year.

2.2 Program Description

In order to comply with Section 8-103B(b-20) of FEJA and to achieve energy savings that support its energy efficiency portfolio goals, AIC developed the VO Program as described in the Ameren Illinois Voltage Optimization Plan.[7] Per the plan, AIC anticipates deploying VO on all circuits for which VO is estimated to be cost-effective by 2024. Based on calculated assumptions, industry results, and past AIC VO pilot results, AIC anticipates deploying VO on a total of 1,047 circuits. The actual number of circuits with VO could fluctuate based on deployment results.

Before the program launch, AIC identified multiple technology upgrades required to deploy VO. In 2017, AIC began installing VO hardware, software, and communications components on a subset of the 1,047 eligible circuits on a phased basis using four different VO vendor solutions: Utilidata, DVI, OSI, and ABB.[8] 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 kilovolt (kV) and circuits that served only exempt customers (a customer whose highest 15-minute demand is greater than or equal to 10 MW).

VO is a major part of AIC's 2018–2021 and 2022–2025 energy efficiency plans. Per AIC's most recent compliance filing,[9] VO was expected to produce 68,439 MWh in energy savings in 2021, about 20% of AIC's estimated 2021 portfolio energy savings goal. In 2021, VO deployment ramped up significantly from 2020; VO deployment is expected to remain relatively consistent throughout the remainder of the VO plan period. Table 3 provides AIC's original implementation plan and savings estimates for the VO Program.

Table 3. VO 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.

[7] Ameren Illinois Voltage Optimization Plan, filed in ICC Docket 18-0211 on January 25, 2018. Accessed at: https://www.icc.illinois.gov/downloads/public/edocket/463457.pdf

[8] AIC has now selected a primary vendor, and remaining VO circuit construction is proceeding with only one solution.

[9] Appendix B to AIC's 2018–2021 EE Plan, most recently revised as part of the March 3, 2021 errata to the February 19, 2019 compliance filing in ICC Docket 17-0311. Accessed at: https://icc.illinois.gov/docket/P2017-0311/documents/305055/files/531929.pdf.

In 2020, AIC completed 180 circuits that were evaluated as part of the 2021 evaluation. These circuits delivered VO to an estimated 76,003 low-income customers. For a detailed list of circuits evaluated in 2021, see Appendix A.

3. Evaluation Approach

3.1 Research Objectives

The 2021 VO evaluation approach was primarily governed by the Illinois Technical Reference Manual for Energy Efficiency (IL-TRM) Version 9.0,[10] which prescribes the use of an algorithmic approach to estimating electric energy and peak demand savings from VO. In addition to the IL-TRM, we leveraged a previously agreed-upon methodology and approach to verifying the continued operation of previously installed VO circuits during 2021.[11]

In this report, the VO evaluation team addresses the following key research questions:

- What are the estimated energy savings from VO?
- What are the estimated peak demand savings from VO?
- Did the 10 evaluated circuits from 2019 and the 36 evaluated feeders from 2020 continue to operate over a 90% threshold in 2021?

Additionally, our team conducted a limited process evaluation, which included annual interviews with program staff as well as a mid-year data review. This activity aided the evaluation team's understanding of the status of the program, informed the team of key developments as the program has matured, and ensured the evaluability of the program based on data availability and coverage.

3.2 Verified Impact Analysis Approach

As described in section 3.1, the 2021 VO evaluation approach estimated annual energy savings and peak demand savings resulting from the VO Program. The 2021 evaluation estimated energy and peak demand savings for the 180 circuits that were operational as of January 1, 2021.

3.2.1 Energy Savings Methodology

The IL-TRM requires the use of an algorithmic approach to evaluating VO energy savings. The algorithmic approach combines deemed parameter values with measured reductions in voltage to calculate energy savings. The algorithm used for AIC's VO Program energy savings evaluation is shown in Equation 1.

Equation 1. AIC VO Energy Savings Algorithm

$$Annual\ Energy\ Savings_i = Annual\ Energy\ Use_{2014-2016_i} * CVR_f * \%\Delta V_i$$

where

- $Annual\ Energy\ Use_{2014-2016_i}$ = the average annual customer energy use for circuit *i* over the 2014–2016 timeframe, excluding exempt customers.
- CVR_f = the estimate of the conservation voltage reduction factor (deemed as 0.80), defined as the percent change in energy usage divided by the percent change in voltage; and

[10] Illinois Technical Reference Manual for Energy Efficiency Version 9.0, Volume 4, Measure 6.2.1. Accessed at: https://ilsag.s3.amazonaws.com/IL-TRM_Effective_010121_v9.0_Vol_4_X-Cutting_Measures_and_Attach_09252020_Final.pdf.
[11] Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach Memo, accessed at: https://ilsag.s3.amazonaws.com/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf.

- $\%\Delta V_i$= the percent change in voltage for circuit *i* resulting from VO implementation relative to the pre-period, using a regression model to control for exogenous factors that may contribute to changes in voltage (e.g., weather).

3.2.2 Peak Demand Savings Methodology

Peak demand savings were also estimated with an algorithmic approach. The peak period is defined as 1:00 p.m.–5:00 p.m. (CDT) on non-holiday weekdays from June 1–August 31.[12] The algorithm used for AIC's VO peak demand program evaluation is shown in Equation 2.

Equation 2. AIC VO Peak Demand Savings Algorithm

$$Peak\ Demand\ Savings_i = Avg\ Peak\ Demand_{2014-2016_{i,PEAK}} * CVR_{f,PEAK} * \%\Delta V_{i,PEAK}$$

where

- $Avg\ Peak\ Demand_{2014-2016_{i,PEAK}}$ = the average demand in the peak hour for circuit *i* over the 2014–2016 timeframe during the peak period adjusted by a calibration factor that captures the relationship between peak demand and average demand in the peak period, excluding exempt customers.[13]
- $CVR_{f,PEAK}$ = the estimate of the peak conservation voltage reduction factor (deemed as 0.68), defined as the percent change in energy usage divided by the percent change in voltage during the peak period; and
- $\%\Delta V_{i,PEAK}$= the percent change in voltage for circuit *i* resulting from VO implementation relative to the peak hours of the pre-period, using a regression model to control for exogenous factors that may contribute to changes in voltage (e.g., weather). Per the guidance in the IL-TRM, this is to be calculated in the same manner as energy savings but with the intention of measuring peak demand savings rather than total energy savings.

3.2.3 Verification of Continued Operation

VO savings are deemed for 15 years after completion of the initial evaluation of a circuit, and no retroactive changes can subsequently be made to deemed savings.[14] Therefore, in the Illinois evaluation framework, impact evaluation for VO does not require retroactive or ongoing verification.

Nevertheless, in 2020, Opinion Dynamics, AIC, and ICC Staff agreed that ongoing verification of VO should be conducted for process purposes to provide information to stakeholders and other parties as to the level of continued VO operation and, if needed, to provide context as to why VO may not have operated continuously. After the evaluation of each year of VO circuits, all parties agreed that Opinion Dynamics would conduct verification activities to assess the degree to which VO continued to operate throughout each year. The acceptable threshold of operation was set to ensure that circuits operated over a 90% threshold.[15]

[12] Illinois Technical Reference Manual for Energy Efficiency, Version 9.0, Volume 1, Section 3.7.
[13] Peak demand was unavailable for four circuits for the period 2014–2016. Per AIC's guidance, we substituted peak demand from 2017–2019.
[14] Illinois Energy Efficiency Policy Manual Version 2.1, Section 11.2. Accessed at: https://ilsag.s3.amazonaws.com/IL_EE_Policy_Manual_Version_2.1_Final_12-7-2021-1.pdf.
[15] See Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach memo here: https://ilsag.s3.amazonaws.com/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf.

As part of the 2021 evaluation, we conducted ongoing verification of VO circuits evaluated in 2019 and 2020. To determine whether these 2019 and 2020 circuits operated over a 90% threshold during 2021, the evaluation team conducted the following analytical activities:

- Selected a random sample of 10 of the 19 circuits evaluated in 2019 and 36 of the 125 circuits evaluated in 2020;
- Requested operation log summaries for the sample of VO circuits. Our variable of interest for this effort included the VO status (e.g., "on/off") for specific hours throughout 2021 at a circuit level;
- Removed excludable events;[16] and
- Divided the total number of hours in which the status logs indicated that VO was on by the total number of non-excludable hours in the year.

3.2.4 Consideration of Net Effects

Because AIC is the sole operator and "participant" in the VO Program, no adjustments to savings are made to reflect net effects (free-ridership and spillover) that are often present for other more traditional energy efficiency programs.

3.3 Sources and Mitigation of Error

Because we relied on regression models to estimate the change in voltage and peak demand, there will be some uncertainty in the estimates. We therefore designed our analysis to address the following types of error:

- **Model Specification Error:** The most difficult type of modeling error, in terms of bias and the ability to mitigate it, is specification error. In this type of error, variables that predict model outcomes are included when they should not be or excluded when they should not be, possibly producing biased estimates. The team addressed this type of error by carefully examining the model diagnostics and goodness-of-fit statistics.
- **Measurement Errors:** Measurement error can come from variables such as weather data, which are commonly included in consumption analysis models. If an inefficient base temperature is chosen for calculating degree-days or an incorrect climate zone weather station is chosen, the model results could be subject to measurement error. We addressed this type of error by very carefully choosing the closest weather station for each circuit in the model. Specifying an incorrect time period (either VO-on or VO-off) can also lead to measurement error. Our team worked extensively with AIC to ensure that all data anomalies were discussed and addressed, where feasible.
- **Multi-collinearity**: This type of modeling error can both bias the model results and produce substantial variances in the results. The team dealt with this type of error by using evaluation model diagnostics, though the relatively simple models used in the impact analysis are unlikely to have problems with multi-collinearity.
- **Heteroskedasticity:** This type of modeling error can result in imprecise model results due to variance changing across circuits with different levels of consumption. The team addressed this type of error by using robust standard errors. Most statistical packages offer a robust standard error option and make conservative assumptions in calculating the errors, which has the effect of making significance tests conservative as well.

[16] For the rationale behind and definition of excludable events, please see the Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach memo: https://ilsag.s3.amazonaws.com/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf.

4. 2021 VO Program Verified Savings

In this section, we present the results of the impact evaluation of the 2021 VO Program. Additional details on the impact analysis methodology used for this evaluation are presented in Appendix B.

4.1 Initiative Annual Savings Summary

The 2021 VO Program achieved 95,431 MWh of verified net energy savings and 15.95 MW of verified net peak demand savings. Table 4 presents the 2021 VO annual energy and peak demand savings. Detailed results by circuit are available in Appendix B.

Table 4. 2021 VO Program Annual Savings

	Energy Savings (MWh)	Peak Demand Savings (MW)	Gas Savings (Therms)
Ex Ante Gross Savings	75,097[a]	N/A[b]	N/A
Gross Realization Rate	127%	N/A	N/A
Verified Gross Savings	95,431	15.95	N/A
NTGR	N/A	N/A	N/A
Verified Net Savings	95,431	15.95	N/A

[a] Ex ante gross savings sourced from AIC. Ex ante gross savings assume 0.80 CVR factor and 3% voltage reduction across the 180 measured circuits.
[b] There are no ex ante demand savings estimates for this program.

Factors driving program performance include the following:

- The VO Program exceeded its ex ante gross energy savings due to larger estimated percent changes in voltage than assumed values (3.00% ex ante compared to 3.81% verified average).
- The greater changes in voltage resulted in greater than expected energy savings and a gross realization rate of 127%.
- The VO Program achieved 15.95 MW of peak demand savings, representing 0.099 MW per circuit per hour on average.[17] Our team found that peak demand savings are highly variable by circuit.

4.1.1 Detailed Energy Savings

The following tables present average energy savings impacts across the 180 circuits calculated using the annual energy savings algorithm, which includes average annual customer energy use over the 2014–2016 timeframe, excluding exempt customers, CVR_f,[18] and percent change in voltage resulting from VO implementation relative to the baseline. We used a regression model to estimate a percent change in voltage for each circuit and applied that to the assumed baseline and CVR_f for each circuit. Table 5 summarizes the total results across all 180 circuits (see Appendix B for circuit-level percent change in voltage results).

[17] This was calculated as a weighted average on all circuits, using the annual peak demand as a weight.
[18] The estimate of the conservation voltage reduction factor, which represents the percent change in load for each percent change in voltage.

Table 5. Ex Ante and Verified Algorithmic Inputs and Associated Energy Savings

Metric	Annual Gross Energy Use (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
Ex Ante[a]	3,129,044	0.8	3.00%	75,097
Verified	3,129,044	0.8	3.81%	95,431
Realization Rate	100%	100%	127%	127%

[a] Ex ante gross savings sourced from AIC. Ex ante gross savings assumes 0.80 CVR factor and 3% voltage reduction across the 180 measured circuits.

4.1.2 Detailed Peak Demand Savings

We estimated peak demand savings using an individual regression analysis approach for each circuit given variability of load across circuits. The percent voltage reduction for each circuit was multiplied by the peak period CVR_f of 0.68 (deemed) and the annual peak demand baseline value (MW). The resulting annual demand savings were summed across circuits to determine the total peak demand reduction of 15.95 MW. The average percent change in voltage during peak demand periods was 3.05%, as shown in Table 6. AIC does not report ex ante demand savings, and therefore there are no ex ante savings or realization rates reported.

Table 6. 2021 VO Electric Peak Demand Savings by Measure

Metric	Peak Demand (MW)	CVR_f	Average Percent Change in Voltage	Peak Demand Savings (MW)
Verified	769.80	0.68	3.05%	15.95

4.1.3 Cumulative Persisting Annual Savings

Table 7 presents CPAS and WAML for the 2021 Voltage Optimization Program. The total verified gross savings for the Program are summarized, and CPAS in 2021–2024 and 2030 are presented.[19] The WAML for the Program is 15 years.

Table 7. 2021 VO Program CPAS and WAML

Evaluation Measure Category	Measure Life	First-Year Verified Gross Savings (MWh)	NTGR	CPAS - Verified Net Savings (MWh)							Lifetime Savings (MWh)
				2021	2022	2023	2024	…	2030	…	
Voltage Optimization – 2021 Cohort	15.0	95,431	N/A	95,431	95,431	95,431	95,431	…	95,431	…	1,431,469
2021 CPAS		**94,431**	**N/A**	**95,431**	**95,431**	**95,431**	**95,431**	**…**	**95,431**	**…**	**1,431,469**
Expiring 2021 CPAS				**0**	**0**	**0**	**0**	**…**	**0**	**…**	
Expired 2021 CPAS				**0**	**0**	**0**	**0**	**…**	**0**	**…**	
WAML	**15.0**										

4.1.4 Verification of Continued Operations

The evaluation team found that all the 10 randomly sampled 2019 circuits and the 36 randomly sampled 2020 circuits operated above the 90% threshold in 2021. For more information on the verification approach, see Appendix D.

[19] For further detail, including achieved CPAS in years not presented in this table, please see Appendix C of this report.

5. Conclusions and Recommendations

Based on the results of this evaluation, the evaluation team offers the following key findings and recommendations for VO moving forward:

- **Key Finding #1:** The VO Program continues to provide a substantial amount of energy savings to the AIC portfolio and exceed AIC's initial expectations for achieved savings.
- **Key Finding #2:** Average percent changes in voltage due to VO were 27% higher than planning values but have substantial variation across circuits (1.56%–5.23% average change in voltage). For 98 of the 180 circuits, the percent change in voltage was estimated to be larger than the planned value of 3.0%.
  - Recommendation: Consider updating planning values to reflect the percent change in voltage derived from evaluated values. As the pool of VO-enabled circuits continues to grow, consider incorporating an assessment of voltage variations by circuit characteristics. This approach can also support a more accurate assessment of the ex ante cost effectiveness for each circuit screened for inclusion in the program.
- **Key Finding #3:** In the 2020 and 2021 evaluations, AIC was able to provide Opinion Dynamics will complete operations logs for all circuits from previous years' evaluations for ongoing VO verification. In 2020, Opinion Dynamics and AIC agreed that since pulling full operations logs was too burdensome for AIC, that simply evaluating a sample would be sufficient.[20] However, since then AIC has been able to provide full operations logs for all circuits, Opinion Dynamics suggests revisiting this approach.
  - Recommendation: Since AIC has been able to provide operations logs for all circuits beyond the sample that Opinion Dynamics requests each year, we suggest that we consider studying and reporting on all the previous years' evaluated circuits to provide a complete evaluation of their ongoing status.

[20] See Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach memo here: https://ilsag.s3.amazonaws.com/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf.

Appendix A. 2021 Circuits Summary

Table 8 presents detailed circuit characteristics for VO circuits evaluated in 2021. This table includes the substation and circuit name for each circuit as well as various circuit characteristics that may, potentially, affect voltage reductions. AIC prioritized low-income customers as part of its VO deployment.[21]

Table 8. 2021 Evaluated VO Circuits

Substation	Circuit	Division	Line Length (Miles)	% Res.	% Comm.	% Large C&I	Voltage Level (kV)	Low-Income Customers
SUMMIT	349001	Division 6	5.003	85%	14%	1%	4.16	106
SUMMIT	349002	Division 6	5.003	85%	14%	1%	4.16	106
SUMMIT	349003	Division 6	5.003	85%	14%	1%	4.16	106
BARTONVILLE	A17021	Division 1	12.907	93%	7%	0%	7.62	661
EAST PEORIA	A97001	Division 1	17.625	90%	9%	1%	7.62	422
EAST PEORIA	A97002	Division 1	13.95	82%	18%	0%	7.62	581
EAST PEORIA	A97003	Division 1	19.231	92%	8%	0%	7.62	543
EAST PEORIA	A97004	Division 1	2.102	0%	74%	26%	7.62	NA
EAST PEORIA	A97005	Division 1	2.132	0%	97%	3%	7.62	NA
EAST PEORIA	A97006	Division 1	13.356	58%	38%	4%	7.62	31
UNIVERSITY	B65001	Division 1	11.093	91%	8%	1%	7.62	526
UNIVERSITY	B65003	Division 1	8.117	96%	4%	0%	7.62	502
UNIVERSITY	B65004	Division 1	10.412	92%	8%	0%	7.62	746
LINBERG	B73003	Division 1	32.25	89%	11%	0%	7.62	322
GROVELAND	B81001	Division 1	21.974	84%	15%	1%	7.62	132
GROVELAND	B81003	Division 1	38.917	96%	4%	0%	7.62	778
CLEAR LAKE	C36001	Division 3	20.513	90%	10%	0%	7.2	218
CLEAR LAKE	C36002	Division 3	32.399	95%	5%	0%	7.2	92
HAUK	C40001	Division 1	11.237	96%	4%	0%	7.62	242
HAUK	C40002	Division 1	13.444	92%	8%	0%	7.62	645
LIMIT	D31016	Division 3	56.628	94%	6%	0%	7.2	382
LIMIT	D31017	Division 3	13.661	89%	11%	0%	7.2	245
LIMIT	D31018	Division 3	40.666	85%	15%	1%	7.2	85
HALLOCK	D36001	Division 1	31.308	89%	11%	0%	7.62	390
HALLOCK	D36002	Division 1	47.75	84%	15%	0%	7.62	541
HALLOCK	D36003	Division 1	26.858	95%	5%	0%	7.62	278
PARK	D37001	Division 1	13.454	96%	3%	0%	7.62	659

[21] Ameren Illinois Voltage Optimization Low Income Prioritization Strategy, February 2019. Accessed at: https://s3.amazonaws.com/ilsag/AIC_VO_Low_Income_Prioritization_Strategy_February_2019_FINAL.pdf.

Substation	Circuit	Division	Line Length (Miles)	% Res.	% Comm.	% Large C&I	Voltage Level (kV)	Low-Income Customers
PARK	D37002	Division 1	0.831	0%	100%	0%	7.62	NA
PARK	D37003	Division 1	12.075	84%	15%	1%	7.62	197
PARK	D37004	Division 1	8.123	87%	13%	0%	7.62	321
HINES	D55001	Division 1	16.851	89%	11%	0%	7.62	713
HINES	D55002	Division 1	15.252	91%	9%	0%	7.62	609
HINES	D55003	Division 1	6.362	90%	9%	0%	7.62	299
FAIRMOUNT	D66001	Division 4	64.16	91%	9%	0%	7.2	344
FAIRMOUNT	D66004	Division 4	64.16	91%	9%	0%	7.2	344
BRADLEY	D81001	Division 1	11.733	94%	6%	0%	7.62	594
BRADLEY	D81002	Division 1	2.883	93%	6%	1%	7.62	87
BRADLEY	D81003	Division 1	5.063	83%	17%	0%	7.62	451
BRADLEY	D81004	Division 1	NA	NA	NA	NA	NA	NA
ST JOSEPH	E05002	Division 4	14.765	87%	12%	0%	7.2	272
WOOD RIVER 6TH ST	H11339	Division 5	11.012	94%	6%	0%	7.2	561
WOOD RIVER 6TH ST	H11340	Division 5	26.827	87%	12%	0%	7.2	489
WOOD RIVER PICKER ST	H22346	Division 5	10.505	96%	3%	0%	7.2	538
WOOD RIVER PICKER ST	H22349	Division 5	7.594	92%	8%	0%	7.2	522
CASEYVILLE BETHEL MINE	HA5430	Division 5	21.759	93%	7%	0%	7.2	273
CASEYVILLE BETHEL MINE	HA5432	Division 5	15.827	87%	11%	1%	7.2	89
ABINGDON	J01119	Division 1	35.537	92%	8%	0%	7.2	718
BLOOMINGTON MORRIS AVE	J58381	Division 3	16.972	93%	7%	0%	7.2	653
BLOOMINGTON PROSPECT	J63172	Division 3	11.847	88%	12%	0%	7.2	490
BLOOMINGTON PROSPECT	J63173	Division 3	18.88	97%	3%	0%	7.2	187
BLOOMINGTON PROSPECT	J63174	Division 3	10.844	77%	23%	0%	7.2	297
BELLEVILLE 65TH ST	J84123	Division 6	12.725	77%	23%	1%	7.2	159
BELLEVILLE 65TH ST	J84124	Division 6	13.766	99%	1%	0%	7.2	261
BELLEVILLE 65TH ST	J84145	Division 6	13.338	89%	11%	0%	7.2	428
BELLEVILLE 65TH ST	J84146	Division 6	10.135	83%	17%	0%	7.2	229
BELLEVILLE C ST	J89105	Division 6	11.086	92%	8%	0%	7.2	547
BELLEVILLE C ST	J89125	Division 6	9.858	94%	6%	0%	7.2	546
BELLEVILLE C ST	J89126	Division 6	10.777	96%	4%	0%	7.2	294
CENTERVILLE 138KV	K15205	Division 6	21.238	92%	8%	0%	7.2	579
CENTRALIA GEARY ST	K22173	Division 6	11.934	88%	11%	0%	7.2	434
CHESTER	K32915	Division 6	40.7	90%	9%	0%	7.2	312

Substation	Circuit	Division	Line Length (Miles)	% Res.	% Comm.	% Large C&I	Voltage Level (kV)	Low-Income Customers
CHESTER	K32916	Division 6	38.371	85%	15%	1%	7.2	244
COLLINSVILLE CLOVERLEAF	K46388	Division 5	42.382	92%	8%	0%	7.2	506
CHAMPAIGN BRADLEY	K69117	Division 4	23.728	92%	8%	0%	7.2	900
CHAMPAIGN MATTIS AVE	K74164	Division 4	15.364	90%	9%	1%	7.2	649
CHAMPAIGN MATTIS AVE	K74166	Division 4	9.142	93%	7%	0%	7.2	684
DECATUR NORTHGATE	L17101	Division 3	20.165	81%	18%	0%	7.2	240
DECATUR NORTHGATE	L17102	Division 3	16.561	88%	12%	0%	7.2	409
DECATUR NORTHGATE	L17104	Division 3	16.153	65%	34%	1%	7.2	234
DECATUR WALNUT GROVE	L35139	Division 3	15.011	88%	12%	0%	7.2	573
DUPO	L50214	Division 6	21.704	92%	7%	1%	7.2	422
DUPO	L50215	Division 6	22.374	91%	9%	0%	7.2	457
DUQUOIN	L59929	Division 6	27.161	96%	4%	0%	7.2	458
DANVILLE EAST FAIRCHILD ST	L70127	Division 4	11.343	89%	10%	1%	7.2	580
DANVILLE NORTH RHEA ST	L81141	Division 4	58.189	90%	10%	0%	7.2	693
DANVILLE WINTER AVE	L86175	Division 4	13.388	91%	9%	0%	7.2	593
EAST BELLEVILLE	L93135	Division 6	15.276	96%	4%	0%	7.2	478
EDWARDSVILLE SECOND STREET	M05368	Division 5	24.951	93%	7%	1%	7.2	183
ELDORADO	M09143	Division 6	49.215	89%	11%	0%	7.2	350
ELDORADO	M09144	Division 6	43.791	84%	15%	0%	7.2	620
ELDORADO	M09175	Division 6	30.929	91%	8%	0%	7.2	444
FAIRVIEW-DECATUR	M18131	Division 3	86.71	88%	11%	1%	7.2	683
GALESBURG NORTH SEMINARY ST	M41112	Division 1	16.542	93%	7%	0%	7.2	635
GALESBURG POWER HOUSE	M42107	Division 1	9.73	90%	10%	0%	7.2	677
GEORGETOWN INDIANOLA RD	M45211	Division 4	53.604	92%	8%	0%	7.2	546
GEORGETOWN INDIANOLA RD	M45212	Division 4	96.818	90%	10%	0%	7.2	656
GILLESPIE MACOUPIN ST	M47802	Division 5	54.933	93%	7%	0%	7.2	659
GRANITE CITY MARYLAND	M78325	Division 5	12.424	96%	4%	0%	7.2	387
HUDSON RURAL	N44215	Division 3	34.853	92%	8%	0%	7.2	115
JACKSONVILLE WEST SIDE	N54108	Division 2	16.245	83%	17%	1%	7.2	64
JACKSONVILLE WEST SIDE	N54213	Division 2	31.489	88%	12%	0%	7.2	377
JACKSONVILLE WEST SIDE	N54214	Division 2	39.715	95%	5%	0%	7.2	399
KNOXVILLE	N60181	Division 1	113.672	89%	10%	0%	7.2	668
KEWANEE SOUTH STREET	N70330	Division 1	61.524	91%	9%	0%	7.2	706
KEWANEE SOUTH STREET	N70331	Division 1	31.153	93%	7%	0%	7.2	635

Substation	Circuit	Division	Line Length (Miles)	% Res.	% Comm.	% Large C&I	Voltage Level (kV)	Low-Income Customers
MADISON INDUSTRIAL	P12290	Division 5	14.801	90%	9%	1%	7.2	569
MARSEILLES	P26283	Division 1	76.254	93%	7%	0%	7.2	601
NORMAL MAIN ST	P98190	Division 3	11.488	95%	5%	0%	7.2	487
NORMAL MAIN ST	P98191	Division 3	11.814	90%	9%	0%	7.2	559
NORMAL MAIN ST	P98192	Division 3	9.737	91%	9%	0%	7.2	729
NORMAL MAIN ST	P98193	Division 3	12.337	91%	9%	0%	7.2	736
NORMAL RTE 66	Q01280	Division 3	18.572	90%	10%	0%	7.2	294
NORMAL RTE 66	Q01281	Division 3	18.147	94%	6%	0%	7.2	656
NORMAL RTE 66	Q01282	Division 3	17.904	93%	7%	0%	7.2	825
NORTH CHAMPAIGN	Q06132	Division 4	11.199	86%	14%	0%	7.2	933
NORTH LASALLE	Q11516	Division 1	14.65	97%	3%	0%	7.2	612
NORTH STAUNTON	Q15844	Division 5	53.409	90%	10%	0%	7.2	647
NORTH VANDALIA	Q16867	Division 5	45.4	88%	12%	0%	7.2	602
NORTH VANDALIA	Q16868	Division 5	26.686	86%	13%	0%	7.2	144
OLD SHAWNEETOWN	Q28141	Division 6	23.644	85%	15%	0%	7.2	463
OQUAWKA RURAL	Q32170	Division 1	106.29	90%	10%	0%	7.2	833
OQUAWKA RURAL	Q32171	Division 1	67.455	81%	18%	1%	7.2	89
OTTAWA CACTUS ST	Q36410	Division 1	10.268	96%	4%	0%	7.2	655
PERCY	Q54908	Division 6	78.794	90%	10%	0%	7.2	799
ROSEWOOD HEIGHTS	Q80352	Division 5	15.932	91%	9%	0%	7.2	463
ROSEWOOD HEIGHTS	Q80353	Division 5	19.405	80%	19%	0%	7.2	315
SANDOVAL	Q85162	Division 6	66.712	88%	12%	0%	7.2	577
SOUTH BLOOMINGTON	R01153	Division 3	18.079	90%	10%	0%	7.2	NA
SOUTH FARNHAM ST-GALESBURG	R05114	Division 1	10.542	95%	5%	0%	7.2	665
SPRING VALLEY	R16511	Division 1	23.818	88%	12%	0%	7.2	602
TILTON ROSS LANE	R48165	Division 4	20.198	92%	8%	0%	7.2	597
TILTON ROSS LANE	R48166	Division 4	40.806	91%	9%	0%	7.2	238
TILTON ROSS LANE	R48167	Division 4	25.913	90%	10%	0%	7.2	763
TROY INDUSTRIAL	R53390	Division 5	26.821	90%	9%	0%	7.2	487
TROY INDUSTRIAL	R53391	Division 5	33.986	95%	4%	0%	7.2	240
TROY INDUSTRIAL	R53416	Division 5	28.818	93%	6%	0%	7.2	306
URBANA FIVE POINTS	R58961	Division 4	21.479	93%	7%	0%	7.2	968
URBANA GOODWIN	R59415	Division 4	5.057	91%	9%	0%	7.2	1387
URBANA GOODWIN	R59417	Division 4	3.553	90%	10%	0%	7.2	630

Substation	Circuit	Division	Line Length (Miles)	% Res.	% Comm.	% Large C&I	Voltage Level (kV)	Low-Income Customers
URBANA GOODWIN	R59421	Division 4	1.549	88%	11%	1%	4.16	68
URBANA PERKINS RD	R60551	Division 4	56.786	95%	5%	0%	7.2	621
URBANA PERKINS RD	R60552	Division 4	104.69	84%	16%	0%	7.2	692
URBANA PHILO RD	R61241	Division 4	20.473	94%	6%	0%	7.2	1472
URBANA WASHINGTON ST.	R66470	Division 4	13.219	93%	7%	0%	7.2	892
CAMBRIA	S09520	Division 6	35.98	91%	9%	0%	7.2	728
CARBONDALE PL HILL RD	S14509	Division 6	6.953	94%	6%	0%	7.2	896
CARBONDALE PL HILL RD	S14511	Division 6	15.526	91%	9%	0%	7.2	604
CARBONDALE UNIV MALL	S19543	Division 6	12.331	53%	44%	3%	7.2	59
CHRISTOPHER W(COELLO)	S25552	Division 6	39.528	88%	12%	0%	7.2	551
HARRISBURG S	S43512	Division 6	25.036	92%	8%	0%	7.2	437
HERRIN SW	S49549	Division 6	28.889	93%	7%	0%	7.2	574
MARION NW	S64501	Division 6	11.382	75%	24%	1%	7.2	145
MARION NW	S64502	Division 6	10.4	62%	31%	7%	7.2	64
MARION NW	S64505	Division 6	4.919	5%	81%	14%	7.2	NA
MARION NW	S64506	Division 6	10.172	70%	24%	6%	7.2	12
MURPHYSBORO	S86580	Division 6	32.038	93%	7%	0%	7.2	440
MURPHYSBORO NW	S88503	Division 6	32.555	95%	5%	0%	7.2	431
HARRISBURG E	T17581	Division 6	8.004	91%	9%	1%	7.2	145
CARBONDALE SW	T22507	Division 6	7.069	93%	7%	0%	7.2	458
CAMP POINT	U29001	Divison 2	47.209	83%	16%	0%	7.2	311
CANTON SPOON RIVER	U33509	Division 2	28.202	89%	10%	0%	7.2	325
CARROLLTON	U35511	Division 2	20.658	80%	20%	0%	7.2	301
CARROLLTON	U35554	Division 2	12.526	90%	10%	0%	7.2	284
CLAYTON E	U39541	Division 2	47.209	83%	16%	0%	7.2	311
MACOMB W	U97520	Division 2	23.442	86%	14%	0%	7.2	502
MEREDOSIA-SWITCHYARD	V04552	Division 2	12.344	87%	12%	1%	7.2	140
MEREDOSIA CITY	V05001	Division 2	NA	NA	NA	NA	NA	NA
NEW BERLIN	V14579	Division 2	49.896	87%	12%	0%	7.2	306
PITTSFIELD	V23522	Division 2	17.235	69%	30%	1%	7.2	143
PITTSFIELD	V23530	Division 2	43.867	90%	10%	0%	7.2	579
QUINCY 16ANDWELLS	V37537	Division 2	6.422	94%	6%	0%	7.2	348
QUINCY 16ANDWELLS	V37583	Division 2	4.511	85%	14%	0%	7.2	143
QUINCY 34ANDHARR	V44504	Division 2	43.743	95%	5%	0%	7.2	439

Substation	Circuit	Division	Line Length (Miles)	% Res.	% Comm.	% Large C&I	Voltage Level (kV)	Low-Income Customers
NIOTA	W03570	Division 2	34.136	85%	15%	0%	7.2	291
BRIDGEPORT W	X23516	Division 4	30.056	84%	16%	0%	7.2	284
CHARLESTON	X29547	Division 4	22.004	82%	18%	0%	7.2	439
CHARLESTON E	X30506	Division 4	12.542	91%	9%	1%	7.2	403
CHARLESTON E	X30527	Division 4	2.206	17%	50%	33%	7.2	NA
CHARLESTON HAYES ST.	X34531	Division 4	6.246	90%	10%	0%	7.2	438
EFFINGHAM N	X60595	Division 4	12.47	81%	18%	1%	7.2	229
EFFINGHAM N	X60596	Division 4	10.778	95%	5%	0%	7.2	199
EFFINGHAM N	X60598	Division 4	28.566	80%	19%	1%	7.2	150
GILMAN S	X77543	Division 4	35.855	83%	16%	1%	7.2	191
HOOPESTON S	X83541	Division 4	11.451	83%	17%	0%	7.2	316
MATTOON NW	Y11556	Division 4	9.997	97%	3%	0%	7.2	359
EAST PANA	Y45504	Division 4	31.134	89%	11%	0%	7.2	321
RANTOUL	Y60593	Division 4	40.902	87%	13%	0%	7.2	220
TAYLORVILLE SHUMWAY	Y91500	Division 4	9.524	94%	6%	0%	7.2	372
TOLONO	Y97512	Division 4	11.1	91%	9%	0%	7.2	257
WATSEKA E	Z06537	Division 4	13.114	89%	10%	1%	7.2	409

Source: AIC

Appendix B. Detailed Impact Analysis Methodology

Data Ingestion and Review

Opinion Dynamics used the following data to perform the energy and peak demand savings evaluation: (1) advanced metering infrastructure (AMI) data extracts; (2) supervisory control and data acquisition (SCADA) extracts; (3) VO status and operation logs; (4) circuit characteristics; and (5) hourly weather data.

- **AMI data extracts.** AIC provided AMI data containing hourly demand (kWh), instantaneous voltage, and average instantaneous voltage at four different base voltages. AMI data is the preferred source for all evaluations in Illinois and measures consumption at the customer meter rather than the circuit level. Because there may be over 1,000 AMI meters on a given circuit, AIC provided average normalized voltage and kWh data. For a given circuit, the AMI data reflects normalized voltage based on the voltage class (e.g., 120V, 240V, 480V) where each AMI meter was located on the circuit.
- **SCADA[22] data extracts.** Two circuits did not have sufficient AMI data for the evaluation. As a result, the evaluation team requested SCADA data to estimate change in voltage for those circuits. SCADA data extracts contain hourly usage (MW), voltage (kV), and reactive power (MR) readings by phase. The AIC team formatted the SCADA voltage data to match the AMI data.
- **System operation log.** This file contains the VO "on' and "off" schedule, as well as critical system operation events that could cause data anomalies such as outages. AIC provided a log with a summary tab containing circuit-level historical milestones and additional circuit-specific tabs with more detailed information. Within the operations log, the evaluation team flagged certain time frames as excludable, adhering to guidance in the Verification and Exclusions memo: Circuit Outage, Repair/Maintenance, Switching, and Technology Events.[23]
- **Circuit characteristics.** This dataset for all circuits planned for VO deployment (n=1,047)[24] contained descriptive information about the circuits as well as usage data from 2014–2016 because VO remains a key input in the algorithmic approach as it establishes the algorithmic baseline.
- **Hourly weather data.** The evaluation team sourced weather data from the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information, which we mapped to circuits using GPS coordinates. We then calculated the cooling and heating degree hours, using base temperatures of 75°F and 65°F[25], respectively, to generate the weather parameters used in modeling.

Energy Savings

Data Cleaning

We summarize the results of our data cleaning effort for the 2021 impacts below (see Table 9). The following data cleaning steps were conducted prior to modeling:

- **Remove duplicate observations:** Observations with duplicated values across all variables were flagged and removed from the analysis.

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[22] SCADA is an acronym for supervisory control and data acquisition, a computer system for gathering and analyzing real time data.
[23] See Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach memo here: https://ilsag.s3.amazonaws.com/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf.
[24] While an initial pool of 1,047 circuits was selected for VO deployment, the specific circuits are subject to change based on feasibility of deployment. If substitutions are made to the eligible pool, AIC will inform Opinion Dynamics of those changes.
[25] These base temperatures are commonly used in the industry.

- **Time periods without weather data:** We downloaded weather data from NOAA. We used circuit longitude and latitude to find the weather station that was closest to each circuit's location. There are instances where the weather data for a particular weather station was not recorded, and so we removed these time periods from the analysis.
- **Negative and zero values:** Negative and zero values in kV and MW data were flagged and removed from the analysis.
- **Outliers:** Outliers were screened on a circuit-by-circuit basis. Outliers are defined as hourly values that are greater than three times the standard deviation from the mean kV or MW for that specific circuit. Outliers on kV and MW were flagged and removed from the analysis.
- **Excludable time periods:** In some circumstances it is best practice, or it is required, to disable VO to support system changes, growth, outages, and maintenance (both planned and unplanned). AIC has indicated that a subset of VO events should be excluded in this analysis. The Illinois Commerce Commission (ICC) verified whether or not specific VO events could be excluded from the analysis. Types of VO events that were approved for exclusion were those for which (1) there was a circuit outage for any reason; (2) the circuit was under repair or maintenance, causing VO to be disabled; (3) VO was disabled due to any necessary switching event; (4) the circuit had experienced a failure in information or communication technology; and (5) any event was flagged for the worldwide pandemic or outages ordered by civil authorities.
- **"On" in pre-period:** To construct a pre-period, "On" events were flagged and removed in 2020. This includes natural "On" events as well as those occurring during "On" and "Off" testing.

Table 9 provides a summary of the data cleaning results for this analysis. Results include all 180 circuits within the analysis. The primary driver for removing observations were occurrences where the VO system was turned "On" in the pre-period (1.6% of total observations), followed by occurrences when the VO system was turned "Off" for an excludable event (1.2% of total observations). Overall, 4% of observations were dropped. No circuits were removed from the energy savings analysis due to data insufficiency.

Table 9. Data Cleaning Results for 2021 VO Energy Savings Impacts

Step	Circuits	Records	Change	% Change
Initial	180	3,171,110	NA	NA
Exact Duplicates	180	3,162,539	8,571	0.3%
Time Periods without Weather Data	180	3,140,095	22,444	0.7%
kV Less than or Equal to 0	180	3,129,754	10,341	0.3%
Outliers	180	3,129,714	40	0.0%
On in Pre-Period	180	3,078,365	51,349	1.6%
Exclusion Time Periods	180	3,041,812	36,553	1.2%
Total	**180**	**3,041,812**	**129,298**	**4.1%**

Modeling Percent Change in Voltage for Energy Savings

To develop a pre-period baseline for this evaluation, the evaluation team removed 'On' periods in 2020. As a result, the baseline reflects 'Off' periods and voltage levels without VO. The post-period of interest is 2021, where all circuits are active. Aside from non-excludable 'Off' periods, the post-period consists of largely 'On' events. The evaluation team used this structure to fit individual models on each circuit.

To estimate changes in voltage, we used a regression model described in Equation 3.

Equation 3. Voltage Reductions Model

$$kV_{it} = \alpha + \beta_1 VO_t + \beta_2 cdh_t + \beta_3 hdh_t + \beta_4 Weekend_t + \beta_5 VO_t * cdh_t + \beta_6 VO_t * hdh_t + \beta_7 VO_t * Weekend_t + \varepsilon_{it}$$

Where

- kV_{it} = Kilovolts for circuit *i* at time *t*
- α = model intercept
- β_x = coefficients
- VO_t = set of indicator variables on circuit *i* at time t for VO status where VO status can be fully enabled (VO=1) or fully disabled (VO=0)
- cdh_t = the number of cooling degree-hours at time *t*
- hdh_t = the number of heating degree-hours at time *t*
- $Weekend_t$ = indicator variable for weekend (weekend = 1) or weekday (weekend = 0)
- ε_{it} = error term

Calculating Annual Energy Savings

The IL-TRM prescribes an algorithmic approach to evaluating VO energy savings. The algorithmic approach combines deemed parameter values with measured savings in voltage to calculate energy savings. Since we apply the estimated change in voltage to the circuit-level annual usage, the results are effectively annualized for the entire year.

The algorithm used for the VO energy savings evaluation is shown in Equation 4.

Equation 4. AIC VO Energy Savings Algorithm

$$Annual\ Energy\ Savings_i = Annual\ Energy\ Use_{2014-2016_i} * CVR_f * \%\Delta V_i$$

where

- $Annual\ Energy\ Use_{2014-2016_i}$ = the average annual customer energy use for circuit *i* over the 2014–2016 timeframe, excluding the exempt customers.
- CVR_f = the estimate of the conservation voltage reduction factor (deemed as 0.80), defined as the percent change in energy usage divided by the percent change in voltage; and
- $\%\Delta V_i$ = the percent change in voltage for circuit *i* resulting from VO implementation relative to the pre-period, using a regression model to control for exogenous factors that may contribute to changes in voltage (e.g., weather).

Detailed Circuit Results: Energy Savings

Table 10 provides each algorithmic input by each circuit, as well as the total estimated savings. For 98 of the 180 circuits, the percent change in voltage was estimated to be larger than the planned value of 3.0%. The overall average percent change in voltage was 3.81%.[26]

Table 10. Ex Ante and Verified Algorithmic Inputs and Associated Energy Savings by Circuit

Circuit	Annual Gross Energy Use (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
349001	10,959.81	0.8	1.56%	137
349002	5,166.67	0.8	1.75%	72
349003	4,166.67	0.8	2.04%	68
A17021	15,812.67	0.8	4.67%	591
A97001	18,006.30	0.8	2.57%	371
A97002	16,187.79	0.8	2.74%	355
A97003	18,196.71	0.8	3.60%	524
A97004	6,310.11	0.8	2.62%	132
A97005	2,006.82	0.8	2.41%	39
A97006	31,023.20	0.8	4.33%	1,075
B65001	18,627.44	0.8	3.70%	551
B65003	11,582.81	0.8	3.61%	334
B65004	20,333.35	0.8	3.72%	605
B73003	13,007.05	0.8	4.48%	466
B81001	18,196.73	0.8	3.98%	579
B81003	22,127.00	0.8	3.47%	615
C36001	8,295.39	0.8	3.81%	253
C36002	8,671.19	0.8	3.28%	227
C40001	11,877.60	0.8	3.34%	318
C40002	20,061.98	0.8	4.12%	662
D31016	13,042.22	0.8	4.56%	475
D31017	14,572.85	0.8	4.03%	470
D31018	9,241.43	0.8	3.21%	237
D36001	23,711.29	0.8	4.59%	871
D36002	23,366.20	0.8	4.07%	760
D36003	11,798.65	0.8	4.16%	393
D37001	18,384.14	0.8	4.59%	676
D37002	239.48	0.8	3.33%	6
D37003	30,429.01	0.8	3.89%	947
D37004	11,115.34	0.8	4.25%	378
D55001	21,163.82	0.8	3.52%	595
D55002	19,738.45	0.8	3.57%	563
D55003	9,890.30	0.8	3.57%	282
D66001	16,958.33	0.8	4.41%	598

[26] Average percent change in voltage is weighted by annual gross energy use (MWh).

Circuit	Annual Gross Energy Use (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
D66004	17,610.30	0.8	3.25%	458
D81001	31,517.34	0.8	3.41%	859
D81002	2,129.19	0.8	3.38%	58
D81003	11,942.61	0.8	3.33%	318
D81004	20,197.70	0.8	3.66%	592
E05002	17,602.18	0.8	4.15%	584
H11339	16,516.83	0.8	3.11%	412
H11340	33,426.13	0.8	3.16%	846
H22346	14,467.98	0.8	2.90%	335
H22349	12,732.20	0.8	3.60%	367
HA5430	10,319.93	0.8	4.48%	370
HA5432	14,445.50	0.8	3.32%	383
J01119	21,078.97	0.8	3.52%	594
J58381	16,893.26	0.8	5.23%	707
J63172	23,750.02	0.8	3.77%	716
J63173	17,088.93	0.8	3.74%	511
J63174	20,703.25	0.8	4.82%	798
J84123	10,717.31	0.8	3.92%	336
J84124	12,322.57	0.8	4.40%	434
J84145	15,149.00	0.8	4.29%	519
J84146	15,094.04	0.8	3.30%	398
J89105	13,456.06	0.8	4.69%	505
J89125	14,053.33	0.8	3.56%	400
J89126	13,194.36	0.8	4.20%	444
K15205	13,566.04	0.8	3.61%	392
K22173	21,636.46	0.8	4.03%	697
K32915	19,887.10	0.8	3.93%	626
K32916	25,694.28	0.8	3.91%	804
K46388	27,336.57	0.8	4.02%	879
K69117	24,767.07	0.8	4.29%	850
K74164	35,305.71	0.8	3.94%	1,113
K74166	15,317.36	0.8	4.50%	552
L17101	19,890.15	0.8	4.50%	716
L17102	20,851.33	0.8	3.54%	591
L17104	26,472.40	0.8	4.46%	945
L35139	20,193.14	0.8	3.96%	640
L50214	18,608.10	0.8	4.30%	640
L50215	15,645.46	0.8	3.53%	442
L59929	15,219.92	0.8	4.69%	571
L70127	21,988.31	0.8	3.95%	694
L81141	31,187.73	0.8	3.97%	990
L86175	14,371.75	0.8	4.01%	461

Circuit	Annual Gross Energy Use (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
L93135	12,924.84	0.8	4.64%	480
M05368	12,765.59	0.8	3.92%	401
M09143	12,716.55	0.8	4.38%	446
M09144	26,211.54	0.8	4.29%	899
M09175	18,944.64	0.8	3.47%	526
M18131	31,201.97	0.8	3.69%	922
M41112	21,980.88	0.8	3.83%	674
M42107	20,073.80	0.8	2.72%	437
M45211	17,622.22	0.8	3.67%	518
M45212	21,642.74	0.8	4.35%	752
M47802	18,951.43	0.8	3.40%	515
M78325	12,421.29	0.8	4.21%	419
N44215	10,892.27	0.8	4.46%	388
N54108	22,114.96	0.8	4.43%	785
N54213	31,989.31	0.8	3.46%	886
N54214	22,146.57	0.8	4.65%	824
N60181	30,360.43	0.8	3.86%	938
N70330	23,968.09	0.8	3.15%	605
N70331	14,752.51	0.8	3.46%	409
P12290	52,750.49	0.8	2.44%	1,029
P26283	20,711.79	0.8	3.58%	593
P98190	16,462.83	0.8	4.64%	612
P98191	19,634.71	0.8	4.20%	659
P98192	15,320.25	0.8	4.20%	515
P98193	22,375.14	0.8	3.69%	660
Q01280	19,052.46	0.8	4.26%	649
Q01281	17,733.92	0.8	3.00%	425
Q01282	23,542.11	0.8	3.76%	709
Q06132	26,164.89	0.8	3.47%	726
Q11516	16,952.39	0.8	4.32%	585
Q15844	22,057.03	0.8	3.57%	630
Q16867	19,614.81	0.8	4.08%	641
Q16868	11,293.85	0.8	4.52%	408
Q28141	13,428.97	0.8	4.57%	490
Q32170	15,328.19	0.8	3.37%	413
Q32171	12,752.29	0.8	4.00%	408
Q36410	11,957.64	0.8	3.46%	331
Q54908	14,695.09	0.8	4.39%	516
Q80352	15,661.06	0.8	3.55%	445
Q80353	21,895.23	0.8	2.42%	424
Q85162	21,215.65	0.8	3.87%	657
R01153	28,917.52	0.8	4.04%	934

Circuit	Annual Gross Energy Use (MWh)	CVR$_f$	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
R05114	11,733.89	0.8	3.73%	350
R16511	19,172.52	0.8	3.88%	596
R48165	32,660.15	0.8	3.17%	829
R48166	12,008.21	0.8	4.64%	446
R48167	23,209.19	0.8	3.78%	702
R53390	23,863.15	0.8	3.73%	713
R53391	24,105.13	0.8	3.78%	729
R53416	19,190.49	0.8	4.13%	633
R58961	28,089.38	0.8	4.27%	960
R59415	24,374.53	0.8	3.55%	692
R59417	18,529.26	0.8	4.55%	674
R59421	10,090.12	0.8	4.73%	382
R60551	24,759.61	0.8	3.48%	689
R60552	30,901.71	0.8	4.29%	1,062
R61241	32,300.51	0.8	4.11%	1,061
R66470	19,188.45	0.8	4.17%	640
S09520	18,172.39	0.8	4.16%	605
S14509	13,440.73	0.8	3.83%	412
S14511	15,939.67	0.8	3.56%	454
S19543	15,057.42	0.8	3.44%	414
S25552	16,348.69	0.8	4.42%	579
S43512	13,880.93	0.8	3.33%	370
S49549	16,521.36	0.8	4.02%	532
S64501	12,549.21	0.8	3.40%	342
S64502	25,207.51	0.8	3.38%	682
S64505	13,212.57	0.8	2.46%	260
S64506	16,788.77	0.8	2.85%	383
S86580	17,750.47	0.8	4.53%	643
S88503	15,450.58	0.8	4.13%	511
T17581	13,164.85	0.8	4.84%	510
T22507	14,081.48	0.8	3.51%	395
U29001	5,708.33	0.8	3.56%	162
U33509	14,927.08	0.8	3.04%	363
U35511	10,577.39	0.8	4.40%	372
U35554	13,032.25	0.8	4.36%	455
U39541	11,367.88	0.8	4.03%	367
U97520	18,098.62	0.8	4.22%	611
V04552	8,586.58	0.8	4.12%	283
V05001	4,083.33	0.8	4.54%	148
V14579	18,049.26	0.8	3.93%	567
V23522	13,715.07	0.8	3.86%	423
V23530	19,080.43	0.8	3.99%	609

Circuit	Annual Gross Energy Use (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
V37537	10,279.14	0.8	4.87%	401
V37583	11,305.57	0.8	4.86%	440
V44504	24,060.70	0.8	4.93%	948
W03570	9,811.78	0.8	4.25%	334
X23516	9,659.12	0.8	2.97%	229
X29547	16,604.75	0.8	2.88%	382
X30506	14,626.50	0.8	1.90%	222
X30527	14,114.44	0.8	3.59%	405
X34531	15,288.35	0.8	2.51%	306
X60595	19,994.51	0.8	2.93%	469
X60596	10,737.93	0.8	3.62%	311
X60598	15,040.79	0.8	4.43%	533
X77543	14,228.12	0.8	4.44%	506
X83541	13,713.80	0.8	3.06%	336
Y11556	11,446.20	0.8	3.59%	328
Y45504	12,050.48	0.8	3.99%	385
Y60593	9,982.19	0.8	3.48%	278
Y91500	9,795.66	0.8	2.96%	232
Y97512	11,662.33	0.8	3.55%	331
Z06537	13,855.67	0.8	3.53%	392
Total	**3,129,043.81**	**0.8**	**3.81%**	**95,431**

Our approach is designed to be the most rigorous possible with the data available. We employed regression analysis controlling for exogenous factors, such as weather, as documented in the evaluation plan. To validate our model, we evaluated a range of model specifications and selected the best fit determined by model diagnostics (R^2 and adjusted R^2). A detailed binder provides the coefficient estimates and model fit statistics for each circuit-level model. All modeled circuit results were statistically significant at the 90% confidence level.

Measure Life and Cumulative Persisting Annual Savings

The FEJA-defined measure life of 15 years was applied for this measure.[27]

Peak Demand Savings

Data Cleaning

Data cleaning for the peak demand analysis included all of the steps undertaken for the energy savings model, plus the following additional cleaning steps:

- **Include Peak Period Only:** The peak demand model includes only observations during the peak period, defined as the hours of 1:00 p.m.–5:00 p.m. (CDT) on non-holiday weekdays between June and August.

[27] 220 ILCS 5/8-103B(b-20) of Illinois Senate Bill 2814 (the Future Energy Jobs Act).

- **Less than 20 Days in Peak Period:** Circuits with less than 20 days in the peak period were removed from the analysis.
- **No Baseline Peak Period:** Circuits missing the baseline peak period were removed from the analysis.

Table 11 provides a summary of the data cleaning results for this analysis. After subsetting on the peak demand period, the data cleaning reduced the total number of observations by 14.84%.

Table 11. Data Cleaning Results for Peak Demand Savings

Step	Circuits	Records	Change	% Change
Initial Count	180	3,041,812	NA	NA
Peak Days	180	541,569	2,500,243	82.20%
Less than 20 days in Peak Period	180	541,569	0	0.00%
No Baseline in Peak Period	180	541,569	0	0.00%
Peak Hours	180	90,220	451,349	14.84%
Total	**180**	**90,220**	**2,951,592**	**97.03%**

Modeling Percent Change in Voltage for Demand Savings

To develop a baseline, the evaluation team took the cleaned data used for annual impacts and subset to the peak period. Individual models were run by circuit, and savings were aggregated similarly to the annual savings, taking into account the peak CVR_f and the annual peak demand (MW). As with the energy savings model, the demand savings model uses 2020 as the pre-period. The model is run only on peak hours within the summer peak period subset.

To estimate changes in voltage, we used a regression model described in Equation 5.

Equation 5. Voltage Reductions Model

$$kV_{it} = \alpha + \beta_1 VO_t + \beta_2 cdh_t + \beta_3 VO_t * cdh_t + + \varepsilon_{it}$$

where

- kV_{it} = Kilovolts for circuit *i* at time *t*
- α = model intercept
- β_x = coefficients
- VO_t = set of indicator variables on circuit *i* at time t for VO status where VO status can be fully enabled (VO=1) or fully disabled (VO=0)
- cdh_t = the number of cooling degree-hours at time *t*
- ε_{it} = error term

Calculating Peak Demand Savings

Peak demand savings are also estimated with an algorithmic approach. The peak period is defined as 1:00 p.m.–5:00 p.m. (CDT) on non-holiday weekdays from June 1–August 31.[28]

[28] Illinois Technical Reference Manual for Energy Efficiency, Version 9.0, Volume 1, Section 3.7.

The algorithm used for the VO peak demand evaluation is shown in Equation 6.

Equation 6. AIC VO Peak Demand Savings Algorithm

$$Peak\ Demand\ Savings_i = Avg\ Peak\ Demand_{2014-2016_{i,PEAK}} * CVR_{f,PEAK} * \%\Delta V_{i,PEAK}$$

where

- $Avg\ Peak\ Demand_{2014-2016_{i,PEAK}}$ = the demand in the peak hour for circuit *i* over the 2014–2016 timeframe during the peak period adjusted by a calibration factor that captures the relationship between peak demand and average demand in the peak period, excluding exempt customers [29];
- $CVR_{f,PEAK}$ = the estimate of the peak conservation voltage reduction factor (deemed as 0.68), defined as the percent change in energy usage divided by the percent change in voltage during the peak period; and
- $\%\Delta V_{i,PEAK}$ = the percent change in voltage for circuit *i* resulting from VO implementation relative to the peak hours of the pre-period, using a regression model to control for exogenous factors that may contribute to changes in voltage (e.g., weather). Per the guidance in the TRM, this is to be calculated in the same manner as energy savings but with the intention of measuring peak demand impact rather than total energy savings.

Detailed Circuit Results: Peak Demand Savings

Table 12 provides each algorithmic input by each circuit, as well as the total estimated peak demand savings. The overall peak demand voltage savings was 3.05%.[30]

Table 12. Ex Ante and Verified Algorithmic Inputs and Associated Energy Savings by Circuit

Circuit	Annual Peak Demand (MW)	CVRf (peak)	Average Percent Change in Peak Voltage	Annual Demand Savings (MW)
349001	2.60	0.68	1.19%	0.02
349002	1.37	0.68	1.95%	0.02
349003	0.87	0.68	1.92%	0.01
A17021	4.05	0.68	3.52%	0.10
A97001	5.71	0.68	1.63%	0.06
A97002	6.49	0.68	1.65%	0.07
A97003	5.37	0.68	2.71%	0.10
A97004	1.85	0.68	1.50%	0.02
A97005	0.46	0.68	1.46%	0.00
A97006	6.18	0.68	3.95%	0.17
B65001	5.15	0.68	2.58%	0.09
B65003	4.34	0.68	2.34%	0.07
B65004	4.61	0.68	2.46%	0.08
B73003	3.75	0.68	3.61%	0.09
B81001	4.48	0.68	2.47%	0.08
B81003	6.61	0.68	2.34%	0.11

[29] Peak demand was unavailable for four circuits for the period 2014–2016. Per AIC's guidance we substituted peak demand from 2017–2019.

[30] Average percent change in voltage is weighted by annual peak demand (MW).

Circuit	Annual Peak Demand (MW)	CVRf (peak)	Average Percent Change in Peak Voltage	Annual Demand Savings (MW)
C36001	2.56	0.68	2.42%	0.04
C36002	2.72	0.68	3.17%	0.06
C40001	2.20	0.68	3.74%	0.06
C40002	3.60	0.68	3.87%	0.09
D31016	4.35	0.68	3.71%	0.11
D31017	3.91	0.68	2.11%	0.06
D31018	2.33	0.68	1.97%	0.03
D36001	6.30	0.68	3.45%	0.15
D36002	7.44	0.68	2.80%	0.14
D36003	3.43	0.68	2.77%	0.06
D37001	5.73	0.68	2.77%	0.11
D37002	1.71	0.68	4.24%	0.05
D37003	6.40	0.68	3.24%	0.14
D37004	2.76	0.68	4.20%	0.08
D55001	5.27	0.68	2.38%	0.09
D55002	4.79	0.68	2.41%	0.08
D55003	2.56	0.68	2.38%	0.04
D66001	3.97	0.68	4.00%	0.11
D66004	4.55	0.68	2.41%	0.07
D81001	6.00	0.68	2.53%	0.10
D81002	1.43	0.68	2.64%	0.03
D81003	3.03	0.68	2.52%	0.05
D81004	5.50	0.68	2.44%	0.09
E05002	4.74	0.68	2.66%	0.09
H11339	4.73	0.68	2.37%	0.08
H11340	8.59	0.68	2.82%	0.16
H22346	3.79	0.68	1.66%	0.04
H22349	3.27	0.68	1.82%	0.04
HA5430	2.97	0.68	3.78%	0.08
HA5432	4.09	0.68	3.05%	0.08
J01119	3.42	0.68	1.82%	0.04
J58381	4.71	0.68	4.29%	0.14
J63172	5.70	0.68	2.62%	0.10
J63173	5.67	0.68	2.52%	0.10
J63174	5.57	0.68	3.54%	0.13
J84123	2.80	0.68	4.33%	0.08
J84124	3.98	0.68	3.47%	0.09
J84145	4.37	0.68	2.94%	0.09
J84146	3.84	0.68	2.89%	0.08
J89105	3.20	0.68	3.73%	0.08
J89125	4.01	0.68	2.55%	0.07
J89126	4.10	0.68	3.18%	0.09

Circuit	Annual Peak Demand (MW)	CVRf (peak)	Average Percent Change in Peak Voltage	Annual Demand Savings (MW)
K15205	3.45	0.68	3.35%	0.08
K22173	5.07	0.68	2.60%	0.09
K32915	4.77	0.68	3.12%	0.10
K32916	5.20	0.68	3.49%	0.12
K46388	7.93	0.68	2.58%	0.14
K69117	6.29	0.68	3.47%	0.15
K74164	7.94	0.68	3.35%	0.18
K74166	3.27	0.68	3.74%	0.08
L17101	5.22	0.68	3.24%	0.11
L17102	5.95	0.68	1.78%	0.07
L17104	6.18	0.68	3.42%	0.14
L35139	4.84	0.68	2.10%	0.07
L50214	4.33	0.68	3.83%	0.11
L50215	5.04	0.68	2.79%	0.10
L59929	4.26	0.68	3.97%	0.12
L70127	4.30	0.68	2.64%	0.08
L81141	7.05	0.68	3.30%	0.16
L86175	3.64	0.68	2.24%	0.06
L93135	4.18	0.68	4.30%	0.12
M05368	4.06	0.68	4.10%	0.11
M09143	3.71	0.68	3.77%	0.10
M09144	6.40	0.68	2.72%	0.12
M09175	4.88	0.68	2.92%	0.10
M18131	4.60	0.68	2.38%	0.07
M41112	5.71	0.68	2.95%	0.11
M42107	4.50	0.68	1.14%	0.03
M45211	4.04	0.68	3.09%	0.08
M45212	5.21	0.68	3.46%	0.12
M47802	4.11	0.68	2.10%	0.06
M78325	4.01	0.68	3.27%	0.09
N44215	3.37	0.68	3.43%	0.08
N54108	4.05	0.68	3.98%	0.11
N54213	8.15	0.68	2.67%	0.15
N54214	6.58	0.68	4.07%	0.18
N60181	7.53	0.68	2.46%	0.13
N70330	4.98	0.68	2.36%	0.08
N70331	4.25	0.68	2.57%	0.07
P12290	4.31	0.68	2.44%	0.07
P26283	6.04	0.68	2.43%	0.10
P98190	3.97	0.68	3.69%	0.10
P98191	4.97	0.68	3.46%	0.12
P98192	3.69	0.68	3.21%	0.08

Circuit	Annual Peak Demand (MW)	CVRf (peak)	Average Percent Change in Peak Voltage	Annual Demand Savings (MW)
P98193	5.24	0.68	2.90%	0.10
Q01280	5.53	0.68	3.37%	0.13
Q01281	5.27	0.68	2.11%	0.08
Q01282	6.67	0.68	2.59%	0.12
Q06132	4.90	0.68	2.87%	0.10
Q11516	5.21	0.68	2.51%	0.09
Q15844	5.79	0.68	2.13%	0.08
Q16867	4.43	0.68	2.55%	0.08
Q16868	2.67	0.68	3.64%	0.07
Q28141	3.34	0.68	3.93%	0.09
Q32170	3.03	0.68	2.12%	0.04
Q32171	2.05	0.68	3.67%	0.05
Q36410	3.83	0.68	1.75%	0.05
Q54908	4.19	0.68	3.70%	0.11
Q80352	3.93	0.68	2.30%	0.06
Q80353	6.30	0.68	2.29%	0.10
Q85162	4.93	0.68	4.10%	0.14
R01153	5.70	0.68	2.60%	0.10
R05114	2.87	0.68	3.33%	0.06
R16511	5.47	0.68	2.37%	0.09
R48165	6.30	0.68	1.42%	0.06
R48166	2.72	0.68	4.56%	0.08
R48167	5.93	0.68	2.20%	0.09
R53390	6.55	0.68	2.89%	0.13
R53391	6.25	0.68	3.16%	0.13
R53416	5.97	0.68	3.03%	0.12
R58961	6.96	0.68	4.35%	0.21
R59415	4.93	0.68	4.36%	0.15
R59417	3.16	0.68	4.89%	0.11
R59421	1.50	0.68	4.96%	0.05
R60551	6.64	0.68	2.81%	0.13
R60552	7.29	0.68	3.82%	0.19
R61241	8.13	0.68	4.23%	0.23
R66470	5.12	0.68	3.79%	0.13
S09520	4.51	0.68	4.49%	0.14
S14509	2.85	0.68	4.11%	0.08
S14511	3.49	0.68	3.65%	0.09
S19543	2.54	0.68	1.89%	0.03
S25552	3.88	0.68	4.34%	0.11
S43512	3.57	0.68	2.59%	0.06
S49549	3.88	0.68	3.60%	0.09
S64501	3.29	0.68	3.96%	0.09

Circuit	Annual Peak Demand (MW)	CVRf (peak)	Average Percent Change in Peak Voltage	Annual Demand Savings (MW)
S64502	4.69	0.68	4.35%	0.14
S64505	2.01	0.68	4.67%	0.06
S64506	3.02	0.68	4.80%	0.10
S86580	2.88	0.68	3.99%	0.08
S88503	3.96	0.68	3.55%	0.10
T17581	3.38	0.68	4.16%	0.10
T22507	3.50	0.68	2.57%	0.06
U29001	1.24	0.68	2.10%	0.02
U33509	3.95	0.68	1.94%	0.05
U35511	2.73	0.68	3.15%	0.06
U35554	2.96	0.68	3.09%	0.06
U39541	3.82	0.68	3.87%	0.10
U97520	3.58	0.68	3.78%	0.09
V04552	2.33	0.68	3.61%	0.06
V05001	1.06	0.68	3.60%	0.03
V14579	4.63	0.68	2.76%	0.09
V23522	2.86	0.68	3.55%	0.07
V23530	4.99	0.68	2.80%	0.10
V37537	2.85	0.68	4.24%	0.08
V37583	2.74	0.68	3.98%	0.07
V44504	4.61	0.68	4.44%	0.14
W03570	2.17	0.68	4.33%	0.06
X23516	2.16	0.68	2.29%	0.03
X29547	3.79	0.68	2.35%	0.06
X30506	3.12	0.68	0.92%	0.02
X30527	3.18	0.68	5.20%	0.11
X34531	3.17	0.68	2.78%	0.06
X60595	4.08	0.68	3.44%	0.10
X60596	2.99	0.68	3.82%	0.08
X60598	4.01	0.68	4.80%	0.13
X77543	2.68	0.68	4.02%	0.07
X83541	2.90	0.68	2.18%	0.04
Y11556	3.43	0.68	2.37%	0.06
Y45504	3.10	0.68	2.45%	0.05
Y60593	2.41	0.68	2.61%	0.04
Y91500	3.20	0.68	3.38%	0.07
Y97512	3.21	0.68	3.40%	0.07
Z06537	3.57	0.68	3.03%	0.07
Total	**769.80**	**0.68**	**3.05%**	**15.95**

Our approach is designed to be the most rigorous possible with the data available. We employed regression analysis controlling for exogenous factors, such as weather, as documented in the evaluation plan. To validate our model, we evaluated a range of model specifications and selected the best fit determined by model diagnostics (R^2 and adjusted R^2). A detailed binder provides the coefficient estimates and model fit statistics for each circuit-level model. All modeled circuit results were statistically significant at the 90% confidence level.

Appendix C. Cumulative Persisting Annual Savings

Table 13 provides CPAS and WAML for the 2021 VO Program through 2044. Lifetime savings for the 2021 VO Program are 1,431,469 MWh.

Table 13. 2021 VO Program CPAS and WAML through 2047

Evaluation Measure Category	Measure Life	First-Year Verified Gross MWh	NTGR	CPAS (Verified Net MWh)											
				2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Voltage Optimization – 2021 Cohort	15.0	95,431	N/A	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431
2021 CPAS		95,431	N/A	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431
Expiring 2021 CPAS				0	0	0	0	0	0	0	0	0	0	0	0
Expired 2021 CPAS				0	0	0	0	0	0	0	0	0	0	0	0

Evaluation Measure Category	Measure Life	First-Year Verified Gross MWh	NTGR	CPAS (Verified Net MWh)											
				2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
Voltage Optimization – 2021 Cohort	15.0	95,431	N/A	95,431	95,431	95,431	0	0	0	0	0	0	0	0	0
2021 CPAS		95,431	N/A	95,431	95,431	95,431	0	0	0	0	0	0	0	0	0
Expiring 2021 CPAS				0	0	0	95,431	0	0	0	0	0	0	0	0
Expired 2021 CPAS				0	0	0	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431	95,431
WAML	15.0														

Appendix D. Verification of Continued Operations

Opinion Dynamics conducted a verification analysis on the 2019 and 2020 cohorts of VO circuits. Since VO savings are deemed for 15 years after completion of the initial evaluation of a circuit and no retroactive changes are subsequently made to the savings, verification is necessary to confirm continued operation.

In 2020, Opinion Dynamics, AIC, and ICC Staff agreed that ongoing verification of VO should be conducted for process purposes to provide information to stakeholders and other parties as to the level of continued VO operation and, if needed, to provide context as to why VO may not have operated continuously. After the initial evaluation of each year of VO circuits, all parties agreed that Opinion Dynamics would conduct verification activities to assess the degree to which VO continued to operate throughout each year. The acceptable threshold of operation was set to ensure that circuits operated over a 90% threshold.[31]

The purpose of this verification is to provide information to stakeholders and other parties as to the level of continued operation of VO throughout the 15-year deemed period of savings and, if needed, to provide context as to why VO may not have operated continuously throughout the period.

The evaluation team conducted the following activities to determine whether these circuits operated over a 90% threshold.

- Sample Selection: The evaluation team randomly selected 10 of the 19 circuits evaluated in 2019 and 36 of the 125 circuits evaluated in 2020 using a cross-sectional sample design, which optimizes the sample for each cohort while minimizing the overall sample size across all cohorts. We performed sample selection retrospectively and provided AIC no knowledge of which circuits would be sampled until after the evaluation period had passed. Table 14 presents the sample of the VO circuits evaluated as part of the 2019 and 2020 circuit verification.

Table 14. Sample of 2019 and 2020 Evaluated VO Circuits

Circuit	Substation	Year Deployed	Division
K52401	COLLINSVILLE REESE DR	2020	Division 5
K27153	CENTRALIA SOUTH PLEASANT ST	2020	Division 6
K01236	BELLEVILLE PONTIAC	2020	Division 6
K39153	CLINTON RT 54	2020	Division 3
J99128	BELLEVILLE MARIKNOLL	2020	Division 6
K89142	DECATUR BALTIMORE AVE	2020	Division 3
R06212	SOUTH JACKSONVILLE	2020	Division 2
Q83172	SALEM	2020	Division 6
K76541	CHAMPAIGN OAK ST	2020	Division 4
P58156	MT VERNON 27TH ST	2020	Division 6
K01241	BELLEVILLE PONTIAC	2020	Division 6
P57102	MT VERNON 11TH ST SUB	2020	Division 6
Y37593	OLNEY S	2020	Division 4
D16001	NORTHMOOR	2020	Division 1
L79180	DANVILLE LIBERTY LN	2020	Division 4

[31] See Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach memo here: https://ilsag.s3.amazonaws.com/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf.

Circuit	Substation	Year Deployed	Division
K32932	CHESTER	2020	Division 6
D16003	NORTHMOOR	2020	Division 1
K76546	CHAMPAIGN OAK ST	2020	Division 4
K89141	DECATUR BALTIMORE AVE	2020	Division 3
J87150	BELLEVILLE 8TH ST	2020	Division 6
B80001	SHERIDAN	2020	Division 1
D16004	NORTHMOOR	2020	Division 1
A91003	ALLEN	2020	Division 1
Y89535	TAYLORVILLE E	2020	Division 4
B44003	CHESTER	2020	Division 1
A91004	ALLEN	2020	Division 1
L24123	DECATUR RTE 51	2020	Division 3
S22594	CARTERVILLE	2020	Division 6
H06135	WESTVILLE WEST MAIN	2020	Division 4
Y55003	PAXTON	2020	Division 4
X12525	ARTHUR	2020	Division 4
M81403	GRANITE CITY PARKVIEW	2020	Division 5
M36185	GALESBURG FREMONT RD	2020	Division 1
J99127	BELLEVILLE MARIKNOLL	2020	Division 6
D89003	BEVERLY MANOR	2020	Division 1
V36002	QUINCY 15ANDKOCHS LN	2020	Division 2
P58155	MT. VERNON 27TH ST	2019	Division 6
P69173	MT. ZION RTE 121	2019	Division 3
Y79500	SHELBYVILLE-WEST	2019	Division 4
J34377	BETHALTO	2019	Division 5
B00003	NORTHWEST	2019	Division 1
D31015	LIMIT	2019	Division 3
C52001	RIDGE	2019	Division 3
C52002	RIDGE	2019	Division 4
J83140	BELLEVILLE 44TH STREET	2019	Division 6
V42572	QUINCY 30 & HAMP	2019	Division 2

Source: AIC

- **Review and request operation log summaries for the sample.** Our variable of interest for this effort included the VO status (i.e., "On" and "Off") for specific hours throughout the year at a circuit level. We were able to rely on the VO status summaries for this analysis since we generally expected VO to run for nearly all hours in a year.
- **Data cleaning.** Opinion Dynamics did not perform any data cleaning prior to the verification activities, with the exception of removing excludable events. Excludable events are discussed in more detail in Appendix B.

- **Calculated operation status.** We calculated the proportion of hours that each circuit's VO status was "On" for a given year. We then divided the total number of hours in which the status logs indicated that VO was on by the total number of non-excludable hours in the year.

The evaluation team found that all of the sampled 2019 and 2020 VO circuits were "On" for more than 90% of non-excludable hours in 2021.

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