AMEREN ILLINOIS COMPANY 2023 VOLTAGE OPTIMIZATION PROGRAM IMPACT EVALUATION REPORT

FINAL

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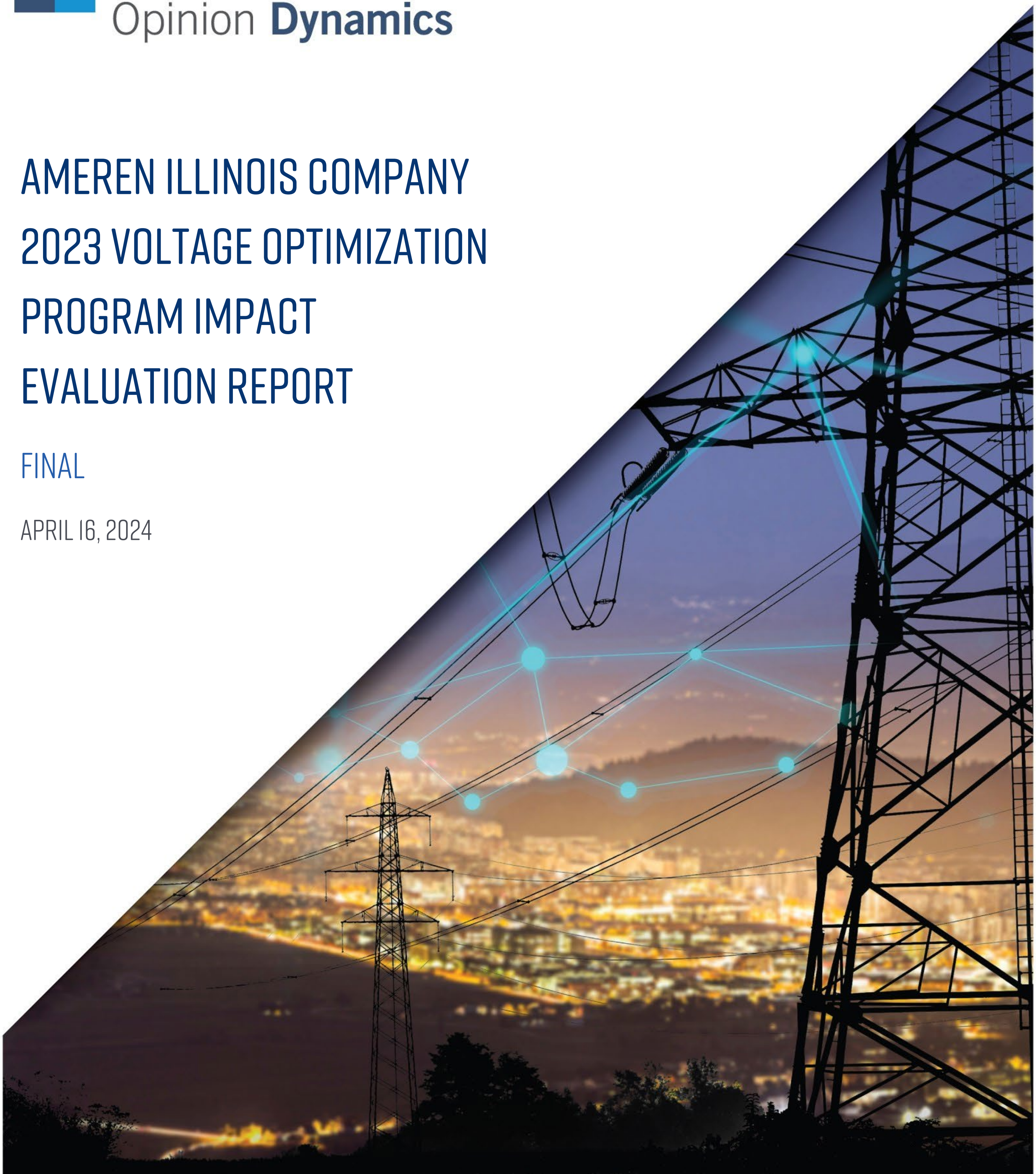

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I. EXECUTIVE SUMMARY

This report presents the impact evaluation results from Ameren Illinois Company's (AIC) Voltage Optimization (VO) Program implemented during 2023. The objective of the 2023 impact evaluation was to determine energy and peak demand savings associated with the VO Program in 2023 and to verify continued operation of voltage optimization for a sample of previously evaluated circuits.

I.I BACKGROUND

VO is a form of energy efficiency technology implemented by electric utilities at the distribution substation or circuit level. The technology optimizes voltage levels along distribution circuits to reduce electricity usage. AIC's VO Program implements hardware, software, and communications solutions using VO technologies. Two main VO technologies are used: Volt-VAR Optimization (VVO) and Conservation Voltage Reduction (CVR). VVO improves the power factor to reduce line losses, and CVR reduces customer energy consumption by reducing line voltage. Once implemented, VO technologies are intended to operate 24 hours a day for all days of the year. This report discusses the investigation and analysis of circuits that are integrated with VO technology, and these will herein be referred to as "circuits."

Prior to the program launch, AIC identified multiple technology upgrades required to deploy the VO Program successfully and selected a pool of potential candidate circuits for VO deployment.[1] In 2017, AIC began installing VO hardware, software, and communications components on a subset of the selected circuits on a phased basis. As defined in the AIC Voltage Optimization Plan,[2] AIC is only allowed to claim savings only for circuits that are operational during a full calendar year. Program Year 2023 represents the fifth full calendar year in which AIC is claiming energy savings.

The 2023 evaluation activities included estimating energy and peak demand savings for all 194 circuits that were operational in 2023, as well as verifying the continued operation of a sample of circuits previously evaluated in 2019, 2020, 2021, and 2022 (10, 14, 19 and 20 sampled circuits, respectively).

[1] 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 customers exempt at the time of this determination (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.

[2] 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 2023 VOLTAGE OPTIMIZATION PROGRAM SAVINGS

1.2.1 ANNUAL SAVINGS

We estimated energy and peak demand savings for all 194 circuits that became operational in 2023. Overall, the 2023 VO Program achieved 83,416 MWh of verified net energy savings and 13.10 MW of verified net peak demand savings (Table 1).

Table 1. 2023 VO Program Annual Savings

	Energy Savings (MWh)	Peak Demand Savings (MW)	Gas Savings (Therms)
Ex Ante Gross Savings[a]	71,264	N/A	N/A
Gross Realization Rate	117%	N/A	N/A
Verified Gross Savings	83,416	13.10	N/A
NTGR	N/A	N/A	N/A
Verified Net Savings	83,416	13.10	N/A

[a] Ex ante energy savings sourced from AIC. Ex ante gross savings assume 0.80 CVR factor and 3.2% voltage reduction across the 194 measured circuits. 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 2023 VO Program. The overall WAML for the VO Program is 15 years. For additional detail around CPAS and WAML, please see Appendix B of this report.

Table 2. 2023 VO Program CPAS and WAML

Measure	Measure Life	Annual Verified Gross Savings (MWh)	NTGR	CPAS – Verified Net Savings (MWh)							Lifetime Savings (MWh)
				2023	2024	2025	2026	…	2030	…	
Voltage Optimization – 2023 Cohort	15.0	83,416	N/A	83,416	83,416	83,416	83,416	…	83,416	…	1,251,236
2023 CPAS		**83,416**	**N/A**	**83,416**	**83,416**	**83,416**	**83,416**	**…**	**83,416**	**…**	**1,251,236**
Expiring 2023 CPAS				**0**	**0**	**0**	**0**	**…**	**0**	**…**	
Expired 2023 CPAS				**0**	**0**	**0**	**0**	**…**	**0**	**…**	
WAML	**15.0**										

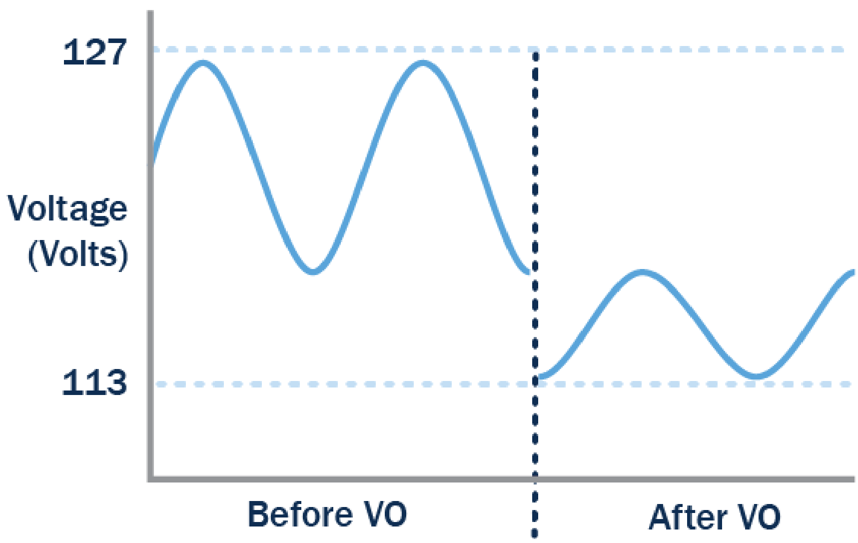
2. OVERVIEW OF VOLTAGE OPTIMIZATION PROGRAM

Illinois state law[3] defines voltage optimization as an energy efficiency measure and allows AIC to make cost-effective voltage optimization investments as part of its energy efficiency portfolio.

2.1 BACKGROUND

AIC defines VO as a combination of VVO and CVR, which are implemented first to reduce the reactive power[4] flows on a circuit and then to lower the voltage in order 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, VVO and CVR technologies work together to 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. However, AIC regulates voltage in the lower portion of the range, which 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. While AIC's VO Program was developed to provide energy savings, not peak demand savings, some associated demand reduction on some circuits is to be expected during the hours of operation of the system.

[3] Specifically, 220 ILCS 5/8-103B(b-20).

[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.

2.2 PROGRAM DESCRIPTION

AIC developed the VO Program, described in the Ameren Illinois Voltage Optimization Plan, to comply with Illinois state law and to achieve energy savings that support its energy efficiency portfolio goals.[7] Per the Plan, AIC anticipates deploying VO on all circuits for which VO is estimated to be cost-effective by 2024. AIC initially planned to deploy VO on a total of 1,047 circuits by 2024.[8] The program team has indicated that they now expect to deploy VO to more than 1,200 circuits by the end of 2024.[9]

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 eligible circuits on a phased basis using four different VO vendor solutions: Utilidata, DVI, OSI, and ABB.[10] AIC staff used voltage level as the primary criteria for establishing the initial pool of candidate circuits, and excluded circuits served by voltage levels >20 kilovolt (kV) and circuits that at the time served only customers exempt under Illinois state law (customers whose highest 15-minute demand is greater than or equal to 10 MW).[11]

Table 3 provides AIC's original implementation plan and savings estimates for the VO Program.

Table 3. AIC's Original VO Implementation Plan and Savings Estimates

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

VO is a major part of AIC's 2022–2025 energy efficiency plan. Per AIC's most recent filing,[12] VO was expected to yield 73,281 MWh in energy savings in 2023, about 17% of AIC's total estimated 2023 portfolio energy savings goal. In 2022, AIC completed deployment of VO technology to 194 new circuits that were then evaluated as part of the 2023 program year.

[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] The number of circuits planned for VO deployment was determined based on a cost-effectiveness study using calculated assumptions, industry results, and past AIC VO pilot results. The actual number of circuits with VO could fluctuate based on deployment results. See Ameren Illinois Voltage Optimization Plan for details.

[9] Interview with VO implementation staff of AIC on July 7, 2023.

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

[11] Note that as a result of the Climate and Equitable Jobs Act, customers with >10MW demand are no longer automatically exempt.

[12] Appendix F to AIC's 2022–2025 EE Plan. Accessed at: https://www.icc.illinois.gov/docket/P2021-0158/documents/322771/files/561827.pdf

3. VOLTAGE OPTIMIZATION EVALUATION APPROACH

3.1 EVALUATION RESEARCH OBJECTIVES

The 2023 VO evaluation approach was primarily governed by the Illinois Technical Reference Manual for Energy Efficiency (IL-TRM) Version 11.0,[13] which prescribes the use of an algorithmic approach to estimating electric energy and peak demand savings from VO activities. In addition to the IL-TRM, we leveraged a previously agreed-upon methodology and approach to verifying the continued operation of previously installed circuits during 2023.[14]

In this report, we address 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, 14, 19, and 20 sampled circuits from 2019, 2020, 2021, and 2022 deployment operate for over 90% of non-excludable hours in 2023?[15]

3.2 VERIFIED IMPACT ANALYSIS APPROACH

The 2023 VO evaluation estimated annual energy savings and peak demand savings for the 194 circuits that were operational as of January 1, 2023.

3.2.1 ENERGY SAVINGS METHODOLOGY

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 = conservation voltage reduction factor, defined as the percent change in energy usage divided by the percent change in voltage (deemed at 0.80 by the IL-TRM V11.0); and,
- $\%\ \Delta V_i$ = the percent change in voltage for circuit *i* resulting from VO implementation relative to the pre-period, estimated using a regression model to control for exogenous factors that may contribute to changes in voltage (e.g., weather).

[13] Illinois Statewide Technical Reference Manual for Energy Efficiency Version 11.0, Volume 4, Cross-Cutting Measures and Attachments, Measure 6.2.1. Accessed at: https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010123_v11.0_Vol_4_X-Cutting_Measures_and_Attach_09222022_FINAL.pdf

[14] Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach Memo, accessed at: https://www.ilsag.info/wp-content/uploads/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf

[15] Ibid.

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.[16] The algorithm used for AIC's VO peak demand savings program evaluation is shown in Equation 2.

Equation 2. AIC VO Peak Demand Savings Algorithm

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

where

- $Avg\ Peak\ Demand_{2014-2016,i}$ = 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 >10 MW customers;
- $CVR_{f,PEAK}$ = the estimate of the peak conservation voltage reduction factor, defined as the percent change in energy usage divided by the percent change in voltage during the peak period (deemed at 0.68 by the IL-TRM V11.0); 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

The IL-TRM V11.0 deems VO savings for 15 years[17] after completion of the initial evaluation of a circuit, and no retroactive changes can subsequently be made to deemed savings.[18] 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 all stakeholders as to the level of continued VO operation and, if needed, to provide context as to why VO may not have operated continuously. All parties agreed that Opinion Dynamics would conduct verification activities to assess the degree to which VO continued to operate in a sample of circuits deployed and evaluated prior to the current evaluation period. An acceptable uptime threshold of operation was set to ensure that circuits operated over 90% of the time, barring non-operation due to excludable events.[19]

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[16] Illinois Statewide Technical Reference Manual for Energy Efficiency Version 11.0, Volume 4, Cross-Cutting Measures and Attachments, Measure 6.2.1. Accessed at: https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010123_v11.0_Vol_4_X-Cutting_Measures_and_Attach_09222022_FINAL.pdf

[17] Note that the IL-TRM V11.0 outlines a process through which the measure life for VO, including circuits that have already been evaluated and had savings claimed, can be "extended." AIC and its evaluator will revisit past circuits at the expiration of their existing measure life, beginning in the 2034 program year.

[18] Illinois Energy Efficiency Policy Manual Version 2.1, Section 11.2. Accessed at: https://www.ilsag.info/wp-content/uploads/IL_EE_Policy_Manual_Version_2.1_Final_12-7-2021-1.pdf

[19] Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach Memo, accessed at: https://www.ilsag.info/wp-content/uploads/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf

As part of the 2023 evaluation, Opinion Dynamics conducted verification of ongoing operation in circuits evaluated in 2019, 2020, 2021, and 2022. To determine whether these circuits operated at or over the target 90% uptime threshold during 2023, we conducted the following analytical activities:

- Selected a random sample of 10 of the 19 circuits evaluated in 2019, 14 of the 125 circuits evaluated in 2020, 19 of the 180 circuits evaluated in 2021, and 20 of the 181 circuits evaluated in 2022;
- Requested operation log summaries for the sample of circuits. Our variable of interest for this effort included the VO status (e.g., "On/Off") at a circuit level for all hours throughout 2023;
- Removed excludable events;[20] 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 VOLTAGE OPTIMIZATION NET EFFECTS

Because AIC is the sole operator and "participant" in the VO Program, no adjustments to savings were 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 the evaluation team relied on regression models to estimate the change in voltage and peak demand, there is some uncertainty to be expected in the model-produced estimates. The team therefore designed analyses to address the following types of errors:

- **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 determine model outcomes are excluded when they should not be, with the potential of producing biased estimates. We addressed this type of error by carefully examining the model diagnostics and goodness-of-fit statistics of the data variables.
- **Measurement Errors:** Specifying an incorrect time period (either VO "On" or VO "Off") can lead to measurement error. We worked extensively with AIC to ensure that operations log data anomalies were discussed and addressed where possible. Measurement error can also 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 mitigated this type of error by meticulously choosing the closest weather station for each circuit in the model to ensure the most accurate weather data was used in the model.
- **Multi-collinearity:** This type of modeling error can both bias and produce substantial variances in the results. We dealt with this type of error by using evaluation model diagnostics, though the models used in the impact analysis are unlikely to have problems with multi-collinearity.
- **Heteroskedasticity:** This type of modeling error can result in imprecise statistical inference due to variance changing across circuits with different levels of consumption. We addressed this type of error by using robust standard errors. Most statistical packages offer a robust standard error option and make conservative

[20] For the rationale behind and definition of excludable events, please see the IL-TRM Voltage Optimization measure: Illinois Statewide Technical Reference Manual for Energy Efficiency Version 11.0, Volume 4 Cross-Cutting Measures and Attachments, Measure 6.2.1. Accessed at: https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010123_v11.0_Vol_4_X-Cutting_Measures_and_Attach_09222022_FINAL.pdf

assumptions in calculating the errors, which has the benefit of making the model's significance tests conservative, as well.

4. 2023 VOLTAGE OPTIMIZATION PROGRAM VERIFIED SAVINGS

In this section, we present the results of the impact evaluation of the 2023 VO Program. Additional details on the impact analysis methodology used for this evaluation are presented in Appendix B.

4.1 ANNUAL SAVINGS SUMMARY

The 2023 VO Program achieved 83,416 MWh of verified net energy savings and 13.10 MW of verified net peak demand savings. Table 4 presents the 2023 VO Program annual energy and peak demand savings. Detailed results by circuit are available in Appendix B.

Table 4. 2023 VO Program Annual Energy and Peak Demand Savings

	Energy Savings (MWh)	Peak Demand Savings (MW)	Gas Savings (Therms)
Ex Ante Gross Savings[a]	71,264	N/A	N/A
Gross Realization Rate	117%	N/A	N/A
Verified Gross Savings	83,416	13.10	N/A
NTGR	N/A	N/A	N/A
Verified Net Savings	83,416	13.10	N/A

[a] Ex ante energy savings sourced from AIC. Ex ante gross savings assume 0.80 CVR factor and 3.2% voltage reduction across the 194 measured circuits. There are no ex ante peak demand savings estimates for this program.

Factors driving program performance include the following:

- The 2023 VO Program exceeded its ex ante gross energy savings due to larger estimated percent changes in voltage than assumed values (3.20% ex ante compared to 3.75% verified average).
- Greater changes in voltage resulted in greater than expected energy savings and a gross realization rate of 117%.

4.1.1 DETAILED ENERGY SAVINGS

Savings were calculated using the annual energy savings algorithm, which includes average annual customer energy use over the 2014–2016 timeframe, excluding exempt customers, CVR_f, 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 energy savings results across all 194 circuits (see Appendix B for circuit-level percent change in voltage results).

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	2,783,761	0.80	3.20%	71,264
Verified	2,783,761	0.80	3.75%[a]	83,416[b]
Realization Rate	100%	100%	117%	117%

[a] Weighted average percent change in voltage is obtained after weighing feeder level voltage reductions in percentage terms by their 2014-2016 average yearly energy usage in MWh.

[b] Application of Equation 1 to values in Table 5 does not produce 83,416 MWh savings due to rounding in the value of Average Percent Change in Voltage.

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 (measured in MW). The resulting peak demand savings were summed across circuits to determine the total peak demand reduction of 13.10 MW. The weighted average percent change in voltage during peak demand periods was 2.92%, 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. Verified Algorithmic Inputs and Associated Demand Savings

Metric	Peak Demand (MW)	CVR_f	Average Percent Change in Peak Voltage	Peak Demand Savings (MW)
Verified	660.58	0.68	2.92% [a]	13.10

[a] Weighted average percent change in peak voltage is obtained after weighing feeder level voltage reductions in percentage terms by their 2014-2016 average yearly energy usage in MWh.

4.2 CUMULATIVE PERSISTING ANNUAL SAVINGS

Table 7 presents CPAS and WAML for the 2023 VO Program. The total verified gross savings for the Program are summarized, and CPAS in 2023–2026 and 2030 are presented. The WAML for the Program is 15 years.

Table 7. 2023 VO Program CPAS and WAML

Measure	Measure Life	Annual Verified Gross Savings (MWh)	NTGR	CPAS – Verified Net Savings (MWh)							Lifetime Savings (MWh)
				2023	2024	2025	2026	…	2030	…	
Voltage Optimization – 2023 Cohort	15.0	83,416	N/A	83,416	83,416	83,416	83,416	…	83,416	…	1,251,236
2023 CPAS		**83,416**	**N/A**	**83,416**	**83,416**	**83,416**	**83,416**	**…**	**83,416**	**…**	**1,251,236**
Expiring 2023 CPAS				**0**	**0**	**0**	**0**	**…**	**0**	**…**	
Expired 2023 CPAS				**0**	**0**	**0**	**0**	**…**	**0**	**…**	
WAML	**15.0**										

4.3 VERIFICATION OF CONTINUED OPERATIONS

As discussed in Section 3.2.2, we analyzed status logs for a randomly selected sample of previously implemented circuits to verify continued VO operation. In 2023, we sampled 10 of the 19 circuits evaluated in 2019, 14 of the 125 circuits evaluated in 2020, 19 of the 180 circuits evaluated in 2021, and 20 of the 181 circuits evaluated in 2022. Per the terms of the verification agreement, detailed further in Section 3.2.2, we set a threshold of operation of 90% of non-excludable hours. Our analysis found that all sampled circuits were "On" for more than 90% of non-excludable hours in 2023.

More information on the verification approach can be found in Appendix D.

5. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this evaluation, we offer the following key findings and recommendations for AIC's VO Program 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 change in voltage due to VO was 3.75%, much higher than the planning value of 3.20%. There is substantial variation across circuits in percentage change in voltage (0.55%–5.49%). For 143 of the 194 circuits, the percent change in voltage was estimated to be larger than the planning value of 3.20%.
  - **Recommendation**: Consider further updates to planning values to reflect the percent change in voltage derived from evaluated values. AIC updated the planning value from 3% to 3.20% in 2022, which better aligns with evaluation findings to date, but the planning value continues to significantly understate verified results. Updating the planning value could also support a more accurate assessment of the ex ante cost effectiveness for each circuit screened for inclusion in the program.

APPENDIX A. 2023 VOLTAGE OPTIMIZATION CIRCUIT SUMMARY

Table 8 presents detailed characteristics for VO circuits evaluated in 2023. This table includes the circuit name and substation for each circuit, as well as various circuit characteristics that may affect voltage reductions. Since AIC prioritized low-income customers as part of its VO deployment,[21] we also note the number of low-income customers estimated to be served by each circuit evaluated in 2023.

Table 8. 2023 Evaluated VO Circuits

Circuit	Substation	Line Length (Miles)	% Res.	% Com.	% Large C&I	Voltage Level	Low Income Customers
329144	NORTH ALTON D	5.1	96%	4%	0%	4.16	20
329145	NORTH ALTON W	9.4	76%	23%	1%	4.16	2
329146	NORTH ALTON D	9.1	89%	11%	0%	4.16	7
329147	NORTH ALTON W	12.1	96%	4%	0%	4.16	*
329148	NORTH ALTON D	7.1	93%	6%	0%	4.16	4
329149	NORTH ALTON W	8.1	83%	16%	0%	4.16	7
A81001	ELM GROVE 1	43.0	95%	5%	0%	7.62	12
A81002	ELM GROVE 1	2.2	0%	100%	0%	*	*
A81003	ELM GROVE 2	8.9	59%	39%	1%	7.62	4
A81004	ELM GROVE 2	59.4	87%	12%	0%	7.62	1
B00001	NORTHWEST 1	10.5	87%	11%	1%	7.62	11
B00004	NORTHWEST 2	9.7	83%	16%	2%	7.62	4
B00005	NORTHWEST 2	9.2	97%	3%	0%	7.62	13
B00008	NORTHWEST 1	2.3	74%	24%	2%	7.62	8
B21001	FONDULAC 1	29.5	84%	16%	0%	7.62	1
B21002	FONDULAC 1	26.3	95%	4%	0%	7.62	1
B21003	FONDULAC 1	11.1	88%	10%	1%	7.62	7
B21004	FONDULAC 1	31.9	91%	9%	0%	7.62	7
B27006	ADAMS 1	3.9	49%	48%	4%	7.62	*
B27007	ADAMS 1	1.8	45%	55%	0%	7.62	1
B27008	ADAMS 1	3.5	86%	14%	0%	7.62	3
B27009	ADAMS 1	7.6	92%	8%	0%	7.62	36
B28001	KOCH 2	1.5	90%	10%	0%	7.62	2
B28002	KOCH 1	2.8	27%	68%	5%	7.62	1
B28003	KOCH 2	24.2	87%	12%	0%	7.62	25
B28004	KOCH 1	7.5	93%	7%	0%	7.62	27
B28005	KOCH 1	0.0	0%	57%	43%	7.62	*
B28006	KOCH 2	39.0	64%	33%	3%	7.62	4
B61001	BRIMFIELD (69) 1	99.5	87%	13%	0%	7.62	6
B61002	BRIMFIELD (69) 1	10.3	90%	7%	3%	*	*
B71001	LAKE 1	9.4	82%	18%	0%	7.62	5

[21] Ameren Illinois Voltage Optimization Low Income Prioritization Strategy, February 2019. Accessed at: https://www.ilsag.info/wp-content/uploads/SAG_files/Energy_Efficiency_Dockets/AIC_VO_Low_Income_Prioritization_Strategy_February_2019_FINAL.pdf

Circuit	Substation	Line Length (Miles)	% Res.	% Com.	% Large C&I	Voltage Level	Low Income Customers
B71002	LAKE 1	14.3	94%	6%	0%	7.62	7
B71003	LAKE 1	2.3	9%	85%	6%	7.62	*
B76001	KICE 1	20.5	91%	9%	0%	7.62	4
B76002	KICE 1	4.5	66%	32%	3%	7.62	*
B76003	KICE 2	59.9	93%	6%	0%	7.62	1
B76004	KICE 2	**	**	**	**	**	**
B93001	FULTON 1	13.8	84%	16%	0%	7.62	3
B93002	FULTON 1	110.2	83%	17%	1%	7.62	4
C70001	MANSFIELD 1	110.5	83%	16%	1%	7.2	8
C70004	MANSFIELD 1	47.1	97%	3%	0%	7.2	5
D53001	MINDALE (69) 1	39.5	82%	17%	0%	7.2	4
D53002	MINDALE (69) 1	31.1	87%	13%	0%	7.2	11
D90002	MCGRATH 1	53.8	86%	13%	1%	7.2	4
D90003	MCGRATH 1	5.5	89%	11%	0%	7.2	5
D90004	MCGRATH 1	14.3	95%	5%	0%	7.2	18
G50001	BEMENT 1	3.9	89%	11%	0%	*	4
G50002	BEMENT 1	23.4	83%	17%	0%	7.2	7
H65272	COLUMBIA RT 158 1	19.8	84%	16%	0%	7.2	2
HD0573	HERRIN SOUTH 1	20.9	96%	4%	0%	7.2	*
HD0574	HERRIN SOUTH 1	19.7	85%	15%	0%	7.2	5
HK8115	DECATUR OLIVE STREET	16.6	85%	14%	1%	7.2	*
HK8117	DECATUR OLIVE STREET	16.6	93%	7%	0%	7.2	*
J39391	BLOOMINGTON BEICH ROAD 1	28.6	95%	5%	0%	7.2	5
J46182	BLOOMINGTON DIVISION ST 2	7.4	83%	16%	0%	4.16	5
J88162	BELLEVILLE BELLE VALLEY 1	2.1	0%	96%	0%	*	*
J88163	BELLEVILLE BELLE VALLEY 2	40.6	91%	8%	1%	7.2	1
J88165	BELLEVILLE BELLE VALLEY 1	14.7	88%	11%	0%	7.2	19
J88166	BELLEVILLE BELLE VALLEY 2	39.8	96%	4%	0%	7.2	2
K15207	CENTERVILLE 138KV 3	24.4	95%	5%	0%	7.2	4
K28180	CERRO GORDO LINCOLN ST 2	105.0	84%	16%	0%	7.2	14
K30205	CHENOA 1	42.7	87%	13%	0%	7.2	2
K39156	CLINTON RT 54 2	13.1	94%	6%	0%	7.2	17
K43385	COLLINSVILLE 1	7.8	92%	8%	0%	*	2
K43386	COLLINSVILLE 1	22.5	95%	5%	0%	7.2	26
K65220	COOKSVILLE 1	24.0	90%	10%	0%	*	*
K65221	COOKSVILLE 1	58.3	85%	15%	0%	7.2	7
K74162	CHAMPAIGN MATTIS AVE 1	31.3	61%	35%	4%	7.2	8
L12127	DECATUR MOUND RD 1	16.6	98%	2%	0%	7.2	1
L24121	DECATUR RTE 51 1	7.6	76%	23%	1%	7.2	1
L24124	DECATUR RTE 51 2	19.8	97%	3%	0%	7.2	2
L80221	DANVILLE LYNCH ROAD 1	5.7	40%	51%	9%	7.2	1
L80222	DANVILLE LYNCH ROAD 1	2.3	44%	38%	19%	7.2	*
L99392	EAST ST. JACOBS 1	59.3	91%	9%	0%	7.2	6

Circuit	Substation	Line Length (Miles)	% Res.	% Com.	% Large C&I	Voltage Level	Low Income Customers
M07235	EL PASO 1	46.2	80%	20%	1%	7.2	13
M07236	EL PASO 1	50.5	91%	8%	0%	7.2	4
M41111	GALESBURG NORTH SEMINARY ST 2	90.3	88%	11%	0%	7.2	8
M41113	GALESBURG NORTH SEMINARY ST 1	6.2	94%	6%	0%	*	2
M41182	GALESBURG NORTH SEMINARY ST 1	11.2	90%	9%	1%	7.2	*
M49410	GLEN CARBON MAIN ST 1	11.6	97%	3%	0%		2
M49411	GLEN CARBON MAIN ST 1	21.0	93%	7%	0%	7.2	7
M49424	GLEN CARBON MAIN ST 2	35.2	92%	7%	0%	7.2	1
M54292	GRANITE CITY 22ND STREET 3	7.1	88%	11%	1%	7.2	8
N15849	GREENVILLE RURAL 1	10.0	90%	10%	0%	7.2	3
N15850	GREENVILLE RURAL 1	60.3	92%	7%	1%	7.2	8
N70332	KEWANEE SOUTH STREET 2	34.2	60%	38%	2%	7.2	1
N93260	LILLY	38.1	90%	9%	0%	19	12
P17107	MAHOMET 1	39.5	87%	13%	0%	7.2	9
P17109	MAHOMET 2	60.9	93%	7%	0%	7.2	1
P18102	MANSFIELD 1	13.0	94%	5%	0%	*	4
P18104	MANSFIELD 1	21.0	93%	7%	0%	7.2	4
P25150	MAROA CHESTNUT ST 1	33.0	88%	12%	0%	7.2	6
P49183	MONMOUTH HARLEM AVE 2	15.9	91%	9%	0%	7.2	9
P49187	MONMOUTH HARLEM AVE 2	8.7	92%	8%	0%	7.2	9
P49188	MONMOUTH HARLEM AVE 1	5.9	96%	4%	0%	*	1
P52305	MONTICELLO 3	90.8	86%	14%	0%	7.2	7
P54827	MORRISONVILLE 1	35.3	82%	17%	0%	7.2	11
P54828	MORRISONVILLE 1	44.0	87%	12%	0%	*	6
P85141	NORMAL 2	3.7	88%	12%	0%	4.16	2
P85146	NORMAL 1	3.2	80%	19%	1%	4.16	*
Q11517	NORTH LASALLE 1	50.4	78%	21%	0%	7.2	12
Q14390	NORTH OTTAWA 1	15.4	79%	20%	1%	7.2	6
Q14392	NORTH OTTAWA 1	43.3	78%	21%	2%	7.2	
Q27185	OKAWVILLE 1	85.7	88%	12%	0%	7.2	7
Q95247	SHILOH VALLEY 1	51.2	91%	9%	0%	7.2	1
Q95248	SHILOH VALLEY 1	15.4	90%	9%	0%	*	*
Q95249	SHILOH VALLEY 2	29.9	95%	5%	0%	7.2	1
R04407	SOUTH EDWARDSVILLE 3	18.7	88%	12%	0%	7.2	9
R04409	SOUTH EDWARDSVILLE 1	30.9	86%	13%	0%	7.2	3
R04412	SOUTH EDWARDSVILLE 1	25.4	95%	4%	0%	7.2	14
R04413	SOUTH EDWARDSVILLE 2	19.6	95%	5%	0%	7.2	6
R04414	SOUTH EDWARDSVILLE 2	14.1	89%	10%	1%	7.2	*
R04415	SOUTH EDWARDSVILLE 3	19.1	75%	24%	1%	7.2	2
R16510	SPRING VALLEY 1	33.0	92%	7%	1%	7.2	11
S01501	ANNA 2	22.6	73%	26%	1%	7.2	1

Circuit	Substation	Line Length (Miles)	% Res.	% Com.	% Large C&I	Voltage Level	Low Income Customers
S16596	CARBONDALE,W 1	5.6	83%	17%	0%	7.2	8
S19551	CARBONDALE,UNIV MALL 2	1.5	0%	82%	18%	7.2	*
S19552	CARBONDALE,UNIV MALL 1	2.6	0%	91%	9%	7.2	*
S19553	CARBONDALE,UNIV MALL 1	5.0	81%	18%	1%	7.2	7
S19554	CARBONDALE,UNIV MALL 1	8.7	90%	9%	1%	7.2	2
S19556	CARBONDALE,UNIV MALL 1	3.1	0%	87%	13%	7.2	*
S25551	CHRISTOPHER,W(COELLO) 1	23.0	85%	15%	0%	7.2	8
S27599	COBDEN,SOUTH 1	40.3	83%	16%	1%	7.2	12
S43511	HARRISBURG,S 1	13.2	78%	22%	0%	7.2	12
S49550	HERRIN,SW 1	13.3	92%	8%	0%	7.2	9
S52515	INA 2	15.4	80%	19%	0%	7.2	3
S53541	JOHNSTON CITY 1	7.4	93%	7%	0%	4.16	17
S55534	JONESBORO 1	9.1	78%	21%	1%	7.2	2
S55535	JONESBORO 1	7.0	94%	6%	0%	*	6
S55566	JONESBORO 1	10.6	93%	7%	0%	*	3
S60581	MAKANDA NORTH 1	49.3	89%	10%	0%	7.2	13
S62520	MARION,COURT ST 2	7.4	89%	11%	0%	7.2	13
S62521	MARION,COURT ST 2	8.3	92%	8%	1%	7.2	18
S62522	MARION,COURT ST 1	17.6	95%	5%	0%	7.2	20
S62523	MARION,COURT ST 1	10.0	98%	2%	0%	7.2	3
S83532	MOUNDS 1	8.7	63%	36%	1%	7.2	3
S86581	MURPHYSBORO 1	9.0	81%	18%	1%	7.2	5
S86582	MURPHYSBORO 1	25.8	81%	18%	1%	7.2	14
T15570	BENTON,NORTH 1	19.1	76%	23%	1%	7.2	5
T16526	ENERGY SOUTH 1	16.8	64%	36%	0%	7.2	1
T16527	ENERGY SOUTH 1	6.8	41%	57%	0%	*	*
T16528	ENERGY SOUTH 1	14.4	93%	7%	0%	*	2
T17582	HARRISBURG E 1	6.5	36%	60%	4%	7.2	1
T23527	GOREVILLE,N 1	22.2	83%	17%	0%	7.2	4
T59902	SPARTA NORTH MARKET ST 1	14.5	65%	34%	0%	7.2	3
T59942	SPARTA NORTH MARKET ST 1	9.5	86%	14%	0%	7.2	16
U06524	ATHENS 1	29.9	94%	6%	0%	7.2	15
U06551	ATHENS 1	43.5	78%	20%	2%	7.2	2
U16500	BEARDSTOWN, 15 ST 1	19.5	70%	28%	1%	7.2	9
U86500	LEWISTOWN 1	26.2	88%	12%	0%	7.2	5
U92593	MACOMB,E 2	48.5	80%	20%	1%	7.2	8
U97528	MACOMB,W 4	15.7	93%	6%	1%	7.2	15
V22555	PIASA JCT 1	61.9	81%	19%	0%	7.2	25
V28597	QUINCY, 3ANDJEFF	5.8	91%	9%	0%	7.2	12
V33003	QUINCY,10&HAMP 1	1.6	87%	12%	1%	4.16	1
V35001	QUINCY,15&ELM 1	2.4	89%	10%	1%	4.16	2
V35002	QUINCY,15&ELM 1	2.3	93%	7%	0%	4.16	6
V35003	QUINCY,15&ELM 1	1.9	94%	5%	1%	4.16	5

Circuit	Substation	Line Length (Miles)	% Res.	% Com.	% Large C&I	Voltage Level	Low Income Customers
V36001	QUINCY,15&KOCHS LN 1	20.1	93%	7%	0%	7.2	5
V45526	QUINCY,36&COLLEGE 1	15.1	91%	9%	1%	7.2	7
V45590	QUINCY,36&COLLEGE 1	1.0	0%	95%	5%	7.2	*
V50001	QUINCY,GARD DNVR 1	8.6	94%	5%	0%	7.2	10
V59561	RUSHVILLE 2	31.0	83%	17%	0%	7.2	18
V74513	VIRDEN 2	18.1	90%	9%	0%	7.2	9
V99562	NAUVOO 1	32.2	76%	23%	1%	7.2	6
X34530	CHARLESTON,HAYES ST. 1	11.4	96%	4%	0%	7.2	3
X34532	CHARLESTON,HAYES ST. 1	6.2	85%	14%	1%	7.2	6
X42502	CLIFTON,N 1	21.0	84%	15%	0%	7.2	3
X57566	EFFINGHAM(CHERRY ST) 1	16.4	60%	38%	2%	7.2	2
X65540	FAIRBURY,E 1	12.3	89%	10%	1%	7.2	1
X75512	GIBSON CITY, W 1	48.7	83%	16%	1%	7.2	9
X78536	GRAYVILLE 1	8.3	96%	4%	0%		6
X78537	GRAYVILLE 1	16.0	75%	24%	0%	7.2	9
X99538	LOUISVILLE,S 2	14.3	76%	23%	0%	7.2	23
Y08551	MATTOON,E 1	2.4	36%	64%	0%	*	*
Y08552	MATTOON,E 1	6.4	83%	17%	1%	7.2	16
Y08553	MATTOON,E 1	5.6	2%	89%	10%	7.2	*
Y12559	MATTOON,W 4	17.1	90%	9%	0%	7.2	6
Y12560	MATTOON,W 4	6.3	60%	31%	9%	7.2	*
Y23513	MOWEAQUA,N 3	26.0	87%	13%	1%	7.2	*
Y23521	MOWEAQUA,N 3	17.9	88%	12%	0%	7.2	4
Y26520	NEOGA 1	25.3	83%	15%	2%	7.2	17
Y26580	NEOGA 1	14.8	86%	13%	1%	7.2	5
Y35513	OLNEY 1	10.5	72%	27%	1%	7.2	4
Y35515	OLNEY 1	9.6	90%	10%	0%	7.2	11
Y63527	ROBINSON,E 1	14.1	85%	14%	1%	7.2	7
Y63531	ROBINSON,E 1	0.0	*	*	*	7.2	2
Y96564	TEUTOPOLIS 1	40.6	88%	12%	0%	7.2	3
Z16547	EFFINGHAM JAYCEE AVE 1	18.1	84%	16%	1%	7.2	13
Z17503	EFFINGHAM NW 1	53.1	87%	12%	0%	7.2	8
Z18553	PARIS IND PK 1	9.1	85%	14%	1%	7.2	10
Z18554	PARIS IND PK 1	0.7	0%	67%	33%	7.2	*
Z18555	PARIS IND PK 1	0.4	0%	0%	100%	7.2	*
Z18557	PARIS IND PK 2	0.5	0%	0%	100%	7.2	*

* Circuit characteristics data unavailable.

** In 2021, circuit B76003 was split into B76003 and B76004.

APPENDIX B. DETAILED IMPACT ANALYSIS METHODOLOGY

DATA INGESTION AND REVIEW

Opinion Dynamics used the following data to perform the energy and peak demand savings evaluations: (1) advanced metering infrastructure (AMI) data extracts; (2) VO status and operations logs; (3) circuit characteristics; and (4) hourly weather data.

- **AMI data extracts.** AIC provided Opinion Dynamics with 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.
- **System operations log.** This log contains the VO “On” and “Off” schedule, as well as information on critical system operation events that could cause data anomalies such as outages. AIC provided this log with a summary tab containing VO status events (VO “On” and VO “Off”), timestamps for the events, and notes on the cause of the event. Within the system operations log, we flagged certain timeframes as excludable, adhering to guidance in the IL-TRM V11.0.
- **Circuit characteristics.** AIC provided Opinion Dynamics a number of datasets with descriptive circuit characteristic information, including data presented in Appendix A and baseline usage information.
- **Hourly weather data.** We sourced weather data from the National Oceanic and Atmospheric Administration’s (NOAA) National Centers for Environmental Information, which were mapped to circuits using GPS coordinates. We then calculated the cooling and heating degree hours, using base temperatures of 75ºF and 65ºF, respectively, to generate the weather parameters used in modeling.

ENERGY SAVINGS

DATA CLEANING

To support the 2023 impact evaluation, we cleaned provided data to meet analytical needs. 2023 VO data was provided by AIC in increments during the year to support interim impact analyses. As such, before we took further data cleaning steps, we incrementally aggregated VO data provided. During this aggregation, we took two steps to prepare data:

- **Removed perfectly duplicated observations:** Observations with duplicated values across all variables (e.g. perfect overlaps between data files) were flagged and removed from the analysis.
- **Aggregated remaining duplicate observations**: After removing perfect duplicates, a small number of observations remained with duplicate timestamps by circuit but different voltage data. In these cases, we averaged observations to arrive at a dataset with a unique set of timestamps by circuit. This affected 0.4% of records.

Once data were aggregated, we conducted the following data cleaning steps prior to modeling:

- **Removed time periods without weather data:** As previously noted, we downloaded weather data from NOAA. We used circuit longitude and latitude to find the weather station closest to each circuit’s location. For instances where weather data for a particular weather station was not recorded, we removed the corresponding time periods from the analysis.

- **Removed negative and zero values:** Negative and zero values in kV and MW data were flagged and removed from use in the analysis.
- **Examined outliers:** Outliers were screened on a circuit-by-circuit basis. Exploration of the outliers showed them all to be within a reasonable range to be included in the analysis.
- **Flagged excludable time periods:** In some circumstances, it is best practice or required to disable VO during support system changes, growth, outages, and maintenance, both planned and unplanned. Consequently, AIC indicated that a subset of VO events should be excluded from this analysis. In 2020, AIC, Opinion Dynamics, ICC Staff, and other stakeholders reached agreement on specific VO events that could be considered excludable, which were documented in a memo.[22] VO events that were approved for exclusion included 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 a necessary switching event; (4) the circuit had experienced a failure in information or communication technology; and, (5) any event that was flagged for the worldwide pandemic or outages ordered by civil authorities. This information has been memorialized in IL-TRM V11.0.
- **Removed VO "On" events in pre-period:** To construct a pre-period, VO "On" events were flagged and removed from the 2022 dataset.

Table 9 provides a summary of the data cleaning for this analysis. Results include all 194 circuits within the analysis. The primary reason for removing observations were for occurrences when VO was turned "Off" for an excludable event (2.7% of total observations), followed by occurrences of imperfect duplicates (1.1% of total observations). Overall, after data cleaning activity, 4.1% of observations were dropped. It should be noted that no circuits were removed from the energy savings analysis due to data insufficiency.

Table 9. Summary of Data Cleaning Results for 2023 VO Energy Savings Impacts

Step	Circuits	Remaining Observations	# Dropped Observations	% Remaining
Initial Count	194	3,331,680	N/A	100.0%
Aggregate Duplicates	194	3,295,569	36,111	98.9%
Time Periods Without Weather Data	194	3,290,578	4,991	98.8%
kV Less Than or Equal to 0	194	3,290,578	0	98.8%
On in Pre-Period	194	3,286,758	3,820	98.7%
Excludable Time Periods	194	3,195,391	91,367	95.9%
Final	**194**	**3,195,391**	**136,289**	**98.9%**

MODELING PERCENT CHANGE IN VOLTAGE FOR DEMAND SAVINGS

To develop a pre-period baseline for this evaluation, we removed VO "On" periods in 2022 data. As a result, the baseline includes VO "Off" periods only. The post-period of interest is 2023, where all circuits are active. The post-period consists of largely "On" periods, as well non-excludable "Off" periods. We used this structure to fit individual models on each circuit.

[22] Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach Memorandum, accessed at: https://www.ilsag.info/wp-content/uploads/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf

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

Equation 3. Voltage Reduction Model

$$kV_{it} = a_i + \beta_{1i}Post_{it} + \beta_{2i}CDH_{it} + \beta_{3i}HDH_{it} + \beta_{4i}Weekend_t + \beta_{5i}Post_{it} * CDH_{it} + \beta_{6i}Post_{it} * HDH_{it} + \beta_{7i}Post_{it} * Weekend_t + \varepsilon_{it}$$

where:

- kV_{it} = Kilovolts for circuit *i* at time *t*
- a_i = Model intercept for circuit *i*
- β_{xi} = Regression coefficients for circuit *i*
- $Post_{it}$ = Indicator variable for circuit *i* at time *t* for the time relative to VO deployment where circuit *i* is in the post-period (Post = 1) or in the pre-period (Post = 0)
- CDH_{it} = The number of cooling degree-hours at time *t* corresponding to circuit *i*
- HDH_{it} = The number of heating degree-hours at time *t* corresponding to circuit *i*
- $Weekend_t$ = Indicator variable for weekend (Weekend *t* = 1) or weekday (Weekend *t* = 0)
- ε_{it} = Error term

CALCULATING ANNUAL ENERGY SAVINGS

The IL-TRM V11.0 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. 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 >10MW customers;
- CVR_f = The estimate of the conservation voltage reduction (CVR) 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: ANNUAL ENERGY SAVINGS

Table 10 provides each algorithmic input by circuit as well as the total estimated savings per circuit that can be attributed to the VO Program. For 142 of the 194 circuits, the percent change in voltage was estimated to be larger than the planned value of 3.2%. The overall average percent change in voltage was 3.75%.[23]

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

Circuit	Annual Gross Energy Use 2014-2016 (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
329144	5,862	0.80	1.09%	51
329145	13,082	0.80	0.55%	58
329146	12,507	0.80	1.79%	179
329147	7,913	0.80	2.49%	158
329148	8,286	0.80	0.93%	61
329149	13,849	0.80	1.94%	215
A81001	25,008	0.80	3.04%	608
A81002	4,968	0.80	5.23%	208
A81003	19,886	0.80	3.90%	620
A81004	16,967	0.80	4.43%	601
B00001	18,565	0.80	2.21%	329
B00004	18,224	0.80	4.13%	602
B00005	9,002	0.80	3.84%	277
B00008	7,475	0.80	3.85%	230
B21001	23,297	0.80	2.06%	383
B21002	10,179	0.80	0.72%	59
B21003	6,586	0.80	2.37%	125
B21004	22,150	0.80	2.55%	452
B27006	28,531	0.80	3.00%	684
B27007	2,644	0.80	3.10%	66
B27008	2,854	0.80	3.14%	72
B27009	11,242	0.80	3.22%	289
B28001	1,165	0.80	0.97%	9
B28002	28,578	0.80	2.31%	528
B28003	13,003	0.80	2.32%	241
B28004	10,478	0.80	2.28%	191
B28005	30,643	0.80	2.30%	564
B28006	15,345	0.80	2.64%	324
B61001	22,021	0.80	4.01%	707
B61002	2,950	0.80	3.05%	72

[23] Average percent change in voltage is weighted by 2014-2016 annual energy usage.

Circuit	Annual Gross Energy Use 2014-2016 (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
B71001	15,726	0.80	2.86%	360
B71002	15,375	0.80	2.90%	357
B71003	13,259	0.80	2.92%	310
B76001	20,848	0.80	3.40%	566
B76002	9,670	0.80	5.28%	408
B76003	17,127[a]	0.80	2.22%	305
B76004	14,013[a]	0.80	4.68%	525
B93001	9,760	0.80	3.88%	303
B93002	16,400	0.80	3.20%	419
C70001	23,084	0.80	4.00%	738
C70004	19,892	0.80	4.29%	682
D53001	10,061	0.80	3.49%	281
D53002	11,487	0.80	2.90%	266
D90002	6,716	0.80	1.91%	102
D90003	9,604	0.80	1.79%	137
D90004	15,293	0.80	2.72%	332
G50001	5,332	0.80	4.80%	205
G50002	9,754	0.80	4.87%	380
H65272	13,337	0.80	4.27%	455
HD0573	9,105	0.80	3.59%	262
HD0574	14,562	0.80	4.33%	504
HK8115	14,311	0.80	3.45%	396
HK8117	18,045	0.80	3.18%	459
J39391	17,453	0.80	4.25%	593
J46182	13,342	0.80	4.00%	427
J88162	8,843	0.80	4.42%	313
J88163	12,120	0.80	4.54%	441
J88165	25,574	0.80	4.68%	958
J88166	17,890	0.80	4.95%	708
K15207	8,835	0.80	4.01%	283
K28180	16,298	0.80	3.80%	496
K30205	10,768	0.80	3.50%	301
K39156	13,990	0.80	4.07%	456
K43385	8,075	0.80	4.48%	289
K43386	9,938	0.80	3.75%	297
K65220	5,043	0.80	4.04%	163
K65221	12,674	0.80	1.91%	194

Circuit	Annual Gross Energy Use 2014-2016 (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
K74162	32,267	0.80	4.07%	1,050
L12127	13,563	0.80	4.84%	525
L24121	10,370	0.80	2.96%	246
L24124	12,088	0.80	3.72%	360
L80221	48,795	0.80	4.00%	1,560
L80222	12,166	0.80	4.32%	421
L99392	14,424	0.80	4.04%	466
M07235	18,615	0.80	3.38%	503
M07236	15,741	0.80	4.76%	599
M41111	21,500	0.80	4.32%	743
M41113	8,018	0.80	4.42%	284
M41182	14,585	0.80	3.84%	448
M49410	8,594	0.80	4.27%	293
M49411	12,585	0.80	4.32%	435
M49424	24,322	0.80	4.77%	927
M54292	9,821	0.80	2.44%	192
N15849	16,337	0.80	3.90%	510
N15850	17,416	0.80	3.46%	482
N70332	13,091	0.80	4.03%	422
N93260	20,027	0.80	0.93%	148
P17107	28,613	0.80	3.97%	910
P17109	26,880	0.80	2.14%	461
P18102	6,913	0.80	3.21%	178
P18104	11,056	0.80	4.79%	424
P25150	11,128	0.80	3.46%	308
P49183	25,453	0.80	4.19%	853
P49187	13,381	0.80	4.11%	440
P49188	6,573	0.80	4.63%	244
P52305	25,375	0.80	4.63%	941
P54827	12,605	0.80	3.40%	343
P54828	11,811	0.80	2.70%	255
P85141	10,661	0.80	4.60%	392
P85146	7,868	0.80	4.97%	313
Q11517	15,769	0.80	3.50%	442
Q14390	27,441	0.80	4.59%	1,008
Q14392	16,506	0.80	4.51%	596
Q27185	21,063	0.80	3.83%	645

Circuit	Annual Gross Energy Use 2014-2016 (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
Q95247	13,771	0.80	4.56%	502
Q95248	4,452	0.80	4.70%	168
Q95249	21,959	0.80	4.79%	841
R04407	30,499	0.80	4.82%	1,175
R04409	29,414	0.80	4.32%	1,016
R04412	33,596	0.80	4.42%	1,188
R04413	16,547	0.80	5.13%	679
R04414	21,597	0.80	2.53%	437
R04415	31,181	0.80	2.67%	666
R16510	16,360	0.80	3.90%	510
S01501	18,301	0.80	4.74%	695
S16596	8,776	0.80	4.94%	347
S19551	8,726	0.80	4.50%	314
S19552	7,911	0.80	2.93%	186
S19553	11,059	0.80	5.04%	446
S19554	15,238	0.80	5.49%	669
S19556	12,033	0.80	3.72%	358
S25551	8,012	0.80	4.95%	317
S27599	15,512	0.80	4.02%	498
S43511	12,392	0.80	4.40%	436
S49550	15,306	0.80	3.93%	481
S52515	12,607	0.80	3.56%	359
S53541	8,244	0.80	3.05%	201
S55534	11,659	0.80	3.74%	348
S55535	6,606	0.80	4.81%	254
S55566	7,582	0.80	4.79%	291
S60581	14,239	0.80	2.83%	322
S62520	9,862	0.80	4.62%	364
S62521	11,569	0.80	4.90%	454
S62522	13,330	0.80	4.42%	471
S62523	11,393	0.80	4.90%	447
S83532	9,037	0.80	4.72%	342
S86581	10,957	0.80	3.44%	302
S86582	11,517	0.80	2.70%	248
T15570	16,090	0.80	4.85%	625
T16526	16,968	0.80	4.05%	550
T16527	5,663	0.80	4.36%	198

Circuit	Annual Gross Energy Use 2014-2016 (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
T16528	8,670	0.80	4.04%	280
T17582	10,389	0.80	5.19%	431
T23527	11,626	0.80	4.04%	376
T59902	16,383	0.80	4.91%	643
T59942	12,615	0.80	4.38%	442
U06524	14,424	0.80	2.67%	308
U06551	11,022	0.80	4.02%	354
U16500	15,556	0.80	5.35%	666
U86500	9,252	0.80	3.91%	290
U92593	17,365	0.80	4.73%	657
U97528	17,847	0.80	4.47%	638
V22555	13,382	0.80	4.14%	443
V28597	11,736	0.80	4.42%	415
V33003	8,014	0.80	3.92%	252
V35001	10,528	0.80	4.09%	344
V35002	9,552	0.80	4.28%	327
V35003	10,917	0.80	3.84%	335
V36001	14,287	0.80	4.78%	547
V45526	15,135	0.80	4.53%	549
V45590	7,291	0.80	4.67%	272
V50001	10,005	0.80	4.63%	371
V59561	13,574	0.80	2.75%	298
V74513	13,130	0.80	4.35%	457
V99562	17,385	0.80	3.29%	458
X34530	10,139	0.80	3.14%	255
X34532	10,079	0.80	2.92%	235
X42502	13,991	0.80	4.14%	463
X57566	17,389	0.80	3.68%	512
X65540	10,060	0.80	3.96%	318
X75512	21,755	0.80	4.01%	698
X78536	6,410	0.80	3.59%	184
X78537	10,697	0.80	3.30%	282
X99538	11,122	0.80	3.56%	317
Y08551	4,881	0.80	2.58%	101
Y08552	10,695	0.80	3.49%	299
Y08553	17,858	0.80	3.68%	525
Y12559	9,004	0.80	2.64%	190

Circuit	Annual Gross Energy Use 2014-2016 (MWh)	CVR_f	Average Percent Change in Voltage	Annual Gross Energy Savings (MWh)
Y12560	12,198	0.80	2.55%	248
Y23513	11,186	0.80	4.08%	365
Y23521	14,847	0.80	3.37%	400
Y26520	15,174	0.80	3.25%	395
Y26580	12,652	0.80	3.31%	335
Y35513	11,585	0.80	4.20%	389
Y35515	11,937	0.80	4.07%	388
Y63527	26,404	0.80	2.95%	623
Y63531	9,512	0.80	4.16%	317
Y96564	13,493	0.80	3.99%	430
Z16547	16,801	0.80	4.49%	603
Z17503	17,555	0.80	3.46%	486
Z18553	11,507	0.80	3.62%	333
Z18554	23,165	0.80	5.25%	974
Z18555	12,808	0.80	4.86%	498
Z18557	48,523	0.80	3.59%	1,392

[a] In 2021, circuit B76003 was split into B76003 and B76004. AIC staff informed the evaluation team that circuit B76003 retained 55% of the 2014-2016 energy usage, and the remainder went to B76004.

PEAK DEMAND SAVINGS

DATA CLEANING

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

- **Peak Period Data Only:** The VO 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.
- **Less than 20 Days in Peak Period:** Circuits with less than 20 days of data in the peak period were removed from the analysis. No feeders were affected by this step.
- **Missing Peak Period:** Circuits missing the 2022 or 2023 peak period were removed from the analysis. No feeders were affected by this step.

Table 11 provides a summary of the data cleaning results for this analysis. After subsetting the data to the peak period, the data cleaning reduced the total number of observations by 16.8%.

Table 11. Summary of Data Cleaning Results for Peak Demand Savings

Step	Circuits	Remaining Observations	# Dropped Observations	% Remaining
Initial Count	194	2,708,361	N/A	100.0%
Non-Peak Days	194	562,640	2,145,721	20.8%
Less than 20 Days in Peak Period	194	562,640	0	20.8%
Missing Peak Period	194	562,640	0	20.8%
Peak Hours	194	94,660	467,980	3.5%
Final	**194**	**94,660**	**2,613,701**	**3.5%**

MODELING PERCENT CHANGE IN VOLTAGE FOR PEAK DEMAND SAVINGS

To develop a baseline, we applied the cleaned data used for annual impacts and subset to the peak period. Individual models were run by circuit, and savings were aggregated similar to the annual savings, taking into account the peak CVR_f and the annual peak demand (MW). As with the energy savings model, the peak demand savings model uses 2022 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 Reduction Model

$$kV_{it} = \alpha_i + \beta_{1i}Post_{it} + \beta_{2i}CDH_{it} + \beta_{3i}Post_{it} * CDH_{it} + \varepsilon_{it}$$

Where:

- kV_{it} = Kilovolts for circuit *i* at time *t*
- α_i= Model intercept for circuit *i* at time *t*
- β_{xi} = Regression coefficients for circuit *i*
- $Post_{it}$ = Indicator variable on circuit *i* at time *t* for the time relative to VO deployment where circuit *i* is in the post-period (Post=1) or in the pre-period (Post=0)
- CDH_{it} = The number of cooling degree-hours at time y corresponding to circuit iε_{it} = Error term

CALCULATING PEAK DEMAND SAVINGS

VO peak demand savings were also estimated with an algorithmic approach. The peak period was defined as 1:00 p.m.–5:00 p.m. (CDT) on non-holiday weekdays from June 1–August 31.[24]

[24] Illinois Statewide Technical Reference Manual for Energy Efficiency Version 11.0, Volume 4, Cross-Cutting Measures and Attachments, Measure 6.2.1. Accessed at: https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010123_v11.0_Vol_4_X-Cutting_Measures_and_Attach_09222022_FINAL.pdf

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 >10 MW customers;[25]
- $CVR_{f,PEAK}$ = 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 V11.0, 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.

Detailed Circuit Results: Peak Demand Savings

Table 12 provides each algorithmic input by circuit as well as the total estimated savings per circuit that can be attributed to the VO Program. For 91 of the 194 circuits, the percent change in voltage was estimated to be larger than the planned value of 3.2%. The overall average percent change in voltage was 2.92%.

Table 12. Verified Algorithmic Inputs and Associated Peak Demand Savings by Circuit

Circuit	Annual Peak Demand 2014-2016 (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Peak Demand Savings (MW)
329144	1.77	0.68	1.02%	0.01
329145	2.90	0.68	-1.04%	-0.02
329146	3.78	0.68	1.25%	0.03
329147	2.27	0.68	1.99%	0.03
329148	1.97	0.68	0.66%	0.01
329149	3.13	0.68	1.05%	0.02
A81001	7.42	0.68	2.38%	0.12
A81002	1.53	0.68	4.68%	0.05
A81003	4.51	0.68	2.51%	0.08
A81004	3.75	0.68	3.55%	0.09
B00001	4.95	0.68	0.23%	0.01
B00004	3.90	0.68	4.05%	0.11
B00005	2.85	0.68	2.23%	0.04
B00008	1.79	0.68	4.01%	0.05
B21001	3.81	0.68	0.40%	0.01
B21002	2.98	0.68	-0.77%	-0.02

[25] Peak demand was unavailable for seven circuits.

Circuit	Annual Peak Demand 2014-2016 (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Peak Demand Savings (MW)
B21003	1.99	0.68	0.87%	0.01
B21004	8.65	0.68	2.49%	0.15
B27006	6.06	0.68	2.60%	0.11
B27007	0.72	0.68	2.65%	0.01
B27008	1.35	0.68	2.67%	0.02
B27009	3.01	0.68	2.82%	0.06
B28001	0.29[a]	0.68	1.80%	0.00
B28002	4.53	0.68	0.67%	0.02
B28003	3.20[a]	0.68	3.34%	0.07
B28004	3.17	0.68	0.72%	0.02
B28005	3.61	0.68	0.70%	0.02
B28006	6.84	0.68	3.40%	0.16
B61001	4.86	0.68	2.63%	0.09
B61002	1.98	0.68	3.89%	0.05
B71001	4.36	0.68	2.23%	0.07
B71002	5.29	0.68	2.23%	0.08
B71003	3.65	0.68	2.28%	0.06
B76001	5.45	0.68	1.54%	0.06
B76002	2.01	0.68	5.11%	0.07
B76003	4.66[b]	0.68	1.71%	0.05
B76004	3.8[b]	0.68	3.50%	0.09
B93001	2.62	0.68	3.22%	0.06
B93002	4.03	0.68	1.82%	0.05
C70001	6.09	0.68	2.93%	0.12
C70004	6.79	0.68	3.18%	0.15
D53001	2.42	0.68	2.16%	0.04
D53002	2.53	0.68	1.30%	0.02
D90002	1.96	0.68	1.53%	0.02
D90003	2.50	0.68	0.49%	0.01
D90004	5.67	0.68	1.79%	0.07
G50001	1.63	0.68	3.72%	0.04
G50002	2.53	0.68	3.84%	0.07
H65272	1.06	0.68	3.25%	0.02
HD0573	1.90	0.68	3.97%	0.05
HD0574	2.37	0.68	4.52%	0.07
HK8115	3.39	0.68	2.48%	0.06
HK8117	4.71	0.68	2.26%	0.07

Circuit	Annual Peak Demand 2014-2016 (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Peak Demand Savings (MW)
J39391	5.57	0.68	2.62%	0.10
J46182	2.49	0.68	2.43%	0.04
J88162	2.40	0.68	4.00%	0.07
J88163	3.29	0.68	4.04%	0.09
J88165	5.80	0.68	3.61%	0.14
J88166	5.72	0.68	3.99%	0.15
K15207	2.08	0.68	2.72%	0.04
K28180	3.84	0.68	3.12%	0.08
K30205	2.94	0.68	2.52%	0.05
K39156	3.66	0.68	2.33%	0.06
K43385	1.72	0.68	3.01%	0.03
K43386	2.23	0.68	2.70%	0.04
K65220	1.03	0.68	3.32%	0.02
K65221	4.94	0.68	1.72%	0.06
K74162	5.50	0.68	4.07%	0.15
L12127	4.63	0.68	3.76%	0.12
L24121	1.39	0.68	2.12%	0.02
L24124	3.09	0.68	2.86%	0.06
L80221	3.68	0.68	1.96%	0.05
L80222	2.70	0.68	4.00%	0.07
L99392	3.41	0.68	2.98%	0.07
M07235	4.71	0.68	2.01%	0.06
M07236	4.48	0.68	3.48%	0.11
M41111	4.77	0.68	3.61%	0.12
M41113	2.29	0.68	3.22%	0.05
M41182	3.78	0.68	2.44%	0.07
M49410	2.71	0.68	4.61%	0.09
M49411	3.47	0.68	2.70%	0.06
M49424	5.78	0.68	3.92%	0.15
M54292	2.36	0.68	1.74%	0.03
N15849	3.44	0.68	2.99%	0.07
N15850	3.42	0.68	3.43%	0.08
N70332	3.22	0.68	2.67%	0.06
N93260	4.93	0.68	0.53%	0.02
P17107	7.58	0.68	3.63%	0.19
P17109	7.11	0.68	1.96%	0.09
P18102	1.86	0.68	2.49%	0.03

Circuit	Annual Peak Demand 2014-2016 (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Peak Demand Savings (MW)
P18104	3.17	0.68	3.91%	0.08
P25150	1.97	0.68	2.44%	0.03
P49183	6.10	0.68	2.43%	0.11
P49187	3.24	0.68	2.34%	0.06
P49188	1.67	0.68	4.00%	0.05
P52305	6.19	0.68	3.75%	0.16
P54827	2.21	0.68	2.13%	0.03
P54828	2.47	0.68	1.64%	0.03
P85141	2.25	0.68	3.99%	0.06
P85146	1.78	0.68	5.33%	0.06
Q11517	3.72	0.68	3.17%	0.08
Q14390	6.11	0.68	3.82%	0.16
Q14392	3.58	0.68	3.50%	0.08
Q27185	3.96	0.68	3.14%	0.08
Q95247	3.76	0.68	4.46%	0.11
Q95248	1.97	0.68	3.92%	0.05
Q95249	5.75	0.68	4.27%	0.17
R04407	8.26	0.68	3.64%	0.20
R04409	8.13	0.68	3.24%	0.18
R04412	7.44	0.68	4.29%	0.22
R04413	4.81	0.68	4.43%	0.14
R04414	6.48	0.68	1.03%	0.04
R04415	6.60	0.68	1.14%	0.05
R16510	4.42	0.68	2.67%	0.08
S01501	4.11	0.68	4.06%	0.11
S16596	3.14	0.68	4.58%	0.10
S19551	1.87	0.68	4.31%	0.05
S19552	1.89	0.68	4.13%	0.05
S19553	2.17	0.68	4.47%	0.06
S19554	2.62	0.68	4.74%	0.08
S19556	1.65	0.68	3.59%	0.04
S25551	2.14	0.68	4.55%	0.07
S27599	3.70	0.68	3.38%	0.08
S43511	3.45	0.68	3.63%	0.08
S49550	3.50	0.68	3.07%	0.07
S52515	2.25	0.68	2.96%	0.05
S53541	1.55	0.68	0.10%	0.00

Circuit	Annual Peak Demand 2014-2016 (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Peak Demand Savings (MW)
S55534	2.66	0.68	1.97%	0.03
S55535	1.92	0.68	4.50%	0.06
S55566	1.75	0.68	4.42%	0.05
S60581	3.09	0.68	3.20%	0.07
S62520	2.34	0.68	2.80%	0.04
S62521	2.66	0.68	3.85%	0.07
S62522	2.62	0.68	4.21%	0.07
S62523	3.62	0.68	5.02%	0.12
S83532	1.91	0.68	3.59%	0.05
S86581	2.43	0.68	3.27%	0.05
S86582	3.05	0.68	1.50%	0.03
T15570	3.64	0.68	3.96%	0.10
T16526	3.35	0.68	2.18%	0.05
T16527	1.39	0.68	4.96%	0.05
T16528	1.69	0.68	4.18%	0.05
T17582	2.44	0.68	4.42%	0.07
T23527	2.66	0.68	3.56%	0.06
T59902	3.58	0.68	4.59%	0.11
T59942	3.26	0.68	3.49%	0.08
U06524	3.59	0.68	1.33%	0.03
U06551	2.90	0.68	2.83%	0.06
U16500	3.53	0.68	4.23%	0.10
U86500	2.37	0.68	2.58%	0.04
U92593	3.36	0.68	3.47%	0.08
U97528	3.69	0.68	3.74%	0.10
V22555	3.33	0.68	3.19%	0.07
V28597	3.10	0.68	3.47%	0.07
V33003	1.89	0.68	2.79%	0.04
V35001	1.34	0.68	2.25%	0.02
V35002	1.77	0.68	2.93%	0.04
V35003	2.33	0.68	2.17%	0.04
V36001	3.55	0.68	3.67%	0.09
V45526	3.75	0.68	3.50%	0.09
V45590	1.62	0.68	4.92%	0.05
V50001	2.54	0.68	4.33%	0.07
V59561	3.24	0.68	-1.02%	-0.02
V74513	3.26	0.68	3.76%	0.08

Circuit	Annual Peak Demand 2014-2016 (MW)	CVR_f	Average Percent Change in Peak Voltage	Annual Peak Demand Savings (MW)
V99562	4.43	0.68	3.10%	0.09
X34530	2.30	0.68	3.40%	0.05
X34532	2.33	0.68	2.95%	0.05
X42502	3.39	0.68	2.76%	0.06
X57566	3.41	0.68	3.17%	0.07
X65540	2.69	0.68	3.39%	0.06
X75512	5.22	0.68	3.16%	0.11
X78536	2.40	0.68	3.97%	0.06
X78537	1.23	0.68	3.53%	0.03
X99538	2.64	0.68	2.69%	0.05
Y08551	1.23	0.68	3.51%	0.03
Y08552	2.36	0.68	3.27%	0.05
Y08553	3.63	0.68	4.55%	0.11
Y12559	2.55	0.68	2.59%	0.04
Y12560	3.28	0.68	2.45%	0.05
Y23513	2.41	0.68	2.15%	0.04
Y23521	4.62	0.68	1.61%	0.05
Y26520	2.79	0.68	3.48%	0.07
Y26580	1.52	0.68	4.12%	0.04
Y35513	2.48	0.68	3.32%	0.06
Y35515	3.21	0.68	2.89%	0.06
Y63527	4.67	0.68	1.82%	0.06
Y63531	2.34[a]	0.68	2.27%	0.04
Y96564	3.29	0.68	3.08%	0.07
Z16547	4.03	0.68	3.37%	0.09
Z17503	3.99	0.68	1.97%	0.05
Z18553	2.53	0.68	3.06%	0.05
Z18554	3.78	0.68	5.51%	0.14
Z18555	2.00	0.68	4.97%	0.07
Z18557	9.51	0.68	3.42%	0.22
Y35513	2.48	0.68	3.32%	0.06

[a] Annual Peak Demand value was unavailable. To estimate 2014-2016 MW peak demand, the evaluation team applied the average ratio of 2014-2016 energy usage to 2014-2016 peak demand to the circuit's 2014-2016 energy usage.
[b] In 2021, circuit B76003 was split into B76003 and B76004. Circuit B76003 retained 55% of the 2014-2016 energy usage, and the remainder went to B76004. The same ratio was applied to obtain peak demand value for circuits B76003 and B76004.

APPENDIX C. CUMULATIVE PERSISTING ANNUAL SAVINGS

Table 13 provides CPAS and WAML for the 2023 VO Program through 2038. Lifetime savings for the 2023 VO Program were calculated to be 1,251,236 MWh.

Table 13. 2023 VO Program CPAS and WAML through 2038

Measure Category	Measure Life	Annual Verified Gross Savings (MWh)	NTGR	CPAS - Verified Net Savings (MWh)							
				2023	2024	2025	2026	2027	2028	2029	2030
Voltage Optimization - 2023 Cohort	15.0	83,416	N/A	83,416	83,416	83,416	83,416	83,416	83,416	83,416	83,416
2023 CPAS		83,416	N/A	83,416	83,416	83,416	83,416	83,416	83,416	83,416	83,416
Expiring 2023 CPAS				0	0	0	0	0	0	0	0
Expired 2023 CPAS				0	0	0	0	0	0	0	0

Measure	Measure Life	Annual Verified Gross Savings (MWh)	NTGR	CPAS - Verified Net Savings (MWh)							
				2031	2032	2033	2034	2035	2036	2037	2038
Voltage Optimization - 2023 Cohort	15.0	83,416	N/A	83,416	83,416	83,416	83,416	83,416	83,416	83,416	0
2023 CPAS		83,416	N/A	83,416	83,416	83,416	83,416	83,416	83,416	83,416	0
Expiring 2023 CPAS				0	0	0	0	0	0	0	83,416
Expired 2023 CPAS				0	0	0	0	0	0	0	83,416
WAML	15.0										

Table 14 presents cumulative verified CPAS and expected CPAS per the original AIC VO plan. As of the end of program year 2023, cumulative verified CPAS exceeded the expected CPAS by 26%.

Table 14 Total CPAS vs. Expected CPAS Per AIC's Original VO Implementation Plan

Year Ending	2018	2019	2020	2021	2022	2023	2024	2025
Expected Cumulative Persisting Annual Savings (MWh) per AIC's VO Implementation Plan	0	7,650	59,994	128,433	201,725	275,006	348,287	421,568
Total Cumulative Persisting Annual Savings (MWh)[a]	0	9,175	81,843	177,275	264,167	347,583	N/A	N/A
% of Expected Savings Reached by End of Evaluation Period	N/A	120%	136%	138%	131%	126%	N/A	N/A

[a] This row contains total CPAS from all years of VO Program implementation (2019-2023) and therefore differs from the values presented in Table 13 above, which presents only CPAS from the 2023 VO Program.

APPENDIX D. VERIFICATION OF CONTINUED OPERATIONS

Opinion Dynamics conducted a verification analysis on the 2019, 2020, 2021, and 2022 cohorts of 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 to provide information to all stakeholders about 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 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 uptime threshold of operation was set to ensure that circuits operated over a 90% threshold.[26]

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 at the acceptable 90% uptime threshold throughout the period.

We conducted the following activities to determine whether these circuits operated over a 90% uptime threshold.

- **Sample Selection:** We selected a random sample of 10 of the 19 circuits evaluated in 2019, 14 of the 125 circuits evaluated in 2020, 19 of the 180 circuits evaluated in 2021, and 20 of the 181 circuits evaluated in 2022, using a cross-sectional sample design which optimizes the sample for each cohort while minimizing the overall sample size across all cohorts. Sample selection was performed retrospectively and provided AIC no knowledge of which circuits would be sampled until after the evaluation period had passed. Table 15 presents the sample of the circuits evaluated as part of the 2019, 2020, 2021, and 2022 circuit verification.

Table 15. Sample of Circuits Evaluated in 2019, 2020, 2021, and 2022

Feeder	Substation	Year Previously Evaluated
C52001	RIDGE	2019
C52002	RIDGE	2019
J34357	BETHALTO	2019
J34377	BETHALTO	2019
L93132	EAST BELLEVILLE	2019
P69173	MT ZION RTE 121	2019
V40556	QUINCY 2 AND CHERRY	2019
V41533	QUINCY 28 AND ADAMS	2019
V42572	QUINCY 30 AND HAMP	2019
X35501	CHARLESTON S (EIU)	2019
B44002	CHESTER	2020
B80003	SHERIDAN	2020
J99121	BELLEVILLE MARIKNOLL	2020
L23145	DECATUR RT. 48 SOUTH	2020

[26] See Ameren Illinois Company Voltage Optimization Verification and Exclusion Approach Memorandum here: https://www.ilsag.info/wp-content/uploads/AIC-2019-Voltage-Optimization-Operation-Verification-Memo-FINAL-2020-04-17.pdf

Feeder	Substation	Year Previously Evaluated
L93133	EAST BELLEVILLE	2020
M26164	FORSYTH	2020
M81405	GRANITE CITY PARKVIEW	2020
N95823	LITCHFIELD	2020
P17108	MAHOMET	2020
R07381	SOUTH OTTAWA	2020
R60553	URBANA PERKINS RD	2020
S22594	CARTERVILLE	2020
T08502	WEST FRANKFORT IDA	2020
U32594	CANTON S	2020
B65003	UNIVERSITY	2021
D31016	LIMIT	2021
D31017	LIMIT	2021
D36001	HALLOCK	2021
HA5432	CASEYVILLE BETHEL MINE	2021
J58381	BLOOMINGTON MORRIS AVE	2021
J63172	BLOOMINGTON PROSPECT	2021
J84145	BELLEVILLE 65TH ST	2021
J89125	BELLEVILLE C ST	2021
L86175	DANVILLE WINTER AVE	2021
M05368	EDWARDSVILLE SECOND STREET	2021
P98191	NORMAL MAIN ST	2021
R16511	SPRING VALLEY	2021
R53390	TROY INDUSTRIAL	2021
S49549	HERRIN SW	2021
X30506	CHARLESTON E	2021
X60595	EFFINGHAM N	2021
X60598	EFFINGHAM N	2021
Y11556	MATTOON NW	2021
A45001	OZARK	2022
A48001	NEW YORK	2022
A48005	NEW YORK	2022
B68002	KICKAPOO	2022
J76804	BRIGHTON	2022
J85160	BELLEVILLE 74TH ST	2022
K46389	COLLINSVILLE CLOVERLEAF	2022
K73366	CHAMPAIGN LEVERETT RD	2022

Feeder	Substation	Year Previously Evaluated
L00134	DECATUR GREENSWITCH ROAD	2022
M40116	GALESBURG MONMOUTH BLVD	2022
N50331	JACKSONVILLE POWER PLANT	2022
P26280	MARSEILLES	2022
S30518	DESOTO	2022
S42579	HARRISBURG NORTH	2022
T06505	WEST FRANKFORT	2022
V20502	PAYSON S	2022
V46563	QUINCY 42ANDCOLUMBUS	2022
Y51506	PARIS HIGH ST	2022
Z41536	TEUTOPOLIS WEST	2022
Z50544	ARCOLA EAST	2022

- **Review and request operation log summaries for the sample.** The variable of interest for this effort included the VO status (i.e., VO “On” and VO “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 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 operational by the total number of non-excludable hours in the year.

Opinion **Dynamics**

CONTACT:

Zach Ross
Director
zross@opiniondynamics.com

Shihab Siddiqui
Principal Consultant
ssiddiqui@opiniondynamics.com

BOSTON
PORTLAND
SAN DIEGO
SAN FRANCISCO