AEP
AMERICAN ELECTRIC POWER

Legal Department

July 14, 2022

The Honorable Greta See
Attorney Examiners
Public Utilities Commission of Ohio
180 East Broad Street
Columbus Ohio 43215-3793

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Re: *In the Matter of the Application of Ohio Power Company for Authority to Establish a Standard Service Offer Pursuant to Section 4928.143, Revised Code, in the Form of an Electric Security Plan*, Case No. 16-1852-EL-SSO; *In the Matter of the Application of Ohio Power Company for Approval of Certain Accounting Authority*, Case No. 16-1853-EL-AAM

Dear Examiner:

On behalf of Ohio Power Company (AEP Ohio), I would like to submit the enclosed report concerning the microgrid pilot conducted under the Commission's approved Electric Security Plan in these proceedings. In order to transparently convey the experience and promote public learning from the microgrid pilot, AEP Ohio is submitting this report.

Respectfully Submitted,

//s/ Steven T. Nourse

cc: Parties of Record

JUNE 3, 2022

AEP OHIO – MICROGRID EVALUATION

Revision	Date	Description
Rev 0	08/26/21	Initial Submittal
Rev 1	01/25/22	Added additional testing and results from Athens with update on Zoo
Rev 2	06/03/22	Added in lessons learned and evaluation of final results

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Executive Summary

AEP Ohio, under the Smart City Rider, has commissioned and generated testing of two microgrids to date at the Columbus Zoo (Zoo) and Athens Water Treatment Plant (AWTP). These microgrids evaluate how customer systems can integrate with AEP Ohio's Distribution Management System (DMS) and provide benefit for customers during grid events. Both systems are comprised of assets that include three main components: solar generation, lithium-ion energy storage, and a utility controller for the system.

The contents of this report outline different attempts made by AEP Ohio to test the readiness of each system as well as sustained load using the customer owned assets during a simulated outage. In addition to the testing provided, AEP Ohio has also provided an overview of the selection process, details of the sites selected, and lessons learned.

For each successful simulated outage, AEP Ohio has provided a sample of data attached to this report as an exhibit of various points and the stored values during these tests. The simulations produced results that help shape AEP Ohio's understanding and further decision-making surrounding future growth and implementation of microgrids within the distribution system.

The systems installed incurred various schedule delays due to the pandemic, issues with the control systems, and lessons learned for future considerations. The results of the attempted tests provided a mix of results ranging from success to failure to start. As with earlier conversations, AEP Ohio maintains its stance that for assets intended to support the greater distribution operations, it is to the benefit of the customer for the utility to own, maintain, and operate all assets within the boundaries of a microgrid in the future.

Contents

Microgrid Selection and Overview

The follow sections outline the criteria by which the microgrids were defined, selected, and overview of the three selected sites awarded under the order.

Demonstration Criteria

A PUCO Opinion and Order approving the stipulation for Case No. 16–1853–EL-AAM regarding AEP Ohio's Electric Security Plan III granted approval of a microgrid technology demonstration project. One or more demonstration microgrid projects with a completed cost of no more than $10.5 million for recovery through the Smart City Rider authorized by the PUCO. Of the projects selected, one location should reside within the Smart City Columbus Region.

The demonstration microgrids were to target non-profit, public serving AEP Ohio customers who would own and maintain the microgrid generator/battery facility. While other customers could participate, recovery costs were limited to EDU investments to the distribution system and costs incurred on the Company's side of the meter. AEP Ohio agreed not to own the generation resources and batteries for the demonstration projects.

The Smart City Rider provided the funds for the demonstration projects and any distribution grid investments would have recovery provided through the DIR. AEP Ohio competitively bid the contracts to build and maintain the microgrid equipment using a selection process with multiple criteria. Data collection on the demonstration projects to assess the merits of the microgrid facilities were required and have been provided through the Microgrid Evaluation reports presented on August 26, 2021, January 25, 2022 and March 30, 2022 in addition to this report.

Project Selection

Microgrids have a variety of configurations and use cases. Initially, AEP Ohio sought out circuits with a history of resiliency issues, a small number of customers that included a non-profit, public serving customer and some existing generation. We were not successful primarily due to the costs borne by the participating customers and the criteria regarding ownership and operations of the generators, batteries and controllers. During an inquiry from the Columbus Zoo regarding a solar PV system, we approached them about a demonstration microgrid project that would incorporate five of their accounts served from the end of a radial tap off our distribution circuit, which they agreed to participate. Then we issued a Request for Proposals to several developers of microgrid projects. We received five proposals and selected two, one of which later withdrew because they would not be able to complete the project prior to April 2022 primarily due to the impact of COVID-19. Of the others not selected most of the customer accounts of one of them were not AEP Ohio customers and for the other two, their costs and time to complete the projects exceeded the available funds and April 2022 date. Just after selecting the Athens Water Treatment Plant the City of Columbus approached AEP Ohio with multiple locations, from which the Tussing Booster Station was selected.

Overall Project Criteria

For each site, common standards exist to assimilate proper functioning with AEP Ohio's distribution grid. This included both physical standards such as the size of the transformer and protection schemes as well as the communication protocols to properly integrate the system into the Distribution Management System (DMS).

For physical considerations, for distributed generation interconnection, the service point, which in many instances is the AEP Ohio owned transformer, the overall nameplate of the generation cannot exceed the size of the transformer. In the case of the Zoo, the added total of the Solar PV and the Battery Energy Storage System equaled a total generation potential of 700kW. Assuming that the controllers were to fail and there was no load, present, this requires the transformer kVA nameplate to be greater than what is potentially supplied to the distribution grid and required a size increase of the existing transformer. The cost of this improvement was applied against the distribution improvement rider (DIR) versus the smart city rider. Additionally, when supplying the distribution assets with an inverter incapable of providing adequate fault current, no traditional protection schemes are necessary to ensure proper protection of Utility owned assets. In many cases, the relaying designed for the customer microgrid was inadequate, disallowing the ability for the battery to back feed into the grid during an outage, and instead serve the loads located within the boundaries of the service only.

When evaluating the integration for DMS, required significant redesign to how the microgrid controller, which is owned by AEP, would communicate with customer assets, such as the inverters, relays, and battery management systems. At the time of installation, the current protocols developed by AEP Ohio dictated any such connection for communication would be done via a serial port. Most of the microgrid designs employ cellular modems connected to the controller that are continuously monitored and controlled via cloud software, and local devices are typically controlled via Ethernet. The reason the communication protocols are set this way is to ensure a communication "gap" between the AEP DMS network and devices outside of the network. This is a higher level of security and restricts many functions or abilities of a third party should they be able to access the customer network, they would not be able to impact the AEP network given the serial link. This is a common method to separate networks and provide a higher level of security in the networks.

All three microgrids chose different controllers for use, but at its core the Solar PV systems used smart inverters paired with a Battery Energy Storage System, also using a power electronics inverter. The difference between the inverters used for the Solar PV and Battery however is that the Solar PV cannot function without a voltage present, whereas the Battery inverters are capable of grid forming or islanding and providing a voltage and frequency to operate when the distribution grid is lost. All three sites had some varying degrees of difficulty with the battery inverter. In the Zoo, one of the two primary inverters had a IGBT board damage during startup, causing the inability for use. At Athens, the harmonics produced from the customer owned motor VFD's caused disconnects within the battery system to open, leaving the system inoperable during an outage. With the Tussing water plant, the large motors were started without VFD's and had to be started across the line. Because of this, the size of the inverter was required to be much larger than needed. Much of the power electronics in use appear to have constant cycling or steady charge/discharge with consistent use. When using these systems directly for the purposes of standby, they have been unreliable compared against a traditional backup system like a generator. For these types of systems to be in ready state, they require greater monitoring and maintenance by the owner to ensure they properly ready to be deployed for an outage. As an example, several owners perform ready tests with their diesel generators on a regular schedule.

Columbus Zoo

A Request for Proposals included the following requirements in order to provide electric service resiliency for 5 accounts for no specified period of time. The 5 accounts had a total annual energy use of 1,464,704 kWh and a combined peak demand of 359 kW. The microgrid would include a solar PV system and battery energy storage system. The project site was approximately 0.5 acres. The solar PV system would utilize fixed-tilt solar arrays with bifacial panels and a minimum capacity of 110 kW (DC). The battery energy storage system would utilize a lithium ion battery with a minimum capacity of 500 kW and 1 MWh.

The selected developer installed a 137.4 kW (DC) solar PV system with a 560 kW/1,200 kWh battery energy storage system. Due to unforeseen electric operations concerns the project was revised to serve only one of the electric service accounts which had a peak demand of 132.6 kW with an annual energy use of 638,880 kWh. Taking into consideration the average energy needs of this account and the average estimated production of the microgrid equipment it is anticipated that the ability to be off-grid for 24 hours is achievable.

As noted above the project was to include 5 accounts located in the Polar Frontier area from which the AEP Ohio distribution system consisted of a radial tap and there was sufficient space for the solar PV system and the battery energy storage system. It also include two of the Zoo's most critical facilities, the Saltwater and Freshwater Life Support System buildings. During the system impact study for interconnection service safety and service concerns were identified. This included the potential for ferro resonance on the 34.5 kV distribution system, the customers' existing protection scheme (i.e. circuit breakers) would not be sufficient without further modification if a fault would occur while the microgrid is in "island mode", and the capacity of the solar PV system and battery energy storage system exceeded the capacity of the host transformer at the Saltwater Life Support System building. This resulted in the project being revised to a microgrid serving only the Saltwater Life Support System building.

For this project AEP Ohio owned, operated and maintained the microgrid controller while the Zoo owned all of the other associated equipment including the solar PV system and battery energy storage system. AEP Ohio monitored and controlled the microgrid from the Distribution Dispatch Center. The Zoo had full authority and ability to operate the microgrid or any of its components locally after notifying the Distribution Dispatch Center.

In April 2019 AEP Ohio and the Zoo began discussions regarding the microgrid project and entered a Memorandum of Understanding June 4, 2019. A Request for Proposals was issued on July 2, 2019 to 18 developers from whom we received 4 proposals. A contract was secured with Worley Group Inc. on October 4, 2019, followed by a Site Kick-off Meeting on October 10, 2019. Physical construction began September 16, 2020 and was completed November 22nd, 2021. The long period from Site Kick-off Meeting to completion was attributed to the re-design when changing project from 5 accounts to 1 account, resolving issues to acquire a permit from the fire department, COVID-19 and supply chain issues.

The original total project cost was $2,058,000. As a result of the above noted items the final total cost was $2,381,618.

Athens Water Treatment Plant

A Request for Proposals with reference to the criteria permissible under the Stipulation was sent to multiple developers. The microgrid was required to include a renewable energy resource generator and battery energy storage system. The battery energy storage system would utilize a lithium ion battery designed for the appropriate peak load and peak load duration of the customer(s).

The selected developer installed a 250 kW/1,140 kWh battery energy storage system that will work in conjunction with an existing 230 kW (DC) solar PV system. The solar PV system was installed in part to enhance electric service resiliency and Athens wanted to achieve greater resiliency through a microgrid with a battery energy storage system. This facility has a peak demand of 160 kW with an annual energy use of 670,200 kWh. It is anticipated that with the microgrid equipment the ability to be off-grid for a long term outage with minimal operational adjustments will exist.

For this project AEP Ohio owned, operated and maintained the microgrid controller while the City of Athens owned all of the other associated equipment including the solar PV system and battery energy storage system. AEP Ohio monitored and controlled the microgrid from the Distribution Dispatch Center. The City of Athens had full authority and ability to operate the microgrid or any of its components locally after notifying the Distribution Dispatch Center.

From a Request for Proposals issued on July 18, 2019 we received 5 proposals and a contract was secured with Worley Group Inc. on August 3, 2020, followed by a Kick-off Meeting on August 18, 2020. Physical construction began January 26, 2021 and was completed June 14, 2021. The delay in securing a contract 1 year after issuing the RFP was issued and extending the construction period 5 weeks was primarily attributed to the impact of COVID-19 and supply chain issues.

The original total project cost was $1,911,153. However, some changes were needed to address safety and operational items that were not addressed in the original scope of work resulting in the final total cost being $2,018,046.

City of Columbus – Tussing Water Pump Station

A Request for Proposals required that at a minimum a microgrid will operate one pump (60 hp), but a system that provides power to the entire station including all axillary equipment is preferred. The microgrid would include a solar PV system and battery energy storage system. The solar PV system would utilize fixed-tilt solar arrays and ideally offset the demand of the account as a whole. The battery energy storage system must be sized appropriately to maintain an average load of 80 kW for a minimum of 4 hours when in "island mode".

The selected developer installed a 115.2 kW (DC) solar PV system with a 375 kW/440 kWh battery energy storage system. The account has an annual energy use of 314,600 kWh and a peak demand of 112 kW. Taking into consideration the cycling of the pumps and energy needs of this account and the estimated production of the microgrid equipment it is anticipated that the microgrid will provided the needed resiliency to endure at least a 48 hour outage.

For this project AEP Ohio owned, operated and maintained the microgrid controller while the City of Columbus owned all of the other associated equipment including the solar PV system and battery energy storage system. AEP Ohio controlled the microgrid at the booster station. The City of Columbus had full authority and ability to operate the microgrid or any of its components locally after notifying the Distribution Dispatch Center.

A Request for Proposals was issued on March 3, 2020 to 26 developers from whom we received 5 proposals. A contract was secured with Eaton Corporation on February 22, 2021, followed by a Virtual Kick-off Meeting on the same day and Site Visit on March 2, 2021. Physical construction began December 21, 2021 with grading and contouring of the site. Excavations, trenching, and solar installation began in January 2022. Final conduit and electrical work commenced in February 2022 when final electrical and easement permits were received. Final construction was completed March 30, 2022. The project took 2 months longer than planned due to a couple of re-engineering of the solar PV system and the transformer/electric service, misunderstandings regarding permits/easements as well as the impact of COVID-19 and related supply chain issues.

The original total project cost was $1,399,052. As a result of the above noted items the final total cost being $1,847,727.

Lessons Learned

Below is a list of different lessons learned identified throughout the design, execution, and testing of the microgrids.

Requirements

- Types of loads within the boundaries of the project. IE: motors, lighting, heating, etc.
- Cyber security requirements of all parties prior to conceptual designs. Depending on the requirements of each party may significantly alter the design and operations of the system.
- Engagement with local jurisdictions, specifically the fire department.
- Warranty considerations and responsibilities by each party
- Utility requirements, such as size and location of the service transformer, or protection requirements.
- Deeper evaluation of the technology and vendors proposed for use.

Design Considerations

- Permitting and easement acquisition
    - Depending on the proposed location and installation, it may require added permitting and even easements. These items can cause significant delays if not identified and engaged upon early in the process.
- Decision making and review matrix
    - Ensure all parties involved provide adequate review of the system and appropriate personnel available during the review cycles to avoid rework.
- Networking and communication pathways need to be identified early in the design process.
- Submission of the interconnection agreement with the utility should be developed and submitted early in the design process as the turn around time can be lengthy with several review cycles.

Construction

- Supply chain issues, specifically during the pandemic pushed several construction dates.
- Unknown conditions that were not identified during the design phase such as underground utilities.

Testing and Operational Maintenance

- During testing at Athens, there was a harmonic issue with the VFD and inverter which caused the batteries to trip. An added harmonic analysis of the system is advised earlier in the process as well as additional metering to get a better understanding of how the electrical system is performing.
- Hardware needs to have proper maintenance and monitoring to ensure the systems are ready for use during an outage. As an example, the Zoo failed to properly maintain the battery systems and alarms, which lead to several failed attempts during the simulation testing.
- All the systems went through several tests, including standard tests such as UL 1741 and IEEE 1547. At the time of inception for the projects, much of the standards for IEEE 1547 were under review and consideration for changes to increase the level of participation for DG interconnection. One of the key areas where the standards need improvement is the level of control provided to the utilities

through vendor equipment. To ensure safe operations and maintenance of the grid via customer assets, the utility requires some level of authority of the equipment that is meant to feed customers and support grid operations. Some of the major areas of concern include the settings programmed into the inverters. As discussed earlier, if the nameplate of the inverters exceeds the transformer, then the transformer requires replacement. In many instances, the inverter is oversized for the specific application, such as the ability to start a motor. While the inverters can be set and tested at the factory with firmware that restricts the output, a customer always has the ability in the future to modify this setting, presenting an uncontrollable circumstance and risk to distribution owned assets. This is but one area AEP sees as an opportunity to strengthen within IEEE 1547, that allows for greater control of how customer assets are set for those wanting to participate in distribution grid operations.

Simulation Results

Below is a more detailed summary of events that occurred during the simulated tests. The two primary tests performed was the readiness check and a sustained outage test. A readiness check is a short disruption in which the system is disconnected from the grid and confirmation the battery energy storage system (BESS) will transition properly and sustain the loads defined within the boundaries of the microgrid. After confirmation, AEP Ohio dispatch will transition the system back to grid connected and restore the system to normal operations.

Alternately, for a short duration simulation or sustained outage, the system is tested using the battery to provide power for an extended outage (anywhere from 30 minutes up to the limits of the system). This is to ensure that the battery State of Charge (SOC) is maintained properly for when an extended outage occurs. AEP Ohio dispatch will transition the system from grid-connected to island, and then monitor the system via SCADA. If at any point the SOC falls below the accepted tolerance, dispatch will switch back to grid connected. Otherwise, dispatch will return the system to normal operations.

Attached as Appendix A are charts showing various values throughout the days of the test, along with a table of values at key intervals of the day.

Columbus Zoo – May 4th, 2021 Readiness Test

The readiness check for the Columbus Zoo began at 11AM EST time zone. The AEP Ohio team along with a customer representative from the Zoo joined a WebEx meeting to discuss the current state of the system. AEP Ohio dispatch noted that battery system 1 had an inverter critical alarm and the Zoo confirmed on the local controller that the alarm existed and the contents of the alarm.

The project team reached out to the vendor and attempted to clear the critical alarms so the test could proceed; however, after several attempts, the critical alarm was not resolved. After discussion amongst the team, a decision was made to postpone the test over an abundance of caution.

The test represents a data point in evaluating how customer assets can be used for grid resilience as well as how critical alarms are handled by AEP Ohio dispatch.

Columbus Zoo – May 24th, 2021 Sustained Outage Test

After the results of the first test, attempts were made to clear the critical alarms on DSS1 without success in-between tests. The project team confirmed that both battery systems were independent and could operate with only one of the systems and did not need both. As with the previous test, AEP Ohio hosted a WebEx meeting for the project team to evaluate the state of the system prior to the test. While one of the two systems was inoperable, the project team reviewed the current load and SOC of the second BESS.

With the SOC adequate to support the load, the project team proceeded with the simulated outage. The system transitioned from grid connected to island without incident. The BESS took on the connected loads without incident and provided adequate power. AEP Ohio dispatch monitored the SOC and output of the system.

During the test, there was a communications failure between the customer assets and the AEP Ohio controller. This limited the ability for AEP Ohio dispatch to monitor the system safely and the decision was made to end the simulation early. AEP Ohio worked with local Zoo personnel to safely turn the battery and solar systems off locally. Once they were confirmed shutdown, the Zoo manually closed the main breaker to restore power from the grid.

This test yielded the desired result of showing the system was capable of sustaining load during an outage controlled by AEP Ohio's SCADA system. The communications failure was another indication of challenges to integrate customer related assets to the distribution management system.

Columbus Zoo – December 8, 2021 Zoo Critical Alarms

AEP Ohio's contracted partner, Worley completed a site visit to resolve issues with the system associated to BESS-2. Due to mis-operation of a fan within one of the battery racks, the system was not able to be brought online. A replacement part has been ordered from Germany. Limited availability part and supply chain issues has caused a delay in obtaining the replacement part and remediation of system.

The Solar array continues to provide local power generation for Zoo Saltwater system.

This issue highlights the need for a long-term maintenance program that will provide reliability of the system. The ability of the owner to monitor and provide continuous support of the system is critical for these applications to become viable as a cornerstone of the electric grid.

Athens Water Treatment Plant – August 2nd, 2021 Readiness Test

As with the Zoo, the first simulated test was one of readiness for the AWTP. The project team setup a WebEx meeting to facilitate the test. The meeting started at 1:00PM EST time. The project team reviewed the points to ensure no alarms were present, evaluated the current load, and checked the current SOC on the BESS. Once all systems were checked and no alarms present, AEP Ohio dispatch sent the commands to simulate the outage.

The commands sent worked properly as well as the system transition from grid-connected to island. After a short delay, the controls engineering team for AEP Ohio observed the battery inverter failed to start multiple times. After approximately 10 minutes of waiting, the project team made the decision to send the commands to end the simulation and connect the system back to the grid.

At 1:30PM EST, the AWTP was restored to grid connected power. The inverter failing to start during the simulated outage constituted a failure of the customer asset.

Athens Water Treatment Plant – August 19th, 2021, Short Duration Test

The team evaluated the conditions from before and diagnosed the issue preventing the system from restoring power in the previous test. Local plant personnel visually confirmed the position of the disconnects prior to the start of the simulated test. AEP Ohio's dispatch and controls engineering team provided confirmation the system did not have any active alarms. The state of charge on the battery exceeded 80% and the team proceeded with the simulation.

The main breaker at the facility was opened remotely. After a short delay, the battery energy system was closed into the system and restored power to the facility. Once the voltage and frequency were confirmed stable, the plant began normal operations and began the normal startup sequence of motors.

While in the startup sequence, the plant issued a command to start the high pump, which represents the largest motor in the system. After 15 minutes of operating on the battery, the starting of the high pump motor caused a trip of the inverter resulting in a loss of power to the system. The inverter attempted several restarts but failed to restore the system. The team observed the conditions for five minutes, before making the decision to transition the facility back to normal grid power, which was done successfully without further incident.

The vendor is returning later in August to run further testing and adjust settings to resolve the startup issues.

Athens Water Treatment Plant – November 18, 2021, Short Duration Test

Prior to the test on November 18, 2021, the team discussed an approach in an attempt to avoid tripping the battery inverter during the test. This included restricting or not attempting to run the larger water pumps at the facility.

At 1:00 PM EST Local plant personnel visually confirmed the position of the disconnects prior to the start of the simulated test. AEP Ohio's dispatch and controls engineering team provided confirmation the system did not have any active alarms.

At 1:06 PM EST The main breaker at the facility was opened remotely. After a short delay, the battery energy system was closed into the system and restored power to the facility. Once the voltage and frequency were confirmed stable, the plant began normal operations and began the normal startup sequence of motors with the exception of the high service pumps.

At 1:25 PM EST transitioned from island to grid connected power. AEP confirmed no alarms present after the transition for a successful island operation of 25 minutes.

Athens Water Treatment Plant – December 14, 2021, Short Duration Test

At 1 PM EST Local plant personnel visually confirmed the position of the disconnects prior to the start of the simulated test. AEP Ohio's dispatch and controls engineering team provided confirmation the system did not have any active alarms. The state of charge on the battery exceeded 84% and the team proceeded with the simulation.

The main breaker at the facility was opened remotely. After a short delay, the battery energy system was closed into the system and restored power to the facility. Once the voltage and frequency were confirmed stable, the plant began normal operations and began the normal startup sequence of motors.

While in the startup sequence, the plant issued a command to start the high pump, which represents the largest motor in the system. Prior to starting this motor, the team discussed reducing the speed of the motor during startup to avoid a possible trip of the battery inverter. This approach proved successful and the plant was able to run the high service pumps during the remainder of the test.

No issue encountered during transition from Grid Following to Grid Forming. The start of the test commenced at 1:16 PM EST and completed at 2:40 PM EST.

Duration of the test was 1 hour and 24 minutes. Battery charge at start of the test was at 84% and was at 77% at the conclusion.

At 2:48 PM EST the command for Grid Following was executed Athens confirmed that they were back into Grid Following at 2:54 PM EST.

Athens Water Treatment Plant – February 8, 2022, Outage

At 12:02 PM EST Primary power from AEP was lost and the Athens Microgrid went into Islanding mode. No issue encountered during transition from Grid Following to Grid Forming.

At 12:07 PM EST Athens Microgrid back into Grid Following mode.

Outage duration: 5 minutes.

Athens Water Treatment Plant – March 9, 2022, Long Duration Test

At 10:01 AM EST Local plant personnel visually confirmed the position of the disconnects prior to the start of the simulated test.

At 10:04 AM EST AEP Ohio dispatch and control engineering team confirmed MGC SCADA override form disabled to enabled.

At 10:06 the Athens plant personnel confirmed that the system was off AEP Primary grid power and in islanding mode. No issue encountered during transition from Grid Following to Grid Forming.

Battery charge rates: 10:08 AM EST: 83%. 11:03 AM EST: 75%, 11:58 AM EST: 67%, 12:13 PM EST 65%

At 12:13 PM EST, Alarm received for Total Harmonic Distortion on the BESS. The system automatically attempted to clear the alarms. After 4 attempts the test was cancelled. Schneider Electric reviewed alarms and recommended termination of the Long duration test and place the site back into Grid Following mode.

At 12:50 PM EST the Athens site was successfully placed back into Grid Following Mode.

Duration of the test was 2 hours and 13 minutes until issue was encountered.

Schneider to be onsite at Athens on 03/21/2022 to review additional changes to system.

Simulation Conclusions

In all simulated tests, there were issues that arose out of the customer related assets preventing the system from working as designed. AEP Ohio is working with the vendors and customers at each system to address the issues surrounding the simulations experienced and develop a solution to continue testing.

The performance from the systems and the arrangement highlights the need for a standardized platform for interconnection and integration of customer assets with the distribution system. This is especially important if an expectation exists for AEP Ohio to utilize these assets to benefit customers, specifically related to reliability goals during an outage event.

The distribution grid uses proven technology and standardized systems to create a stable and equitable grid for its customers. Using technology such as solar, battery storage systems, or others distributed energy resources for grid operations is essential for future grid modernization efforts. The operating company represents the most equitable and reliable method for owning and maintaining these assets in the future.

<u>Production</u>

AEP Ohio logged several data points throughout the simulation periods of the microgrids. As Tussing managed to complete shortly before April 30th, there was little information pertaining to the solar production at the time of turnover.

During summer peak production, the Zoo yielded up to 115kW peak and at Athens 128kW. This was consistent throughout the summer months and would taper in the winter months with a reduction around 35% in both systems. Production was consistent from sunrise to sunset within each system.

For each battery system, since this was a reliability only case study, the charge/discharge cycles generally operated around 1kW to 3kW except for after a discharge event. This type of float is expected as there are parasitic loads within each system that cause the battery to trickle energy back and forth on the battery itself when not in use.

<u>Reliability Improvements</u>

The reliability metrics for a system like this would typically impact CMI and CAIDI the most. During the simulation period, there was only one unplanned outage at Athens in which the battery operated to continue plant operations and lasted under 10 minutes before return of utility. In terms of quantification, which would equate to 10 CMI saved and a negligible improvement to CAIDI.

As a business case, the investment costs compared to reliability improvement is currently lower than other Smartgrid programs AEP Ohio currently uses to improve customer service.

<u>Power Quality</u>

As stated throughout, the intent of this project was for power reliability. As such, there were no direct uses in which the battery attempted to improve the power quality of the system such as voltage support.

Appendix A – Test Results

The table and figures in the following pages provide a snapshot of the data retrieved during the day of the proposed test. This is a list of definitions for various point ID tags:

Zoo Tags

Unique ID for AEP Ohio Tracking	Recorded Time	Value	Unit of Measure	Description
MGC_00001_SYSLOAD.Display Value	5/4/2021 13:21	-15	kW	Total system load, negative kW indicates power flow from the grid to the system
MGC_00001_PV_GEN.Display Value	5/4/2021 13:21	56	kW	Total solar production in kW
MGC_BKR_AMP_AVG.Display Value	5/4/2021 13:16	71	amps	Net 3 phase amps at the main breaker
MGC_BKR_VOLTS_AVG.Display Value	5/4/2021 13:06	473	voltage	Average 3 phase volts at the main breaker
MGC_DSS1_ACLLVLTAVG.Display Value	5/4/2021 13:27	474	voltage	Average 3 phase volts at battery system 1
MGC_DSS2_ACLLVLTAVG.Display Value	5/4/2021 13:27	474	voltage	Average 3 phase volts at battery system 2
MGC_00001_GRIDSTATUS.Scan Value	5/4/2021 11:09	ALARM	Text	Alarm indicates that the system has an issue
MGC_DSS1_INVT_CRIT.Scan Value	5/4/2021 11:09	ALARM	Text	Critical alarm of the inverter for battery system 1
MGC_DSS2_INVT_CRIT.Scan Value	5/4/2021 11:09	Normal	Text	Critical alarm of the inverter for battery system 2
MGC_DSS2_SOC_AVG.Display Value	5/24/2021 10:01	59	Percent	Percent of charge of the battery system

Athens Tags

Point Name	Recorded Time	Value	Unit of Measure	Description
ATH_MGC_BKR_MAIN_3PHKW.Display Value	12/14/2021 14:07	20	kW	Measure of power contribution from the grid.
ATH_MGC_BKR_ESS_3PHKW.Display Value	12/14/2021 14:07	-14	kW	Power contribution provided by battery (REMOVE)
ATH_MGC_ESS_3PHKW.Display Value	12/14/2021 14:07	18	kW	Battery power contribution (negative indicates battery charging from the system)
ATH_MGC_ESS_STATEOFCHG.Display Value	12/14/2021 14:07	84	Percent	Remaining charge of the battery system
ATH_MGC_BKR_PV_3PHKW.Display Value	12/14/2021 14:07	101	kW	Solar power available in the system.
ATH_MGC_BKR_PV_VOLTS_PHA.Display Value	12/14/2021 14:06	489	Voltage	Solar power Phase A voltage.
ATH_MGC_BKR_PV_OPALARM.Scan Value	12/14/2021 12:50	Normal	Text	Critical Alarm of the inverter for the battery system. Manually verified.
ATH_MGC_BKR_MAIN_OPALARM.Scan Value	12/14/2021 14:06	Normal	Text	Critical Alarm of the primary power for the battery system. Manually verified.

May 4th Results – Zoo

System Point ID	Timestamp	value
MGC_00001_SYSLOAD.Display Value	5/4/2021 13:21	-15
MGC_00001_PV_GEN.Display Value	5/4/2021 13:21	56
MGC_BKR_AMP_AVG.Display Value	5/4/2021 13:16	71
MGC_BKR_VOLTS_AVG.Display Value	5/4/2021 13:06	473
MGC_DSS1_ACLLVLTAVG.Display Value	5/4/2021 13:27	474
MGC_DSS2_ACLLVLTAVG.Display Value	5/4/2021 13:27	474
MGC_00001_GRIDSTATUS.Scan Value	5/4/2021 11:09	ALARM
MGC_DSS1_INVT_CRIT.Scan Value	5/4/2021 11:09	ALARM
MGC_DSS2_INVT_CRIT.Scan Value	5/4/2021 11:09	Normal

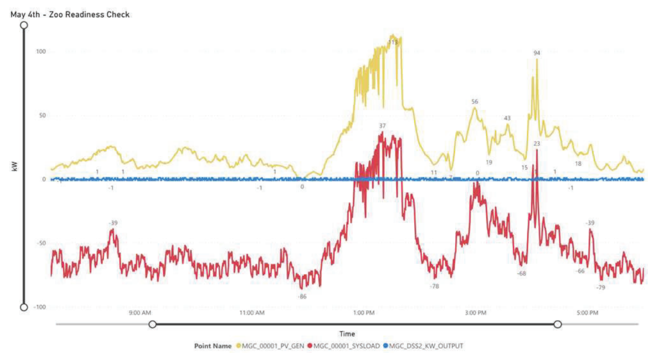


Figure 1 - May 4th Data Trend

Legend:
Yellow – Solar production of the system
Red – System load (negative indicates power provided net from the grid)
Blue – kW output of the battery system

Observations:

- At high production of solar, this offset the total load of the system for the service
- The kW output of the battery system fluctuates between -1 kW (demand) and 1kW (discharge), which indicates the general float of the batteries for maintenance (only DSS2 is shown as DSS1 is sitting in critical failure and not working)

May 24th Results – Zoo

System Point ID	Timestamp	value
MGC_00001_PV_GEN.Display Value	5/24/2021 12:30	65
MGC_00001_SYSLOAD.Display Value	5/24/2021 12:30	-17
MGC_BKR_AMP_AVG.Display Value	5/24/2021 12:30	93
MGC_BKR_VOLTS_AVG.Display Value	5/24/2021 13:15	480
MGC_DSS2_INVT_CRIT.Scan Value	5/24/2021 13:13	Normal
MGC_DSS2_KW_OUTPUT.Display Value	5/24/2021 12:30	1
MGC_DSS2_SOC_AVG.Display Value	5/24/2021 10:01	59
MGC_00001_PV_GEN.Display Value	5/24/2021 13:53	17
MGC_DSS2_KW_OUTPUT.Display Value	5/24/2021 13:53	61
MGC_DSS2_SOC_AVG.Display Value	5/24/2021 13:55	52
MGC_AGGR_DEVICECOMM.Scan Value	5/24/2021 14:02	ALARM

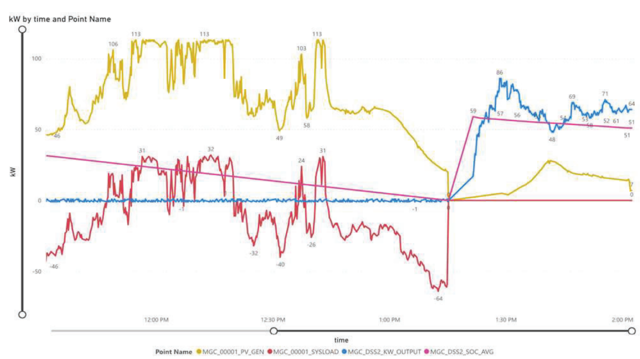


Figure 2 - May 24th Data Trend

Legend:
Yellow – Solar production of the system
Red – System load (negative indicates power provided net from the grid)
Blue – kW output of the battery system
Pink – Battery state of charge

Observations:

- The system and state of charge was stable for battery system 2 and ready for simulated outage
- At the point of transition, all systems registered a 0 while the system transitioned from grid connected to island at 1:15PM EST
- The system restored power shortly before 1:20PM EST and started to power system
- At approximately 2PM EST, the data stops due to the communications failure
- The project team manually reconfigured back to grid connected after the comm failure

December 12th – Zoo

System Point ID	Timestamp	value
MGC_00001_PV_GEN.Display Value	12/12/2021 15:00	53
MGC_00001_SYSLOAD.Display Value	12/12/2021 15:00	-5
MGC_BKR_AMP_AVG.Display Value	12/12/2021 15:00	55
MGC_BKR_VOLTS_AVG.Display Value	12/12/2021 16:19	477
MGC_00001_PV_GEN.Display Value	12/12/2021 15:00	53

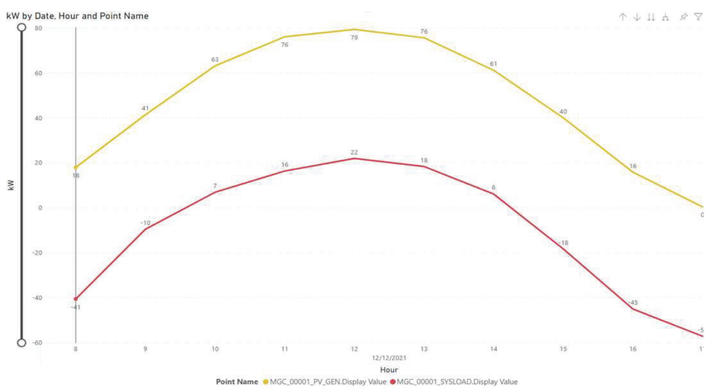
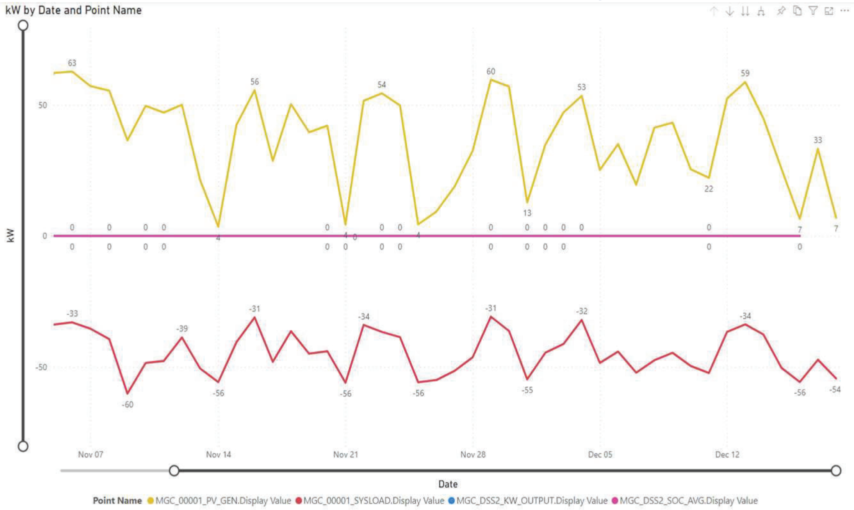


Figure 3 - Zoo Solar PV Production

Legend:
Yellow – Solar production of the system
Red – System load (negative indicates power provided net from the grid)
Blue – kW output of the battery system
Pink – Battery state of charge
Observations:
Lack of customer maintenance on the system causing equipment failure.
Bess-2 in critical alarm.
Malfunctioning W23 Fan operation error. NEC equipment replacement part on order and pending delivery from Germany.
Replaced OV Protection Filter Fuse.
Solar array energy generation continues for Zoo Saltwater system.

November 2022 to December 2022 – Solar Trending Data



Legend:
Yellow – Solar production of the system
Red – System load (negative indicates power provided net from the grid)
Blue – kW output of the battery system
Pink – Battery state of charge
Observations:
The Solar PV continues to offset consumption from the grid to support the Zoo

November 18th – Athens Results

Point Name	Timestamp	Value
ATH_MGC_BKR_MAIN_3PHKW.Display Value	11/18/2021 13:06	4
ATH_MGC_ESS_3PHKW.Display Value	11/18/2021 13:07	13
ATH_MGC_ESS_STATEOFCHG.Display Value	11/18/2021 12:54	85
ATH_MGC_BKR_PV_3PHKW.Display Value	11/18/2021 13:08	6

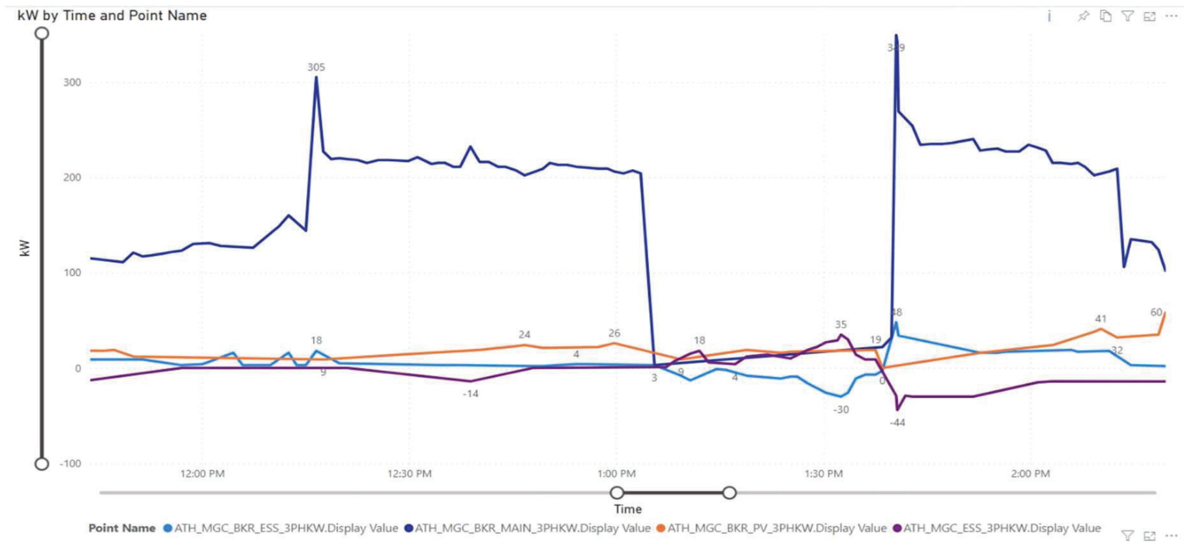


Figure 4 – November 18th Data Trend

Legend:
Dark Blue – Power across the Main breaker.
Orange – Solar power available in the system.
Dark Purple – Battery power contribution (negative indicates battery charging from the system)
Observations:

- Prior to the start of the test, the battery SOC was at 85% and ready for dispatch
- The dark blue line crossing zero shortly after 1PM indicates the start of the testing
- The solar and battery output of the orange and dark purple lines indicate the total load of the system during the outage

December 14th – Athens Results

Point Name	Timestamp	Value
ATH_MGC_BKR_MAIN_3PHKW.Display Value	12/14/2021 14:07	20
ATH_MGC_ESS_3PHKW.Display Value	12/14/2021 14:07	61
ATH_MGC_ESS_STATEOFCHG.Display Value	12/14/2021 14:03	80
ATH_MGC_BKR_PV_3PHKW.Display Value	12/14/2021 14:08	71

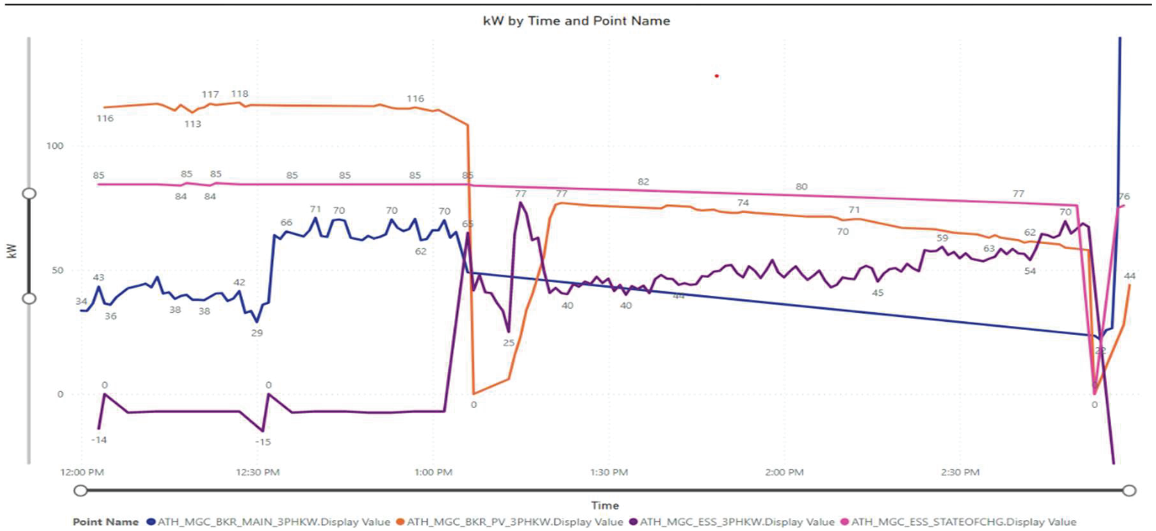


Figure 5 – December 14th Data Trend

Legend:
Dark Blue – Power across the Main breaker.
Orange – Solar power available in the system.
Dark Purple – Battery power contribution (negative indicates battery charging from the system)
Pink – Remaining charge of the battery system.

February 8 – Athens Outage

Point Name	Timestamp	Value
ATH_MGC_BKR_MAIN_3PHKW.Display Value	02/08/2022 12:03	00
ATH_MGC_ESS_3PHKW.Display Value	02/08/2022 12:03	15
ATH_MGC_ESS_STATEOFCHG.Display Value	02/08/2022 12:03	83
ATH_MGC_BKR_PV_3PHKW.Display Value	02/08/2022 12:02	85

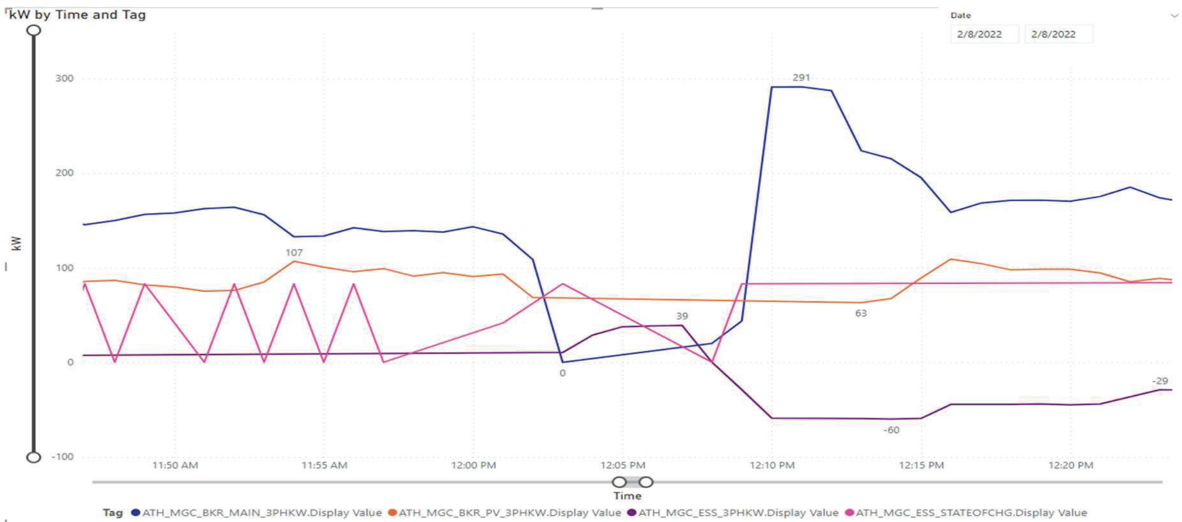


Figure 66 – February 8th Data Trend

Legend:
Dark Blue – Power across the Main breaker.
Orange – Solar power available in the system.
Dark Purple – Battery power contribution (negative indicates battery charging from the system)
Pink – Remaining charge of the battery system.

March 9 – Athens Long Duration Drop Test

Point Name	Timestamp	Value
ATH_MGC_BKR_MAIN_3PHKW.Display Value	03/09/2022 10:06	0.58
ATH_MGC_ESS_3PHKW.Display Value	03/09/2022 10:30	108
ATH_MGC_ESS_STATEOFCHG.Display Value	03/09/2022 10:33	79
ATH_MGC_BKR_PV_3PHKW.Display Value	03/09/2022 10:30	24

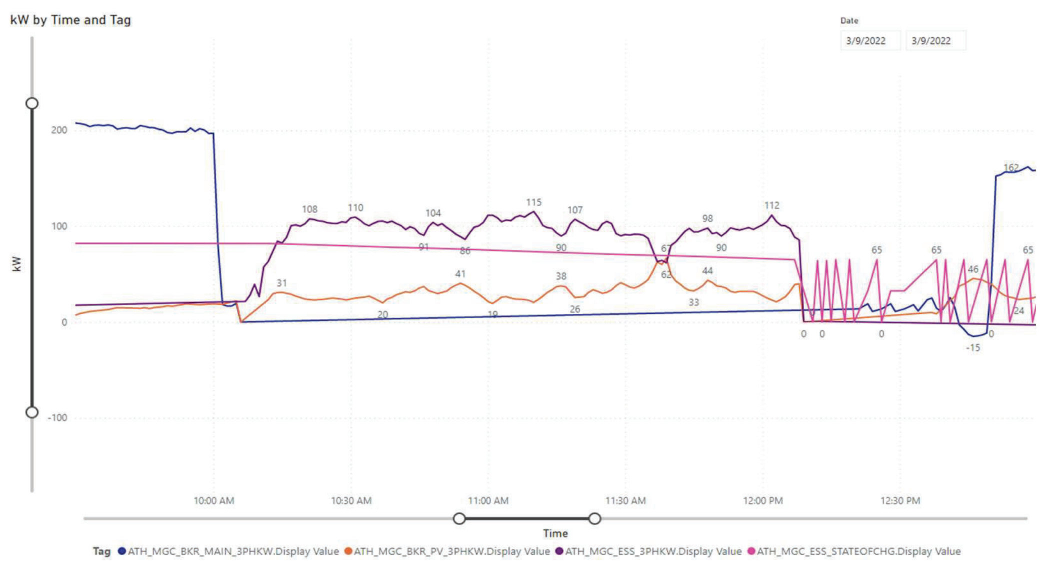


Figure 7 – Match 9th Data Trend

Legend:
Dark Blue – Power across the Main breaker.
Orange – Solar power available in the system.
Dark Purple – Battery power contribution (negative indicates battery charging from the system)
Pink – Remaining charge of the battery system.