2022 Indiana EECO Program EM&V Report

Prepared for:
Indiana Michigan Power

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1. Introduction

This report addresses the measuring, verifying and evaluating of energy savings and demand reductions that resulted from the implementation by Indiana Michigan Power Company (I&M) in 2022 of its Electric Energy Consumption Optimization (EECO) Program. I&M implemented this program in conjunction with Utilidata, Inc.

1.1 Description of Program

Under ANSI Standard C84.1 Electric Power Systems and Equipment, a utility system is to deliver electricity to end-users at a voltage within the range of 120 ± 5% volts (i.e., 114 – 126). With the usual system design, customers close to a substation receive voltages closer to 126 volts and customers farther from the substation receive lower voltages. Voltage regulating equipment is applied as necessary to ensure the required minimum voltages are provided.

The EECO program is based on implementing Conservation Voltage Reduction (CVR), which is a process by which the utility systematically reduces voltages in its distribution network, resulting in a proportional reduction of load on the network. Because most devices operated by electricity (especially motors) are designed to operate most efficiently at 115 volts, any "excess" voltage is typically wasted, usually in the form of heat. Tighter voltage regulation allows end-use devices to operate more efficiently without any action on the part of consumers. Consumers receive a lower but still acceptable voltage and use less energy to accomplish the same tasks.

Voltage is controlled for the circuits at the substations using Utilidata's AdaptiVolt Volt/VAR Optimization (VVO) platform. AdaptiVolt uses secure digital communications to implement a closed-loop control system. Using AdaptiVolt allows I&M to dispatch voltage-based demand control within seconds. The system measures end-of-line voltage and sends the voltage information back to the controller at the substation in real time.

Using the AdaptiVolt™ system, voltages were controlled for each of the three phases being distributed to the circuits served by the substation. Thus, the voltage for Phase A was the same for all three circuits, and similarly for Phases B and C.

1.2 Impact Evaluation Findings

Table 1-1 below presents the total aggregated annual gross and net energy (kWh) savings achieved by the EECO Program during PY2022. Table 1-1 also provides an estimate of the annual net kWh savings that might have been achieved if VVO had been operated continuously during the full year.

Table 1-1. Summary of Ex Post and Counterfactual PY2022 kWh Savings

Ex Ante Annual kWh Savings	*Gross Audited kWh Savings*	*Gross Verified kWh Savings*	*Ex Post Annual Gross kWh Savings*	*Gross Realization Rate*	*Ex Post Annual Net kWh Savings*	*Net-to-Gross Ratio*	*Counterfactual Estimated Annual kWh Savings-100% CVR On Time*
16,388,707	16,388,707	16,388,707	16,388,705	100%	16,388,705	100%	27,723,933

Table 1-2 presents the total gross and net peak demand (kW) impacts achieved by the EECO Program during PY2022.

Table 1-2. Summary of Ex Post PY2022 kW Peak Demand Impacts

Ex Ante Gross kW Savings	*Gross Audited kW Savings*	*Gross Verified kW Savings*	*Ex Post Gross kW Savings*	*Gross Realization Rate*	*Ex Post Net kW Savings*	*Net-to-Gross Ratio*
1,385.94	1,385.94	1,385.94	3,380.20	244%	3,380.20	100%

1.3 Organization of Report

This report is organized as follows:

- Chapter 2: Data Collection
- Chapter 3: Method for Determining Energy Savings
- Chapter 4: Circuit/Phase-Level Energy Savings and CVR Factors
- Chapter 5: Aggregate Energy Savings
- Chapter 6: Peak Reduction

2. Data Collection

The effects of voltage optimization for 2022 were analyzed using voltage and power data extracted from I&M's SCADA system.

I&M and Utilidata used an "on/off" procedure for voltage reductions during various parts of 2022.[1] This procedure involves disengaging the VVO system during specified days to enable the provision of data sets with measurements of voltages and energy use that include both regular voltages (measured on "off" days, during which the VVO system is disengaged) and reduced voltages (measured on "on" days, during which the VVO system is engaged).

During 2022, data were collected for regulated source voltages by phase and power by circuit. Voltage and power were measured at 30 second intervals, giving 120 data-points per hour for each element. Voltages were measured at the substation level for three phases.

While VVO was initially engaged prior to 2022 for most circuits included in the analysis, the VVO system was initially engaged during 2022 for the circuits listed below in Table 2-1. Data associated with these circuits was included in the analysis of 2022 program year impacts.

Table 2-1. Initial VVO System Engagement During 2022 by Circuit by Date

Circuit ID	*Date VVO System Initially Engaged*
Spyrun-4923321	2/24/2022
Spyrun-4923322	2/24/2022
Spyrun-4923329	2/24/2022
McKinley-4055923	4/11/2022
McKinley-4055924	4/11/2022
McKinley-4055925	4/11/2022
McKinley-4055921	4/12/2022
McKinley-4055922	4/12/2022
McKinley-4055926	4/12/2022
Trier-4936421	5/19/2022
Trier-4936422	5/19/2022
Trier-4936423	5/19/2022
Summit-4937824	8/29/2022
Summit-4937825	8/29/2022
Wallen-4923421	11/14/2022
Wallen-4923422	11/14/2022
Wallen-4923423	11/14/2022
Wallen-4923424	11/14/2022
Wallen-4923425	11/14/2022
Wallen-4923426	11/14/2022

[1] For discussion of "on / off" testing, see, for example, Pacific Northwest Regional Technical Forum, *Standard Protocol #1 for Automated CVR,* November 2011.

Hourly temperature readings were available from the quality controlled local climatological data program of the National Climatic Data Center[2] for 2022 for the multiple weather stations selected based on proximity to the substations for which VVO is enabled. This temperature data was used for the analysis.

Table 2-2 shows the percent of time during 2022 during which the VVO system was engaged. Where VVO engagement rates were uniform across circuits, information is presented by station; otherwise, results are shown by group of circuits at a station with uniform VVO engagement rates. The table also presents average voltage levels when the system was engaged and when it was disengaged, as well as achieved energy savings attributable to the VVO system.

[2] For information on the QCLCD data, see http://www.ncdc.noaa.gov/data-access/land-based-station-data/land-based-datasets/quality-controlled-local-climatological-data-qclcd

Table 2-2 PY2022 Percent VVO System Engagement, Voltage, Energy Savings, and CVR Factors by Station

Substation / Circuit Group	*Percent Time Engaged*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Daleville	6%	125.44	123.80	22,752	5,653,903	0.40%	0.31
EastSide (4093121, 4093122, 4093123)	71%	125.15	120.28	921,821	44,346,908	2.04%	0.52
EastSide (4093124, 4093125, 4093126)	58%	125.32	120.66	1,300,746	42,138,166	2.99%	0.80
Elcona	51%	125.33	120.45	594,014	43,508,773	1.35%	0.35
Farmland	47%	125.21	120.74	192,491	12,590,756	1.51%	0.42
Grabill	70%	124.90	121.76	984,079	52,621,822	1.84%	0.73
Hacienda (4933521, 4933523, 4933524)	46%	125.22	120.97	88,619	2,695,079	3.18%	0.94
Hacienda (4933525, 4933526, 4933527)	36%	124.27	120.62	984,349	31,801,055	3.00%	1.02
Harper	47%	123.92	120.07	674,808	33,555,438	1.97%	0.63
Lincoln	3%	115.30	104.07	(2,755)	2,064,917	-0.13%	(0.01)
McKinley (4055921,4055922, 4055926)	42%	123.80	121.45	2,030	47,833,967	0.00%	0.00
McKinley (4055923, 4055924, 4055925)	44%	123.36	119.63	734,460	30,376,758	2.36%	0.78
Northland (4933421, 4933422, 4933423)	74%	124.47	121.86	511,252	49,717,758	1.02%	0.48
Northland (4933424, 4933425, 4933426)	55%	125.16	121.09	1,280,632	46,814,818	2.66%	0.82
Osolo (4058021, 4058022, 4058024)	48%	125.48	121.53	923,696	42,398,047	2.13%	0.68
Osolo (4058023, 4058025, 4058026)	74%	125.38	121.42	1,296,938	52,562,660	2.41%	0.76
Pettit	72%	124.31	120.87	670,867	46,247,280	1.43%	0.52
SouthBend	62%	125.32	119.79	1,986,600	46,988,344	4.06%	0.92
Southside	58%	125.15	120.89	643,016	43,264,503	1.46%	0.43
SouthsideSB	72%	125.29	120.33	1,133,316	39,718,147	2.77%	0.70
Spyrun	56%	124.87	120.92	350,115	43,302,830	0.80%	0.25
StateStreet	42%	124.02	120.84	1,004,471	35,245,328	2.77%	1.08
Summit	5%	124.21	120.73	21,749	923,795	2.30%	0.82
Trier	33%	125.45	120.39	68,641	1,801,549	3.67%	0.91
Wallen	12%	124.77	120.68	-	1,100,565	0.00%	0.00
Total				16,388,705	799,273,165	2.01%	N/A

3. Method for Determining Energy Savings

This chapter discusses the method used for analysis of data to determine energy savings from voltage reduction.

3.1 Protocols for CVR Analysis

Methods for using circuit-level data on voltages and power usage to measure and verify savings from voltage reductions are set out in several existing protocols. Because much of the early work on voltage reduction was performed in the Pacific Northwest, the Northwest Regional Technical Forum (RTF) managed a process to prepare a protocol for estimating savings from automated CVR. This protocol (Automated CVR Protocol No. 1) was approved by the RTF in 2004. The RTF approved a second protocol (Simplified Voltage Optimization Protocol) in 2010.

With the RTF protocols, savings resulting from voltage reduction are estimated by multiplying a change in voltage level by a CVR factor that reflects the estimated relationship between voltage reduction and energy reduction. For application of the protocols in the Pacific Northwest, load research data were used to develop a series of lookup tables with CVR values for participating utilities. However, these CVR values depend on load and weather conditions and end-use equipment saturations (e.g., air conditioning use) that are specific to the Pacific Northwest.

An enhanced version of the RTF protocols has been developed by a CVR working group in Pennsylvania. Using data collected for utility distribution circuits in Pennsylvania, the working group developed a Conservation Voltage Reduction (CVR) Custom Measurement Protocol for Demand Reduction. (Revised version was published September 21, 2011.)

3.2 Method for Determining kWh Savings

As shown by Equation 3-1, the kWh savings that result from voltage reduction can be quantified as the difference between a baseline energy use (when voltage is not reduced) and actual energy use when voltage is reduced.

Equation 3-1

$$kWh\ savings = kWh_{Baseline} - kWh_{Actual\ when\ VVO\ is\ "On"}$$

While the energy use when the VVO system is engaged can be measured, baseline energy use is *counterfactua*l: what the energy use *would have been* during the time when the VVO system was engaged if it had instead been disengaged.

3.2.1 Determining Baseline Voltages

Baseline voltages for hours when VVO was engaged were imputed using mean values of voltages when VVO was disengaged. These mean values were calculated for each circuit for cells defined by hour of day. For each hour that VVO was engaged, the baseline voltage was imputed to be the

disengaged voltage from the cell similarly defined by hour of day. For example, the baseline voltage for 1 PM when VVO was engaged was imputed to be the mean voltage calculated from voltage readings for the 1 PM hour when VVO was disengaged.

3.2.2 Determining Baseline Power

Power for a circuit is not completely independent from voltage changes because not all loads react in the same way to a voltage change. Various studies have shown that the energy savings that result from voltage reduction depend on the characteristics and loads of a feeder.

- Some loads are characterized by constant impedance, where power consumed is proportional to voltage squared. Examples of such loads include resistive water heaters, stovetop and oven cooking loads, for instance.
- Other loads are constant power, where demand is constant regardless of voltage. Examples of constant power loads include electric motors and regulated power supplies.
- A relatively small percentage of loads are constant current, where demand is proportional to voltage. Examples of constant current loads include welding units, smelting, and electroplating processes.

The overall load on a feeder will be a mix of the different load types. Rules of thumb for the split between constant power and constant impedance loads are as follows[3]:

- For summer peak loads, 60% constant power and 40% constant impedance
- For winter peak loads, 40% constant power and 60% constant impedance
- For industrial loads, 80% constant power and 20% constant impedance
- For summer peaking residential loads, 70% constant power and 30% constant impedance
- For winter peaking residential loads, 30% constant power and 70% constant impedance
- For commercial loads, the split between constant power and constant impedance is generally 50%/50% or 60%/40%

Regression analysis was used to relate circuit power data to month of year, day type (business day/non-business day[4]), EECO operating state and weather. The regression model used is given in Equation 3-2 below.

Equation 3-2

$$Power_i = \alpha + \beta_{1,j} CVR_j + \beta_2 CDH_i + \beta_3 HDH_i + \beta_4 Hour_i + \beta_4 Month_i + \beta_5 Day\_Type_i + e_i$$

Key model variables are identified in Table 3-1.

[3] Willis, H. Lee, *Power Distribution Planning Reference Book.*
[4] *Business day* includes all weekdays during 2022 other than 01/03/2022, 01/17/2023, 02/21/2022, 05/30/2022, 07/04/2022, 09/05/2022, 10/10/2022, 11/11/2022, 11/24/2022, 11/25/2022, 11/30/2022, and 12/26/2022.

Table 3-1. Analysis Model Variables

Variable Name	*Variable Description*
Power	Dependent variable; hourly power (kW).
CVR	1 if EECO is on; otherwise 0.
CDH	MAX (Outdoor Temperature - 65°F, 0)
HDH	MAX (65°F - Outdoor Temperature, 0)
Hour	Group of dummy variables for hour of the day.
Month	Group of dummy variables for month.
Day_Type	1 if business day; otherwise 0.

For each circuit and phase, regression models using the specification in Equation 3-2 were estimated. Regression models were performed using a randomly selected subset of data generated through pairing hourly observations occurring during VVO system engagement with hourly observations occurring during VVO system disengagement. Paired observations occurred during adjacent days of the same day type (business/non-business) and during the same hour of day.

The value for β_1 estimated through the regression analysis captures the impact of VVO system engagement on circuit-level energy usage, controlling for month of year, weather, day type, and hour of day.

3.2.3 Determining Energy Savings

The results from studies of voltage reduction are often summarized in terms of a conservation voltage reduction factor (CVR_f). A CVR_f measures the relationship between changes in energy in response to changes in voltage effected under the CVR program. Mathematically, CVR_f is calculated as the ratio between the percentage change in energy and the percentage change in voltage, as shown below in Equation 3-3.

Equation 3-3

$$CVR_f = \frac{\%\Delta\ in\ energy}{\%\Delta\ in\ voltage}$$

where $\%\Delta\ in\ energy$ = $\Delta kWh/kWh_{Base}$ and $\%\Delta\ in\ voltage$ = $\Delta Volts/Volts_{Base}$. ΔkWh is kWh savings and $\Delta Volts$ is the voltage reduction.

3.3 Method to Calculate Aggregate Annual kWh Savings

The method described in section 3.2 provides hourly circuit/phase -level estimates of the average hourly kWh savings that result from VVO voltage reduction. Multiplying that hourly estimate of savings by the number of hours voltage was reduced during the year provides an aggregate estimate of kWh savings. These savings are those that occurred during the hours when VVO was engaged. As shown in Table 2-2, VVO was not engaged during all hours of the year. An additional calculation is therefore made to determine what kWh savings would have been had VVO been

engaged during all hours of the program year. This calculation is made through application of the savings rate applicable to hours of VVO system engagement to the energy usage occurring during times when the VVO system was disengaged.

4. Circuit/Phase-Level Energy Savings and CVR Factors

This chapter presents the results from the analysis of data for the Indiana EECO program in 2022 to determine kWh savings and CVR factors associated with voltage reduction for the various circuits and phases.

For each circuit and phase, kWh savings and CVR factors were calculated. The percentage savings from reducing voltage was calculated and divided by the percentage reduction in voltage to determine the CVR factor. The resulting estimates of kWh savings and CVR factors for the various phases of the circuits and phases are reported by substation in Table 4-1 through Table 4-20.

The estimated CVR factors show a range of values, which is consistent with evidence from previous studies of the voltage reduction strategy.

Results reported from previous studies show the range of CVR factors that have been estimated.

- Kirshner and Giorsetto[5] analyzed trials of voltage reduction at several utilities in the early 1980s. Their analysis showed that most test circuits had energy savings of between 0.5 and 1% for each 1% voltage reduction, implying CVR factors of 0.5 to 1. Their regression analysis showed that each 1% reduction in voltage resulted in energy savings of 0.76% for residential loads, of 0.99% for commercial loads, and of 0.41% for industrial loads.
- More recently, a study conducted for the Northwest Energy Efficiency Alliance (NEEA) evaluated voltage reduction at several utilities in the Pacific Northwest.[6] Evaluation of voltage changes at the circuit level, using temperature adjusted regressions, gave an average CVR factor of 0.69 based on a voltage change of 2.5%. The range of CVR factors was -0.11 to 1.98.
- In EPRI's Green Circuits collaborative project[7], 42 distribution circuits across different utilities were modeled in detail using an open-source distribution system electrical simulation package (OpenDSS). This modeling was augmented with historical circuit-measurement data, allowing the hourly resolution simulation of circuit operation for actual load patterns for each hour in a calendar year (8760 hours). As part of the study, the effects of voltage reduction were modeled using a consistent approach to control an end-of-line primary bus of 118 V. The results showed a median reduction in energy consumption across all circuits of 2%, with upper and lower quartiles of 1.3% and 2.8%.
- In the study that was sponsored by the Northwest Energy Efficiency Alliance (NEEA), it was found that there are differences between seasons in the effectiveness of voltage reduction. The study determined that the CVR factor at the feeder level was 0.74 for the summer and 0.66 for the winter. At the customer level, the CVR factor was 0.78 for the summer and 0.51 for the winter.

[5] Kirshner, D. and Giorsetto, P., "Statistical Tests of Energy Savings Due to Voltage Reduction," IEEE Transactions on Power Apparatus and Systems, vol. PAS-103, no. 6, pp. 1205-10, June 1984.

[6] NEEA 1207, Distribution Efficiency Initiative, Northwest Energy Efficiency Alliance, 2007.

[7] Electric Power Research Institute (EPRI), *Green Circuit: Distribution Efficiency Case Studies,* Technical Report, 2011.

- As part of the EPRI Green Circuit project, extensive field testing was conducted for nine distribution circuits in the southeast United States. The analysis in this study showed that most energy savings from voltage reduction were achieved from summer-peaking residential customers, while winter heating loads showed the least energy savings. The estimated CVR factors were 0.77 for the summer and 0.33 for the winter.

Table 4-1 PY2022 Energy Savings and CVR Factors by Phase: Daleville Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Daleville-4927921	A	124.76	123.35	2,271	841,847	0.27%	0.24
	B	125.55	124.15	4,468	690,944	0.64%	0.58
	C	125.53	123.87	8,240	853,128	0.96%	0.73
	Total /Average	125.26	123.77	14,978	2,385,919	0.62%	0.52
Daleville-4927922	A	125.34	123.36	(1,689)	497,464	-0.34%	(0.22)
	B	126.10	124.15	(1,313)	445,626	-0.30%	(0.19)
	C	126.10	123.87	(1,405)	415,087	-0.34%	(0.19)
	Total /Average	125.82	123.77	(4,407)	1,358,176	-0.33%	(0.20)
Daleville-4927923	A	124.82	123.37	1,224	455,723	0.27%	0.23
	B	125.58	124.18	5,126	598,083	0.85%	0.77
	C	125.56	123.90	5,831	856,001	0.68%	0.51
	Total /Average	125.39	123.86	12,181	1,909,807	0.63%	0.52

Table 4-2 PY2022 Energy Savings and CVR Factors by Phase: EastSide Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
EastSide-4093121	A	124.95	120.38	26,680	2,106,543	1.25%	0.35
	B	125.06	120.31	40,708	2,412,295	1.66%	0.44
	C	125.24	120.20	46,311	2,238,246	2.03%	0.51
	Total /Average	125.08	120.29	113,699	6,757,084	1.65%	0.43
EastSide-4093122	A	125.03	120.38	93,612	6,553,208	1.41%	0.38
	B	125.13	120.30	125,980	5,407,539	2.28%	0.60
	C	125.32	120.20	111,270	5,859,489	1.86%	0.47
	Total /Average	125.15	120.30	330,861	17,820,235	1.82%	0.47
EastSide-4093123	A	125.04	120.35	111,193	6,368,247	1.72%	0.47
	B	125.14	120.27	201,399	6,555,495	2.98%	0.79
	C	125.34	120.18	164,669	6,845,848	2.35%	0.59
	Total /Average	125.18	120.27	477,260	19,769,589	2.36%	0.60
EastSide-4093124	A	125.24	120.63	243,982	6,194,289	3.79%	1.07
	B	125.31	120.53	269,081	6,331,532	4.08%	1.11
	C	125.37	120.75	247,828	6,294,165	3.79%	1.07
	Total /Average	125.31	120.63	760,891	18,819,985	3.89%	1.04
EastSide-4093125	A	125.23	120.65	131,887	4,476,074	2.86%	0.80
	B	125.30	120.55	134,396	4,693,500	2.78%	0.75
	C	125.36	120.77	128,970	4,613,283	2.72%	0.76
	Total /Average	125.30	120.66	395,253	13,782,856	2.79%	0.75
EastSide-4093126	A	125.33	120.70	31,441	2,842,467	1.09%	0.30
	B	125.35	120.56	56,160	3,268,474	1.69%	0.45
	C	125.45	120.82	57,001	3,424,384	1.64%	0.45
	Total /Average	125.38	120.70	144,602	9,535,325	1.49%	0.40

Table 4-3 PY2022 Energy Savings and CVR Factors by Phase: Elcona Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Elcona-4938121	A	125.28	120.35	48,802	4,225,007	1.14%	0.29
	B	125.26	120.43	54,767	4,612,961	1.17%	0.31
	C	125.42	120.57	28,058	4,197,604	0.66%	0.17
	Total /Average	125.32	120.45	131,627	13,035,571	1.00%	0.26
Elcona-4938122	A	125.30	120.37	14,007	2,370,558	0.59%	0.15
	B	125.28	120.45	32,331	2,656,389	1.20%	0.32
	C	125.40	120.56	32,884	2,751,860	1.18%	0.31
	Total /Average	125.33	120.46	79,222	7,778,808	1.01%	0.26
Elcona-4938123	A	125.30	120.35	142,020	7,501,249	1.86%	0.48
	B	125.27	120.42	130,067	7,480,235	1.71%	0.45
	C	125.42	120.56	111,078	7,712,912	1.42%	0.37
	Total /Average	125.33	120.44	383,165	22,694,395	1.66%	0.43

Table 4-4 PY2022 Energy Savings and CVR Factors by Phase: Farmland Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Farmland-4927321	A	125.15	120.28	30,113	1,886,981	1.57%	0.41
	B	125.15	121.06	8,877	1,515,472	0.58%	0.18
	C	125.24	120.78	31,430	1,623,133	1.90%	0.54
	Total /Average	125.18	120.68	70,419	5,025,585	1.38%	0.38
Farmland-4927322	A	125.20	120.32	8,129	338,856	2.34%	0.61
	B	125.16	121.07	3,779	256,718	1.45%	0.45
	C	125.27	120.80	15,729	496,210	3.07%	0.89
	Total /Average	125.22	120.71	27,637	1,091,784	2.47%	0.69
Farmland-4927323	A	125.18	120.30	48,512	1,730,669	2.73%	0.72
	B	125.19	121.09	30,137	2,512,849	1.19%	0.37
	C	125.28	120.82	15,785	2,229,870	0.70%	0.20
	Total /Average	125.22	120.79	94,434	6,473,388	1.44%	0.41

Table 4-5 PY2022 Energy Savings and CVR Factors by Phase: Grabill Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Grabill-4935221	A	124.35	121.41	41,927	5,269,565	0.79%	0.34
	B	124.88	121.38	78,260	4,565,724	1.69%	0.61
	C	125.46	122.43	70,974	6,092,131	1.15%	0.48
	Total /Average	124.93	121.79	191,160	15,927,420	1.19%	0.47
Grabill-4935222	A	124.34	121.43	203,715	9,889,112	2.02%	0.88
	B	124.83	121.36	236,028	9,336,889	2.47%	0.91
	C	125.42	122.41	156,277	8,871,562	1.73%	0.73
	Total /Average	124.84	121.71	596,020	28,097,563	2.08%	0.83
Grabill-4935223	A	124.47	121.51	46,709	2,482,979	1.85%	0.79
	B	124.97	121.46	38,885	3,040,011	1.26%	0.46
	C	125.53	122.49	111,305	3,073,849	3.49%	1.50
	Total /Average	125.02	121.84	196,899	8,596,839	2.24%	0.88

Table 4-6 PY2022 Energy Savings and CVR Factors by Phase: Hacienda Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Hacienda-4933521	A	125.21	121.42	9,309	344,203	2.63%	0.89
	B	125.34	120.91	13,253	373,557	3.43%	1.00
	C	125.11	120.47	7,456	219,701	3.28%	0.91
	Total /Average	125.24	121.00	30,017	937,461	3.10%	0.92
Hacienda-4933523	A	125.19	121.40	8,660	331,286	2.55%	0.86
	B	125.32	120.89	9,205	267,350	3.33%	0.97
	C	125.08	120.44	10,327	274,673	3.62%	1.01
	Total /Average	125.19	120.94	28,192	873,309	3.13%	0.92
Hacienda-4933524	A	125.20	121.42	10,029	326,626	2.98%	1.02
	B	125.31	120.88	10,228	291,982	3.38%	0.99
	C	125.10	120.46	10,153	265,700	3.68%	1.03
	Total /Average	125.21	120.95	30,409	884,309	3.32%	0.98
Hacienda-4933525	A	123.80	120.65	111,469	3,552,667	3.04%	1.23
	B	124.34	120.62	100,512	3,427,746	2.85%	0.98
	C	124.58	120.54	93,244	3,371,896	2.69%	0.85
	Total /Average	124.23	120.60	305,225	10,352,309	2.86%	0.98
Hacienda-4933526	A	123.89	120.72	133,941	2,961,583	4.33%	1.77
	B	124.45	120.70	162,819	3,930,946	3.98%	1.37
	C	124.64	120.58	160,489	3,232,990	4.73%	1.52
	Total /Average	124.35	120.67	457,249	10,125,519	4.32%	1.46
Hacienda-4933527	A	123.80	120.62	69,388	3,810,215	1.79%	0.71
	B	124.37	120.62	70,666	4,236,257	1.64%	0.55
	C	124.60	120.54	81,820	3,276,756	2.44%	0.77
	Total /Average	124.24	120.60	221,874	11,323,228	1.92%	0.65

Table 4-7 PY2022 Energy Savings and CVR Factors by Phase: Harper Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Harper-4928821	A	124.24	120.05	80,344	5,671,386	1.40%	0.42
	B	124.60	120.11	155,785	5,062,236	2.99%	0.85
	C	124.49	120.07	120,198	5,741,851	2.05%	0.59
	Total /Average	124.43	120.08	356,327	16,475,472	2.12%	0.60
Harper-4928822	A	123.21	120.04	85,904	4,640,815	1.82%	0.72
	B	123.56	120.08	133,464	6,684,829	1.96%	0.71
	C	123.47	120.08	99,114	5,754,322	1.69%	0.63
	Total /Average	123.43	120.07	318,481	17,079,966	1.83%	0.67

Table 4-8 PY2022 Energy Savings and CVR Factors by Phase: Lincoln Circuit

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Lincoln-4051822	A	122.30	122.82	(699)	350,902	-0.20%	0.47
	B	123.76	123.98	(670)	343,758	-0.20%	1.07
	C	124.33	124.79	(1,386)	346,773	-0.40%	1.09
	Total/Average	123.46	123.86	(2,755)	1,041,434	-0.27%	0.82

Table 4-9 PY2022 Energy Savings and CVR Factors by Phase: McKinley Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
McKinley-4055921	A	123.45	120.77	(24,116)	6,711,145	-0.36%	(0.17)
	B	123.75	121.35	(17,018)	7,150,975	-0.24%	(0.12)
	C	124.19	122.22	35,343	7,780,457	0.45%	0.29
	Total /Average	123.81	121.48	(5,790)	21,642,577	-0.03%	(0.01)
McKinley-4055922	A	123.46	120.78	70,909	3,287,872	2.11%	0.99
	B	123.77	121.37	62,122	2,908,926	2.09%	1.10
	C	124.26	122.29	42,763	2,381,135	1.76%	1.13
	Total /Average	123.79	121.40	175,794	8,577,933	2.01%	1.04
McKinley-4055923	A	123.44	119.67	102,996	3,712,370	2.70%	0.91
	B	123.35	119.66	74,379	2,685,457	2.70%	0.92
	C	123.42	119.70	79,294	2,585,710	2.98%	1.02
	Total /Average	123.41	119.67	256,669	8,983,537	2.78%	0.92
McKinley-4055924	A	123.41	119.64	76,742	4,186,124	1.80%	0.60
	B	123.30	119.61	87,647	4,075,425	2.11%	0.72
	C	123.31	119.60	98,096	4,351,509	2.20%	0.75
	Total /Average	123.34	119.61	262,485	12,613,058	2.04%	0.67
McKinley-4055925	A	123.42	119.64	88,653	3,075,541	2.80%	0.94
	B	123.30	119.60	56,200	2,671,216	2.06%	0.70
	C	123.29	119.58	70,452	3,033,408	2.27%	0.77
	Total /Average	123.34	119.61	215,306	8,780,164	2.39%	0.79
McKinley-4055926	A	123.46	120.78	(73,464)	5,952,810	-1.25%	(0.57)
	B	123.76	121.36	(47,369)	5,911,275	-0.81%	(0.41)
	C	124.18	122.20	(47,141)	5,749,373	-0.83%	(0.52)
	Total /Average	123.79	121.44	(167,974)	17,613,457	-0.96%	(0.51)

Table 4-10 PY2022 Energy Savings and CVR Factors by Phase: Northland Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Northland-4933421	A	123.91	121.69	80,916	6,210,237	1.29%	0.73
	B	123.94	121.66	71,161	6,195,060	1.14%	0.63
	C	123.54	121.29	50,042	5,534,842	0.90%	0.50
	Total /Average	123.80	121.56	202,119	17,940,139	1.11%	0.61
Northland-4933422	A	124.71	121.87	40,314	3,698,762	1.08%	0.48
	B	124.94	122.11	68,183	3,419,317	1.96%	0.88
	C	124.97	122.17	70,049	3,355,423	2.04%	0.93
	Total /Average	124.87	122.04	178,546	10,473,501	1.68%	0.74
Northland-4933423	A	124.69	121.85	47,168	6,919,094	0.68%	0.30
	B	124.90	122.08	35,098	7,144,949	0.49%	0.22
	C	124.92	122.12	48,321	7,240,077	0.66%	0.30
	Total /Average	124.84	122.02	130,587	21,304,119	0.61%	0.27
Northland-4933424	A	125.14	121.10	135,890	7,231,962	1.84%	0.58
	B	125.21	121.02	187,102	7,061,314	2.58%	0.79
	C	125.14	121.12	146,285	7,760,434	1.85%	0.59
	Total /Average	125.16	121.08	469,277	22,053,710	2.08%	0.64
Northland-4933425	A	125.15	121.13	162,166	4,991,295	3.15%	1.01
	B	125.23	121.05	149,057	4,581,316	3.15%	0.98
	C	125.13	121.13	206,874	5,684,029	3.51%	1.14
	Total /Average	125.17	121.11	518,097	15,256,640	3.28%	1.01
Northland-4933426	A	125.14	121.10	77,583	3,334,096	2.27%	0.72
	B	125.22	121.02	119,903	3,294,822	3.51%	1.09
	C	125.12	121.10	95,771	2,875,551	3.22%	1.04
	Total /Average	125.16	121.07	293,257	9,504,469	2.99%	0.92

Table 4-11 PY2022 Energy Savings and CVR Factors by Phase: Osolo Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Osolo-4058021	A	125.46	121.92	56,059	4,703,684	1.18%	0.42
	B	125.45	121.34	121,251	4,862,985	2.43%	0.76
	C	125.51	121.24	81,812	4,301,187	1.87%	0.56
	Total /Average	125.47	121.51	259,122	13,867,855	1.83%	0.58
Osolo-4058022	A	125.50	121.96	77,996	3,702,720	2.06%	0.75
	B	125.44	121.33	115,929	3,556,813	3.16%	0.99
	C	125.50	121.24	129,979	4,199,015	3.00%	0.91
	Total /Average	125.48	121.50	323,904	11,458,547	2.75%	0.87
Osolo-4058023	A	125.32	121.09	172,486	8,688,978	1.95%	0.59
	B	125.46	121.24	218,480	7,678,463	2.77%	0.84
	C	125.42	121.98	89,467	7,575,206	1.17%	0.43
	Total /Average	125.40	121.42	480,434	23,942,647	1.97%	0.62
Osolo-4058024	A	125.50	121.96	104,800	6,684,376	1.54%	0.56
	B	125.45	121.34	140,860	5,685,395	2.42%	0.76
	C	125.54	121.28	95,010	4,701,875	1.98%	0.60
	Total /Average	125.49	121.57	340,670	17,071,645	1.96%	0.63
Osolo-4058025	A	125.29	121.06	103,548	2,686,336	3.71%	1.14
	B	125.41	121.18	95,491	3,166,172	2.93%	0.90
	C	125.34	121.90	90,416	3,332,056	2.64%	0.99
	Total /Average	125.35	121.41	289,455	9,184,563	3.06%	0.97
Osolo-4058026	A	125.28	121.06	255,069	6,488,425	3.78%	1.17
	B	125.45	121.22	161,647	6,115,550	2.58%	0.78
	C	125.39	121.95	110,332	6,831,477	1.59%	0.59
	Total /Average	125.38	121.42	527,049	19,435,451	2.64%	0.84

Table 4-12 PY2022 Energy Savings and CVR Factors by Phase: Pettit Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Pettit-4917221	A	124.26	120.56	140,380	6,192,279	2.22%	0.76
	B	124.28	120.80	126,113	6,019,287	2.05%	0.75
	C	124.51	121.36	80,966	5,096,590	1.56%	0.63
	Total /Average	124.34	120.88	347,459	17,308,155	1.97%	0.71
Pettit-4917222	A	124.19	120.49	92,894	6,091,698	1.50%	0.51
	B	124.25	120.78	70,931	6,815,177	1.03%	0.37
	C	124.42	121.27	86,604	7,448,050	1.15%	0.46
	Total /Average	124.29	120.87	250,429	20,354,924	1.22%	0.44
Pettit-4917223	A	124.20	120.50	26,867	2,796,751	0.95%	0.32
	B	124.25	120.77	31,469	2,978,011	1.05%	0.38
	C	124.45	121.30	14,644	2,809,439	0.52%	0.21
	Total /Average	124.30	120.86	72,980	8,584,201	0.84%	0.30

Table 4-13 PY2022 Energy Savings and CVR Factors by Phase: SouthBend Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
SouthBend-4050321	A	125.44	120.17	86,219	4,018,059	2.10%	0.51
	B	125.26	119.63	118,243	4,260,633	2.70%	0.62
	C	125.31	119.59	125,807	3,719,577	3.27%	0.74
	Total /Average	125.34	119.80	330,269	11,998,269	2.68%	0.61
SouthBend-4050322	A	125.43	120.16	366,520	8,381,621	4.19%	1.04
	B	125.25	119.61	483,083	9,132,603	5.02%	1.18
	C	125.32	119.60	390,250	6,380,881	5.76%	1.34
	Total /Average	125.33	119.80	1,239,854	23,895,105	4.93%	1.12
SouthBend-4050323	A	125.37	120.14	116,962	3,606,882	3.14%	0.78
	B	125.19	119.58	159,327	4,133,859	3.71%	0.86
	C	125.27	119.58	140,189	3,354,230	4.01%	0.92
	Total /Average	125.27	119.76	416,478	11,094,971	3.62%	0.82

Table 4-14 PY2022 Energy Savings and CVR Factors by Phase: Southside Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Southside-4099921	A	125.12	120.88	70,352	3,894,310	1.77%	0.53
	B	125.03	120.76	92,225	5,876,725	1.55%	0.46
	C	125.27	121.01	77,430	4,343,130	1.75%	0.52
	Total /Average	125.13	120.87	240,008	14,114,164	1.67%	0.49
Southside-4099922	A	125.14	120.90	72,276	6,238,194	1.15%	0.34
	B	125.05	120.78	56,166	6,440,957	0.86%	0.26
	C	125.30	121.04	59,577	6,330,163	0.93%	0.28
	Total /Average	125.16	120.91	188,019	19,009,314	0.98%	0.29
Southside-4099923	A	125.14	120.90	62,929	2,826,277	2.18%	0.66
	B	125.04	120.77	85,307	3,783,774	2.20%	0.66
	C	125.29	121.03	66,753	3,530,975	1.86%	0.56
	Total /Average	125.16	120.90	214,989	10,141,025	2.08%	0.61

Table 4-15 PY2022 Energy Savings and CVR Factors by Phase: SouthsideSB Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
SouthsideSB-4094621	A	124.92	119.95	5,592	382,778	1.44%	0.37
	B	125.62	120.66	24,367	824,880	2.87%	0.75
	C	125.25	120.31	18,627	484,037	3.71%	0.98
	Total /Average	125.36	120.40	48,585	1,691,695	2.79%	0.71
SouthsideSB-4094622	A	124.94	119.97	226,320	7,702,600	2.85%	0.74
	B	125.65	120.69	228,851	6,881,387	3.22%	0.84
	C	125.27	120.33	250,364	8,009,526	3.03%	0.79
	Total /Average	125.27	120.32	705,535	22,593,512	3.03%	0.77
SouthsideSB-4094623	A	124.92	119.96	82,270	3,640,875	2.21%	0.57
	B	125.66	120.69	130,219	4,121,966	3.06%	0.80
	C	125.33	120.38	92,596	3,710,962	2.43%	0.63
	Total /Average	125.32	120.36	305,085	11,473,802	2.59%	0.65
SouthsideSB-4094624	A	124.90	119.94	3,642	975,894	0.37%	0.09
	B	125.62	120.66	32,427	1,324,812	2.39%	0.62
	C	125.28	120.33	38,042	1,658,432	2.24%	0.58
	Total /Average	125.30	120.34	74,110	3,959,138	1.84%	0.46

Table 4-16 PY2022 Energy Savings and CVR Factors by Phase: Spyrun Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Spyrun-4923321	A	124.66	121.13	6,177	2,338,406	0.26%	0.09
	B	124.61	120.85	25,747	3,163,964	0.81%	0.27
	C	125.21	120.80	69,255	2,271,678	2.96%	0.87
	Total /Average	124.80	120.92	101,179	7,774,047	1.28%	0.41
Spyrun-4923322	A	124.65	121.12	(105,933)	9,036,702	-1.19%	(0.41)
	B	124.61	120.84	123,250	9,271,002	1.31%	0.44
	C	125.22	120.81	99,504	9,244,554	1.06%	0.31
	Total /Average	124.83	120.92	116,821	27,552,258	0.42%	0.13
Spyrun-4923329	A	125.01	121.09	20,074	2,817,712	0.71%	0.23
	B	124.85	120.83	58,812	2,498,383	2.30%	0.73
	C	125.44	120.78	53,229	2,660,430	1.96%	0.54
	Total /Average	125.11	120.91	132,115	7,976,525	1.63%	0.49

Table 4-17 PY2022 Energy Savings and CVR Factors by Phase: StateStreet Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
StateStreet-4928721	A	124.25	120.56	122,258	6,181,142	1.94%	0.67
	B	124.07	120.67	210,127	5,956,010	3.41%	1.28
	C	124.25	120.56	227,378	5,962,442	3.67%	1.28
	Total/Average	124.19	120.60	559,763	18,099,594	3.00%	1.04
StateStreet-4928722	A	123.64	121.39	86,965	3,651,212	2.33%	1.31
	B	123.64	121.39	107,508	3,611,160	2.89%	1.64
	C	123.64	121.39	100,877	3,768,366	2.61%	1.47
	Total/Average	123.64	121.39	295,350	11,030,738	2.61%	1.43
StateStreet-4928723	A	124.25	120.56	49,613	2,014,521	2.40%	0.83
	B	124.07	120.67	48,917	2,059,406	2.32%	0.86
	C	124.25	120.56	50,829	2,041,070	2.43%	0.84
	Total/Average	124.19	120.60	149,358	6,114,996	2.38%	0.82

Table 4-18 PY2022 Energy Savings and CVR Factors by Phase: Summit Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Summit-4937824	A	123.68	120.58	4,700	154,012	2.96%	1.22
	B	123.56	120.78	4,870	158,585	2.98%	1.36
	C	123.45	120.81	3,841	169,567	2.22%	1.06
	Total /Average	123.56	120.72	13,411	482,164	2.71%	1.18
Summit-4937825	A	124.91	120.79	3,165	147,575	2.10%	0.65
	B	124.74	120.61	2,468	148,025	1.64%	0.50
	C	125.09	120.82	2,705	146,031	1.82%	0.54
	Total /Average	124.91	120.74	8,339	441,631	1.85%	0.55

Table 4-19 PY2022 Energy Savings and CVR Factors by Phase: Trier Circuits

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Trier-4936421	A	125.58	120.31	11,647	364,806	3.09%	0.76
	B	125.36	120.34	12,556	356,691	3.40%	0.88
	C	125.41	120.49	10,338	352,698	2.85%	0.75
	Total /Average	125.45	120.38	34,542	1,074,195	3.12%	0.77
Trier-4936422	A	125.54	120.38	7,933	174,414	4.35%	1.11
	B	125.34	120.40	6,849	147,484	4.44%	1.18
	C	125.40	120.47	8,656	214,805	3.87%	1.02
	Total /Average	125.43	120.42	23,438	536,704	4.18%	1.05
Trier-4936423	A	125.56	120.25	3,466	61,271	5.35%	1.34
	B	125.33	120.33	3,449	67,490	4.86%	1.28
	C	125.48	120.51	3,747	61,889	5.71%	1.53
	Total /Average	125.45	120.36	10,662	190,650	5.30%	1.31

Table 4-20 PY2022 Energy Savings and CVR Factors by Phase: Wallen Circuits[8]

Circuit ID	*Phase*	*Baseline Disengaged Voltage*	*Engaged State Voltage*	*Engaged State kWh Savings*	*Engaged State kWh Consumption*	*Percent Savings*	*CVR Factor*
Wallen-4923421	A	124.64	120.77	-	110,721	0.00%	0.00
	B	124.89	120.90	-	80,948	0.00%	0.00
	C	124.93	120.86	-	85,754	0.00%	0.00
	Total /Average	124.81	120.84	-	277,423	0.00%	0.00
Wallen-4923422	A	124.67	120.58	-	117,083	0.00%	0.00
	B	124.77	120.61	-	132,419	0.00%	0.00
	C	124.76	120.54	-	114,346	0.00%	0.00
	Total /Average	124.73	120.57	-	363,848	0.00%	0.00
Wallen-4923423	A	125.36	120.85	-	48,597	0.00%	0.00
	B	125.34	120.92	-	25,243	0.00%	0.00
	C	125.34	120.86	-	50,529	0.00%	0.00
	Total /Average	125.34	120.87	-	124,368	0.00%	0.00
Wallen-4923424	A	125.46	121.46	-	15,155	0.00%	0.00
	B	125.08	120.90	-	36,653	0.00%	0.00
	C	125.37	121.09	-	30,567	0.00%	0.00
	Total /Average	125.25	121.07	-	82,375	0.00%	0.00
Wallen-4923425	A	124.22	120.42	-	80,428	0.00%	0.00
	B	124.24	120.43	-	85,083	0.00%	0.00
	C	124.60	120.44	-	87,040	0.00%	0.00
	Total /Average	124.36	120.43	-	252,551	0.00%	0.00

[8] VVO was initially engaged for Wallen circuits during mid-November 2022. Due to very limited availability of interspersed days of VVO engagement and disengagement for these circuits, energy savings achieved during late 2022 through VVO system engaged could not be estimated for these circuits.

5. Aggregate Energy Savings

As discussed in Section 3.3, two sets of aggregate energy savings were calculated for the Indiana circuits.

- One set of aggregate savings are the values calculated over those hours in 2022 when the VVO system was engaged.
- A second set of aggregate savings was calculated to show the savings that would have resulted if the VVO system had been continually engaged during all of 2022, or, if initially engaged during 2022, savings that would have resulted if the VVO system had been continually engaged subsequent to initial engagement.

Circuit-level and total results are presented in Table 5-1.

Table 5-1 PY2022 Ex Post kWh Savings and Counterfactual kWh Savings by Circuit

Circuit ID	*Engaged State kWh Consumption*	*Disengaged State kWh Consumption*	*CVR Factor*	*Engaged State kWh Savings*	*Counterfactual kWh Savings*
Daleville-4927921	2,385,919	22,479,393	0.52	14,978	156,097
Daleville-4927922	1,358,176	13,200,272	(0.20)	(4,407)	(47,237)
Daleville-4927923	1,909,807	16,060,260	0.52	12,181	114,613
Total - Daleville	**5,653,903**	**51,739,924**	**0.31**	**22,752**	**223,472**
EastSide-4093121	6,757,084	3,057,173	0.43	113,699	165,141
EastSide-4093122	17,820,235	7,897,201	0.47	330,861	477,485
EastSide-4093123	19,769,589	9,231,889	0.60	477,260	700,128
EastSide-4093124	18,819,985	15,058,025	1.04	760,891	1,369,686
EastSide-4093125	13,782,856	8,996,449	0.75	395,253	653,245
EastSide-4093126	9,535,325	6,492,858	0.40	144,602	243,065
Total - EastSide	**86,485,074**	**50,733,596**	**0.66**	**2,222,566**	**3,608,752**
Elcona-4938121	13,035,571	15,295,828	0.26	131,627	286,077
Elcona-4938122	7,778,808	11,187,934	0.26	79,222	193,163
Elcona-4938123	22,694,395	16,624,871	0.43	383,165	663,854
Total - Elcona	**43,508,773**	**43,108,633**	**0.35**	**594,014**	**1,143,094**
Farmland-4927321	5,025,585	6,263,549	0.38	70,419	158,185
Farmland-4927322	1,091,784	1,367,657	0.69	27,637	62,257
Farmland-4927323	6,473,388	7,117,668	0.41	94,434	198,268
Total - Farmland	**12,590,756**	**14,748,875**	**0.42**	**192,491**	**418,710**
Grabill-4935221	15,927,420	7,278,515	0.47	191,160	278,516
Grabill-4935222	28,097,563	12,935,835	0.83	596,020	870,422
Grabill-4935223	8,596,839	3,832,132	0.88	196,899	284,669
Total - Grabill	**52,621,822**	**24,046,482**	**0.73**	**984,079**	**1,433,607**
Hacienda-4933521	937,461	1,023,434	0.92	30,017	62,787
Hacienda-4933523	873,309	610,827	0.92	28,192	47,911

Circuit ID	*Engaged State kWh Consumption*	*Disengaged State kWh Consumption*	*CVR Factor*	*Engaged State kWh Savings*	*Counterfactual kWh Savings*
Hacienda-4933524	884,309	702,370	0.98	30,409	54,562
Hacienda-4933525	10,352,309	13,350,199	0.98	305,225	698,840
Hacienda-4933526	10,125,519	10,842,444	1.46	457,249	946,873
Hacienda-4933527	11,323,228	12,642,189	0.65	221,874	469,593
Total - Hacienda	**34,496,134**	**39,171,463**	**1.01**	**1,072,968**	**2,280,567**
Harper-4928821	16,475,472	11,526,954	0.60	356,327	605,629
Harper-4928822	17,079,966	12,617,632	0.67	318,481	553,755
Total - Harper	**33,555,438**	**24,144,585**	**0.63**	**674,808**	**1,159,383**
Lincoln-4051822	**1,041,434**	**34,095,007**	**0.82**	**(2,755)**	**(92,959)**
McKinley-4055921	21,642,577	12,223,545	(0.01)	(5,790)	(9,060)
McKinley-4055922	8,577,933	5,800,928	1.04	175,794	294,677
McKinley-4055923	8,983,537	5,201,934	0.92	256,669	405,294
McKinley-4055924	12,613,058	7,705,795	0.67	262,485	422,846
McKinley-4055925	8,780,164	5,783,771	0.79	215,306	357,135
McKinley-4055926	17,613,457	6,100,985	(0.51)	(167,974)	(226,157)
Total - McKinley	**78,210,725**	**42,816,958**	**0.40**	**736,490**	**1,244,735**
Northland-4933421	17,940,139	6,125,177	0.61	202,119	271,127
Northland-4933422	10,473,501	3,485,895	0.74	178,546	237,972
Northland-4933423	21,304,119	7,141,633	0.27	130,587	174,362
Northland-4933424	22,053,710	16,359,191	0.64	469,277	817,382
Northland-4933425	15,256,640	10,961,819	1.01	518,097	890,348
Northland-4933426	9,504,469	6,680,425	0.92	293,257	499,380
Total - Northland	**96,532,576**	**50,754,139**	**0.68**	**1,791,884**	**2,890,570**
Osolo-4058021	13,867,855	14,078,316	0.58	259,122	522,176
Osolo-4058022	11,458,547	12,524,107	0.87	323,904	677,928
Osolo-4058023	23,942,647	7,556,278	0.62	480,434	632,058
Osolo-4058024	17,071,645	16,091,538	0.63	340,670	661,782
Osolo-4058025	9,184,563	3,184,619	0.97	289,455	389,819
Osolo-4058026	19,435,451	6,320,215	0.84	527,049	698,440
Total - Osolo	**94,960,707**	**59,755,072**	**0.72**	**2,220,634**	**3,582,204**
Pettit-4917221	17,308,155	6,092,167	0.71	347,459	469,758
Pettit-4917222	20,354,924	7,155,241	0.44	250,429	338,460
Pettit-4917223	8,584,201	2,981,690	0.30	72,980	98,329
Total - Pettit	**46,247,280**	**16,229,098**	**0.52**	**670,867**	**906,548**
SouthBend-4050321	11,998,269	3,855,856	0.61	330,269	436,406
SouthBend-4050322	23,895,105	16,669,681	1.12	1,239,854	2,104,799
SouthBend-4050323	11,094,971	6,481,048	0.82	416,478	659,761
Total - SouthBend	**46,988,344**	**27,006,585**	**0.92**	**1,986,600**	**3,200,966**
Southside-4099921	14,114,164	8,965,077	0.49	240,008	392,457

Circuit ID	*Engaged State kWh Consumption*	*Disengaged State kWh Consumption*	*CVR Factor*	*Engaged State kWh Savings*	*Counterfactual kWh Savings*
Southside-4099922	19,009,314	16,994,045	0.29	188,019	356,105
Southside-4099923	10,141,025	6,695,035	0.61	214,989	356,923
Total - Southside	**43,264,503**	**32,654,157**	**0.43**	**643,016**	**1,105,485**
SouthsideSB-4094621	1,691,695	584,351	0.71	48,585	65,368
SouthsideSB-4094622	22,593,512	7,036,586	0.77	705,535	925,269
SouthsideSB-4094623	11,473,802	3,823,697	0.65	305,085	406,756
SouthsideSB-4094624	3,959,138	1,365,233	0.46	74,110	99,666
Total - SouthsideSB	**39,718,147**	**12,809,867**	**0.70**	**1,133,316**	**1,497,059**
Spyrun-4923321	7,774,047	5,693,716	0.41	101,179	175,283
Spyrun-4923322	27,552,258	19,296,395	0.13	116,821	198,638
Spyrun-4923329	7,976,525	5,541,635	0.49	132,115	223,900
Total - Spyrun	**43,302,830**	**30,531,745**	**0.25**	**350,115**	**597,821**
StateStreet-4928721	18,099,594	20,497,322	1.04	559,763	1,193,679
StateStreet-4928722	11,030,738	15,866,863	1.43	295,350	720,188
StateStreet-4928723	6,114,996	6,941,667	0.82	149,358	318,908
Total - StateStreet	**35,245,328**	**43,305,851**	**1.08**	**1,004,471**	**2,232,775**
Summit-4937824	482,164	2,577,609	1.18	13,411	85,103
Summit-4937825	441,631	2,350,940	0.55	8,339	52,728
Total - Summit	**923,795**	**4,928,549**	**0.82**	**21,749**	**137,831**
Trier-4936421	1,074,195	990,083	0.77	34,542	66,379
Trier-4936422	536,704	1,003,285	1.05	23,438	67,251
Trier-4936423	190,650	161,305	1.31	10,662	19,682
Total - Trier	**1,801,549**	**2,154,673**	**0.91**	**68,641**	**153,312**
Wallen-4923421	277,423	482,755		-	-
Wallen-4923422	363,848	715,835		-	-
Wallen-4923423	124,368	209,320		-	-
Wallen-4923424	82,375	122,325		-	-
Wallen-4923425	252,551	541,878		-	-
Total - Wallen	**1,100,565**	**2,072,113**		**-**	**-**
Grand Total	**798,249,682**	**606,807,371**		**16,388,705**	**27,723,933**

During 2022, a VVO system module that leverages AMI interval data – hereafter referenced as "AMI module" – was implemented for selected circuits to enable achievement of further voltage reduction through the VVO system. The incremental savings associated with the employment of the AMI module are included in the savings values presented throughout this report. To estimate the component of aggregate VVO savings that is associated with deployment of the AMI module, the circuit-level incremental voltage reduction achieved during times of AMI module employment

was calculated. The following variables are defined as inputs to the AMI module savings calculation:

- *kwh_AMI* = kWh usage: AMI module-enabled, VVO system engaged state
- *volt_AMI* = voltage: AMI module enabled, VVO system engaged state
- *volt_non_AMI* = voltage: AMI module not enabled, VVO system engaged state
- CVR_f = applicable CVR factor developed through analysis of aggregate VVO savings

The variables defined above were used in the following equation to calculate the savings associated with the deployment of the AMI module.

Equation 5-1

$$AMI\ Module\ kWh\ Savings = kwh\_AMI + ((1 - (volt\_AMI / volt\_non\_AMI)) * CVR_f * kwh\_AMI)) - kwh\_AMI$$

Table 5-2 presents circuit-level energy savings associated with deployment of the AMI module.

Table 5-2 PY2022 AMI Module Ex Post kWh Savings

Circuit ID	*AMI Module kWh Savings*	*AMI Module Savings Share of Total Engaged State kWh Savings*	*AMI Module Enabled Time as Share of Total VVO Engaged Time*
EastSide-4093121	7,332	6%	22%
EastSide-4093122	24,158	7%	22%
EastSide-4093123	34,659	7%	22%
EastSide-4093124	73,331	10%	18%
EastSide-4093125	29,557	7%	18%
EastSide-4093126	12,644	9%	18%
Total - EastSide	**181,682**	**8%**	
Elcona-4938121	4,511	3%	16%
Elcona-4938122	3,168	4%	16%
Elcona-4938123	14,215	4%	16%
Total - Elcona	**21,894**	**4%**	
Farmland-4927321	2,401	3%	15%
Farmland-4927322	963	3%	15%
Farmland-4927323	2,765	3%	15%
Total - Farmland	**6,129**	**3%**	
Grabill-4935221	23,746	12%	24%
Grabill-4935222	78,125	13%	24%
Grabill-4935223	27,888	14%	24%
Total - Grabill	**129,760**	**13%**	
Harper-4928821	48,711	14%	37%

Circuit ID	*AMI Module kWh Savings*	*AMI Module Savings Share of Total Engaged State kWh Savings*	*AMI Module Enabled Time as Share of Total VVO Engaged Time*
Harper-4928822	56,608	18%	37%
Total - Harper	**105,319**	**16%**	
Lincoln-4051822	**3,158**	**-115%**	**30%**
McKinley-4055921	871	-15%	27%
McKinley-4055922	13,439	8%	27%
McKinley-4055923	19,408	8%	27%
McKinley-4055924	17,824	7%	27%
McKinley-4055925	16,131	7%	27%
McKinley-4055926	(13,794)	8%	27%
Total - McKinley	**53,879**	**7%**	
Northland-4933424	26,879	6%	18%
Northland-4933425	31,963	6%	18%
Northland-4933426	14,372	5%	18%
Total - Northland	**73,213**	**4%**	
Pettit-4917221	39,530	11%	22%
Pettit-4917222	26,967	11%	22%
Pettit-4917223	7,744	11%	22%
Total - Pettit	**74,241**	**11%**	
SouthBend-4050321	2,080	1%	42%
SouthBend-4050322	135,964	11%	42%
SouthBend-4050323	34,800	8%	42%
Total - SouthBend	**172,843**	**9%**	
StateStreet-4928721	63,738	11%	20%
StateStreet-4928722	1,883	1%	20%
Total - StateStreet	**65,622**	**7%**	
Trier-4936421	2,316	7%	20%
Trier-4936422	1,510	6%	20%
Trier-4936423	675	6%	20%
Total - Trier	**4,501**	**7%**	
Grand Total	**892,241**	**5%**	**8%**

6. Peak Reduction

This chapter presents the results of the analysis of demand reduction occurring during 2022 PJM 5CP hours. Demand reductions, accounting for those circuits for which the VVO system was enabled during the 5CP hours, are presented in Table 6-1.

Table 6-1. kW Reduction during PY2022 PJM 5CP

Substation	*Circuit*	*7/20/2022*	*7/21/2022*	*7/22/2022*	*8/3/2022*	*8/8/2022*
		5:00 PM - 6:00 PM	*4:00 PM - 5:00 PM*	*5:00 PM - 6:00 PM*	*5:00 PM - 6:00 PM*	*3:00 PM - 4:00 PM*
Daleville	4927921	0.00	0.00	0.00	0.00	0.00
Daleville	4927922	0.00	0.00	0.00	0.00	0.00
Daleville	4927923	0.00	0.00	0.00	0.00	0.00
EastSide	4093121	30.06	31.16	30.30	0.00	28.10
EastSide	4093122	111.14	117.90	114.22	0.00	98.30
EastSide	4093123	142.75	158.09	143.16	0.00	147.90
EastSide	4093124	351.42	363.57	351.51	0.00	320.71
EastSide	4093125	153.06	158.94	153.37	0.00	141.75
EastSide	4093126	40.36	41.88	36.05	0.00	43.05
Elcona	4938121	0.00	0.00	0.00	0.00	0.00
Elcona	4938122	0.00	0.00	0.00	0.00	0.00
Elcona	4938123	0.00	0.00	0.00	0.00	0.00
Farmland	4927321	29.61	27.07	26.84	0.00	0.00
Farmland	4927322	10.26	8.80	9.63	0.00	0.00
Farmland	4927323	37.65	34.65	34.90	0.00	0.00
Grabill	4935221	0.00	0.00	0.00	0.00	48.45
Grabill	4935222	0.00	0.00	0.00	0.00	200.04
Grabill	4935223	0.00	0.00	0.00	0.00	56.63
Hacienda	4933521	15.74	15.05	15.17	0.00	14.85
Hacienda	4933523	15.18	14.65	14.32	0.00	14.62
Hacienda	4933524	17.47	15.97	15.94	0.00	16.51
Hacienda	4933525	186.29	176.79	178.54	0.00	178.06
Hacienda	4933526	303.02	283.11	285.08	0.00	284.33
Hacienda	4933527	104.84	104.83	102.40	0.00	107.58
Harper	4928821	146.48	143.64	138.62	0.00	153.16
Harper	4928822	138.15	133.39	125.47	0.00	142.49
Lincoln	4051822	0.00	0.00	0.00	0.00	0.00
McKinley	4055921	-1.55	-1.46	-1.44	0.00	0.00
McKinley	4055922	98.22	95.88	90.00	0.00	0.00
McKinley	4055923	138.76	132.39	132.06	0.00	0.00
McKinley	4055924	101.82	98.44	93.43	0.00	0.00
McKinley	4055925	78.00	81.95	72.33	0.00	0.00

Substation	*Circuit*	*7/20/2022*	*7/21/2022*	*7/22/2022*	*8/3/2022*	*8/8/2022*
		5:00 PM - 6:00 PM	*4:00 PM - 5:00 PM*	*5:00 PM - 6:00 PM*	*5:00 PM - 6:00 PM*	*3:00 PM - 4:00 PM*
McKinley	4055926	-56.00	-60.49	-54.19	0.00	0.00
Northland	4933421	34.98	34.04	26.83	0.00	0.00
Northland	4933422	59.80	61.48	57.33	0.00	0.00
Northland	4933423	26.98	28.40	15.15	0.00	0.00
Northland	4933424	122.64	119.85	103.85	0.00	0.00
Northland	4933425	184.96	197.89	174.85	0.00	0.00
Northland	4933426	107.04	111.86	98.46	0.00	0.00
Osolo	4058021	0.00	0.00	0.00	0.00	0.00
Osolo	4058022	0.00	0.00	0.00	0.00	0.00
Osolo	4058023	120.41	127.38	112.20	0.00	0.00
Osolo	4058024	0.00	0.00	0.00	0.00	0.00
Osolo	4058025	86.81	92.93	84.42	0.00	0.00
Osolo	4058026	106.98	111.83	92.00	0.00	0.00
Pettit	4917221	108.38	105.48	101.80	0.00	0.00
Pettit	4917222	82.33	77.83	75.27	0.00	0.00
Pettit	4917223	20.70	19.52	18.96	0.00	0.00
SouthBend	4050321	0.00	0.00	0.00	0.00	0.00
SouthBend	4050322	464.05	483.30	457.13	0.00	448.58
SouthBend	4050323	132.06	142.29	132.94	0.00	122.61
Southside	4099921	68.80	67.50	65.25	0.00	0.00
Southside	4099922	50.34	49.17	45.67	0.00	0.00
Southside	4099923	63.08	58.90	56.83	0.00	0.00
SouthsideSB	4094621	11.27	13.08	10.86	0.00	0.00
SouthsideSB	4094622	199.18	204.80	199.11	0.00	0.00
SouthsideSB	4094623	71.43	74.84	70.32	0.00	0.00
SouthsideSB	4094624	20.47	20.95	15.22	0.00	0.00
Spyrun	4923321	0.00	0.00	0.00	0.00	0.00
Spyrun	4923322	0.00	0.00	0.00	0.00	0.00
Spyrun	4923329	0.00	0.00	0.00	0.00	0.00
StateStreet	4928721	237.41	234.11	221.54	0.00	0.00
StateStreet	4928722	142.62	141.81	132.26	0.00	0.00
StateStreet	4928723	72.45	71.66	68.67	0.00	0.00
Summit	4937821	0.00	0.00	0.00	0.00	0.00
Summit	4937822	0.00	0.00	0.00	0.00	0.00
Summit	4937823	0.00	0.00	0.00	0.00	0.00
Summit	4937824	0.00	0.00	0.00	0.00	0.00
Summit	4937825	0.00	0.00	0.00	0.00	0.00
Trier	4936421	21.57	21.49	20.16	0.00	22.07
Trier	4936422	14.99	15.39	14.40	0.00	14.87

Substation	*Circuit*	*7/20/2022*	*7/21/2022*	*7/22/2022*	*8/3/2022*	*8/8/2022*
		5:00 PM - 6:00 PM	*4:00 PM - 5:00 PM*	*5:00 PM - 6:00 PM*	*5:00 PM - 6:00 PM*	*3:00 PM - 4:00 PM*
Trier	4936423	7.55	7.49	7.06	0.00	6.64
Wallen	4923421	0.00	0.00	0.00	0.00	0.00
Wallen	4923422	0.00	0.00	0.00	0.00	0.00
Wallen	4923423	0.00	0.00	0.00	0.00	0.00
Wallen	4923424	0.00	0.00	0.00	0.00	0.00
Wallen	4923425	0.00	0.00	0.00	0.00	0.00

The summarized results for each PJM 5CP hour are presented in Table 6-1 below.

Table 6-2. Summary of kW Reductions during I&M 5CP Events

Date	*Hour Start*	*Hour End*	*Ex Post Net kW Savings*
7/20/2022	5:00 PM	6:00 PM	4,831.99
7/21/2022	4:00 PM	5:00 PM	4,871.45
7/22/2022	5:00 PM	6:00 PM	4,586.26
8/3/2022	5:00 PM	6:00 PM	0.00
8/8/2022	3:00 PM	4:00 PM	2,611.29
Maximum Peak kW Reduction			4,871.45
Average Peak kW Reduction			3,380.20