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October 31, 2023

VIA ELECTRONIC FILING

Ms. A. Shonta Dunston
Chief Clerk
North Carolina Utilities Commission
4325 Mail Service Center
Raleigh, North Carolina 27699-4300

**RE: Duke Energy Progress, LLC's Hot Springs 15-Month Report
Docket No. E-2, Sub 1185**

Dear Ms. Dunston:

In accordance with the Commission's *Order Amending Annual Report Requirement* issued on March 10, 2020, Duke Energy Progress, LLC submits the Hot Springs 15-Month Report for filing in the above-referenced matter. Certain information included in the Report constitutes trade secrets, and information is being filed under seal pursuant to N.C. Gen. Stat. § 132-1.2. Parties to the docket may contact counsel for Duke Energy Progress, LLC regarding obtaining copies pursuant to an appropriate confidentiality agreement.

If you have any questions, please do not hesitate to contact me. Thank you for your attention to this matter.

Sincerely,

Jack E. Jirak

Jack E. Jirak

Enclosure

cc: Parties of Record

2023

Hot Springs Microgrid

ANNUAL OPERATIONAL REPORT AND REQUIRED STUDY OF ANCILLARY SERVICES

DUKE ENERGY PROGRESS

DOCKET NO. E-2, SUB 1185

OCTOBER 31, 2023

Executive Summary

The Hot Springs Microgrid consists of solar photovoltaic ("PV") and a battery energy storage system ("BESS") that can serve the broader system on blue-sky days and microgrid controller equipment that enables the combined PV and BESS to provide backup power to the town of Hot Springs in the event of an outage. In the May 10, 2019, *Order Granting Certificate of Public Convenience and Necessity with Conditions* ("CPCN") in Docket No. E-2, Sub 1185 ("CPCN Order"), the North Carolina Utilities Commission ("NCUC" or "Commission") required Duke Energy Progress, LLC ("DEP" or the "Company") to submit various reports and studies on the Hot Springs Microgrid as a condition of approving the CPCN. This document contains both the first Annual Operational Report[1] and a Required Study of Ancillary Services[2], which are due to be filed within fifteen months after the Hot Springs Microgrid commercial operation date ("COD") of July 31, 2022.[3]

The Annual Operational Report requirement was to cover islanding activity, operational performance, and learnings. The report contained herein provides the details of Annual Operational Report requirement using data collected from August 1, 2022, through July 31, 2023. In that first year of operation, the Hot Springs battery attained an overall availability of 74.6%, with 9.3% of the availability loss due to vendor responsibility and 16.1% due to issues outside the responsibility of the vendor. It experienced 3 islanding events totaling 13 hours of reliability.

Since the Commission issued the CPCN Order, DEP learned of certain site limitations through the interconnection process. Per these learnings, DEP modified the secondary use case for the microgrid. In response to the interconnection limits, DEP has pivoted from providing ancillary services with the Hot Springs battery[4] to performing energy arbitrage, using the battery to store excess solar energy and dispatch it at other times of day. While this prevents DEP from demonstrating the use of Hot Springs to provide ancillary services, the Required Study of Ancillary Services section of this report provides helpful learnings about ancillary services across the DEP system and how learnings from the Hot Springs project are being applied to other batteries being planned across the DEP system. Namely, DEP quantified the need for and value of ancillary services to the whole DEP system and developed a process to translate those values into the evaluation of individual projects as described in the Required Study.

This report covers the many lessons learned that are being leveraged to the benefit of customers in DEP and Duke Energy's other jurisdictions.

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[1] Annual Report requirements are detailed on Pages 13-14 of the CPCN Order.
[2] The Required Study of ancillary services is detailed on Pages 14-15 of the CPCN Order.
[3] The Commission's March 10, 2020, *Order Amending Annual Report Requirement* clarified and amended the CPCN Order to provide that the first Annual Report shall be filed within 15 months after commercial operation of the Hot Springs Microgrid commences.
[4] The planned ancillary services functionality was described in DEP's Revised Semiannual Hot Springs Microgrid Project Progress Report filed on January 15, 2020.

Annual Operational Report

The Hot Springs Microgrid is a combination of a PV site accepted as standard technology and the battery portion as a pilot project. Due to the pilot nature of the battery portion of the microgrid, the Company agreed to several reporting requirements recommended by the Public Staff, which the Commission required as part of the CPCN Order. This section of the report covers all the requirements pursuant to the following requirement from the CPCN Order:

> Annually report, update, and file with the Commission and provide to the Public Staff, confidentially, the results of its operational knowledge and learning goals to demonstrate the operational benefits of the Hot Springs Microgrid.[5]

The Annual Operational Report is organized by category and covers data obtained from August 1, 2022, through July 31, 2023. The **Operation** section includes details of site operations under islanding mode (when the local area served by the microgrid is isolated from the rest of the DEP system) and grid parallel mode (when the PV and BESS are connected to the rest of the DEP system). The **Maintenance** section includes the costs associated with operations and maintenance describing events and repairs as well as a discussion of system availability. The **Lessons Learned** section details experience gained from the project through its first year in operation. Finally, DEP includes a **Quantification of Benefits** section in its Detailed Study of Ancillary Service Benefits that covers the services Hot Springs has provided in that time, along with the valuation of those services where appropriate or possible. That discussion is included in the Detailed Study instead of the Annual Report on Operations to better group the concepts together.

There are specific parameters to report that are covered in Table 1 that were extracted from the Annual Operational Report section of the CPCN Order.

Table 1; Microgrid operation parameters specified in CPCN

Parameter	Description
Islanding event count	Number of islanding event and success rate
Islanding detail	Details of the outage and any notable mitigation and limitations
PV energy	Energy exported to grid and energy to battery, MWh and %
Battery energy	Exported to grid, Energy imported from PV and grid, MWh and %
Battery performance	State of charge, state of discharge, number of charge/discharge cycles
Energy losses	Auxiliary loads, transformer losses,

[5] CPCN Order at 13

Energy consumption	Site consumption vs export
Maintenance costs	Operation and Maintenance cost for year, by category
Lessons learned	Detailed list of gaps found and proposed corrections
Capacity test results	Capacity change from start to end of service year 1

Operation

The microgrid has two operation modes: grid parallel and islanding. For the first service year the Hot Springs Microgrid was in grid parallel operation 99.85% of the time when in operation. DEP is separately providing hourly data as required in the CPCN Order as follows, with summary-level information provided throughout the rest of this section of the report. Figure 1 graphically represents the grid parallel operation. Figure 2 graphically represents an islanding operation. The graphical representations were generated from sub hourly data at the Hot Springs site on specific dates of operation.

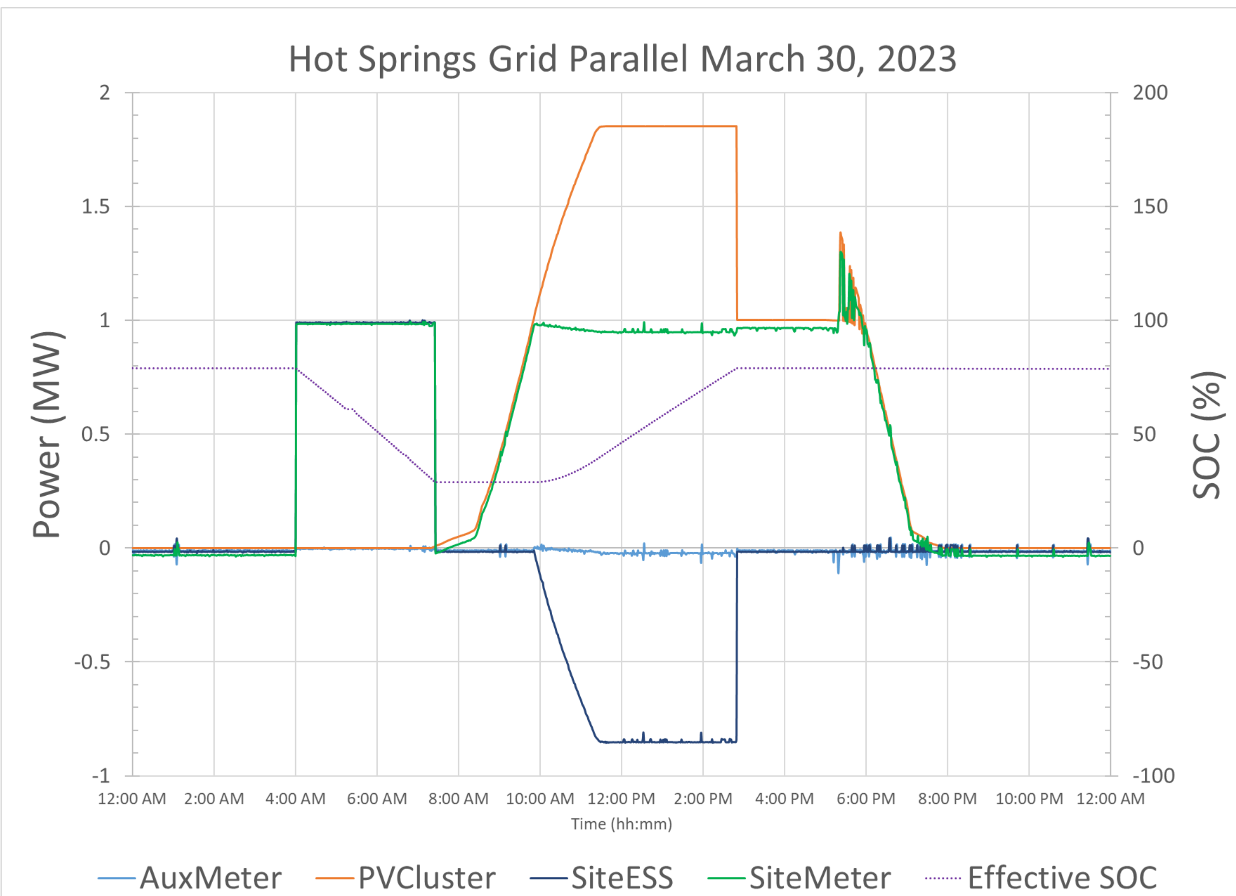

Figure 1: Grid parallel operations

In Figure 1 a typical sunny day starts with discharging the battery starting at ~4:00 AM until ~ 7:30 AM, during the morning peak load, taking the state of charge ("SOC") from 80% down to 30%, exporting ~3.4 MWh of energy. This is represented by the dark blue Site ESS line (the only line that dips below zero in the chart) and the green Site Meter line in Figure 1. The SOC % is represented by the dotted purple line. As the sun rises, just prior to 8:00 am on the graph, the PV system powers up, represented by the orange line in Figure 1. As the PV generation surpasses 1 MW the power greater than 1 MW is diverted to the battery system to charge the batteries, as observed by the negative value of the dark blue SiteESS. Note the Site Meter green line is limited to a 1 MW export limit of the interconnection agreement. As the excess energy is diverted to the battery, the SOC begins to increase. The PV energy more than 1 MW is diverted to the battery until the SOC of 80% is attained[6]. The PV is curtailed at this point to prevent exceeding the 1 MW limit set in the interconnection agreement. The SOC is held at 80% over night in case the stored energy is needed for an islanding event. The next day the process is repeated. Note there is a little wiggle at the end of the day around 6:00 PM where the 1 MW export is exceeded. The rules engine running this operation needs modification to correct this anomaly.

Not shown in a figure is the cloudy day operation. In that instance, the rules engine will take power from the grid in mid-afternoon and charge the battery to 80% SOC. This ensures there would be sufficient energy available to the town of Hot Springs in case an overnight islanding event occurs.

In Figure 2 an islanding operation that occurred on April 2, 2023, is presented. At approximately 3:30 PM the battery began exporting to the islanded portion of the grid. This is demonstrated by the overlay of both the dark blue Site ESS line and the green Site Meter line. Around 3:45 the PV generation turned on. When the PV turned on (orange line), its power began replacing the power from the battery supporting the load. The battery power subsequently decreased over a short period and the PV began to charge the battery as well as export to the grid to match the load. There are a few step changes in the PV generation that is driven by the rules engine. Near the end of the solar day the battery began to export to the islanded portion of the grid, supplementing and then replacing the PV generation. The battery system matched the load for 6.5 hours before it reached its minimum SOC and had to turn off.

[6] DEP tries to keep the SOC between 20% and 80% in normal operations to stay within guardrails set by the vendor to maintain battery health. DEP can exceed those guardrails if needed in emergency but tries not to do so.

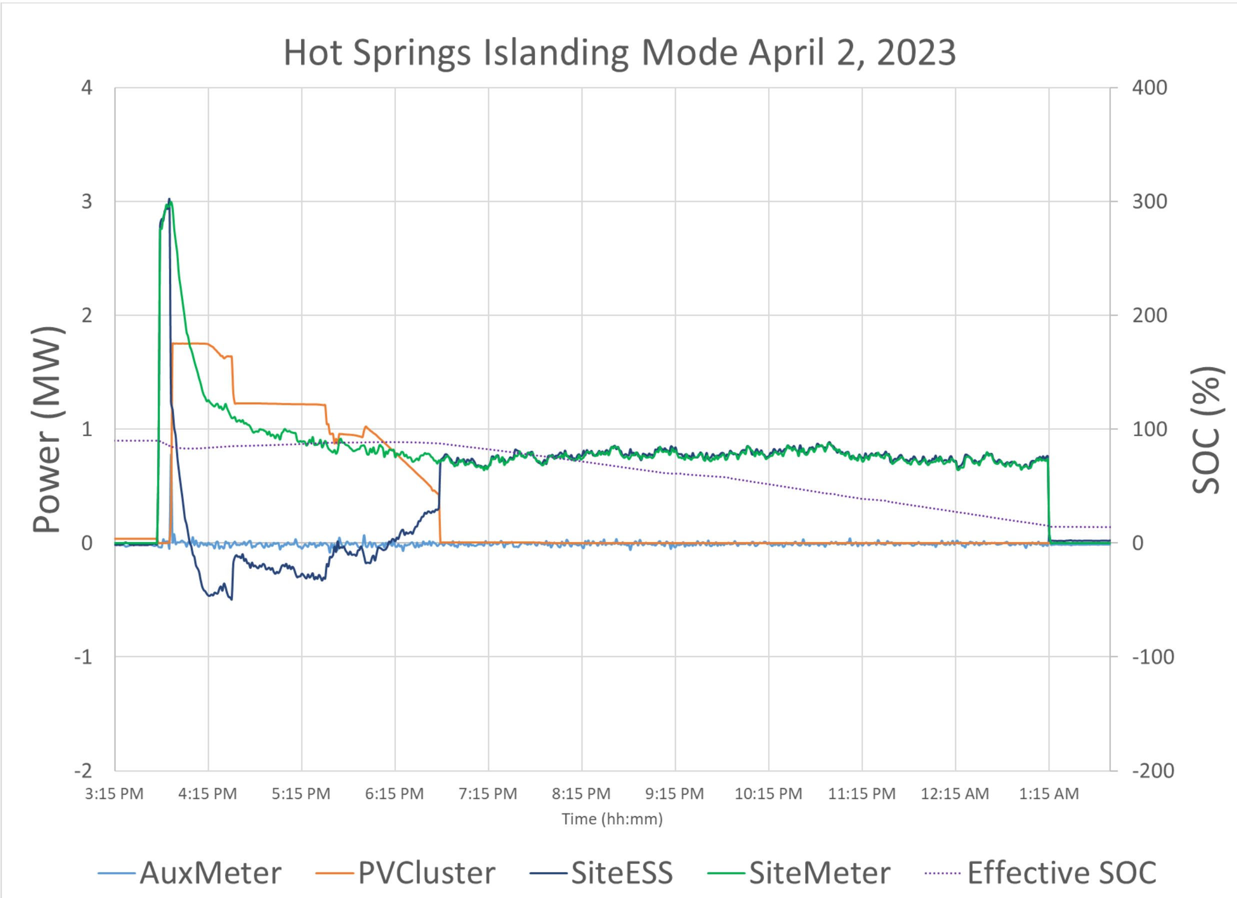

Figure 2: Islanding operation

Islanding Operation

This section addresses reporting requirements regarding islanding operations in compliance with the following:

> A detailed event summary of all instances in which the Hot Springs Microgrid operated in island mode, whether in response to an outage on the Hot Springs distribution line or otherwise. This summary should include a discussion of how outage duration and frequency were affected by the Hot Springs Microgrid, and document any instances in which an outage was not able to be mitigated completely due to the limited capacity of the energy storage system.[7]

The Hot Springs Microgrid was in islanding operation a total of 13.0 hours in its first year of operation. The microgrid automatically performed islanding without human intervention once in the first year of operation. The summary of the islanding events is contained in Table 2 and a description of each event follows the table.

[7] CPCN Order at 13.

Table 2: Islanding event first year of operation

Event number	Automatic Island Start	Island start	Island end	Islanded hour	Solar discharge (MWh)	Battery discharge (MWh)	Total discharge (MWh)
1	Yes	12/9/2022	12/9/2022	0.6	0	0.38	0.38
2	No/manual	4/1/2023	4/1/2023	2.8	0	2.74	2.74
3	No/manual	4/2/2023	4/3/2023	9.5	3.29	5.54	8.84

December 9, 2022
On December 9, 2022, the Hot Springs Microgrid was tested at the full-scale level for supporting customer loads. This was the final test before placing the site in service for microgrid/islanding operation. The test began around 3PM EST and the Hot Springs facility supported the load for slightly over 30 minutes. During this time, meters were placed in numerous locations throughout the island to monitor the load and power quality for in-depth analysis. The site was placed back into normal service after approximately 30 minutes by closing a mid-point recloser to energize the Hot Springs circuit.

April 1, 2023
On April 1, 2023, the Hot Springs area was experiencing a high wind event. That afternoon, an H-frame pole structure supporting distribution lines was crushed by a tree and taken out of service, putting the Hot Springs customers in an outage. During initial startup, the two power conversion system ("PCS") inverters started up simultaneously and out-of-sync. Because of the starting sequence, one of the PCS inverters tripped on overcurrent and required physical intervention to reset the PCS inverter. Duke Energy personnel were deployed to site to examine the system and restore the PCS units. After evaluation, the PCS units were restarted manually and in sequence. Once the PCS units were in operation and stable, personnel proceeded to restore power to the town by closing the downstream reclosers. The facility supported the load for approximately 3-4 hours before the batteries reached their low State of Charge and disconnected. The Hot Springs Microgrid was designed to address 90% of outage durations but having to reconstruct the pole structures took multiple days and exceeded the reliability design intent for the microgrid.

April 2, 2023
On April 2, 2023, the day following the initial outage on April 1, the distribution grid was still in outage as repairs were made. Since the batteries had been depleted while supporting the load the previous day, DEP proceeded to utilize the energy production from the solar facility to manually charge the batteries back up into a

sufficient SOC to energize the Hot Springs customers. Once the batteries had sufficient energy, DEP proceeded to manually close in the distribution reclosers to provide power to the Hot Springs customers while the grid was in outage. Both the solar system and the battery system provided energy for 9.5 hours. After approximately 6 hours of battery only support, the batteries were once again depleted, and the system safety shut down and waited for grid power to be restored, which occurred on the afternoon of April 3. In the April event DEP prevented customers from experiencing a three-day outage event, but due to the way outage frequency is calculated customers experienced separate interruptions over the three days when the islanded activated, deactivated, and then reactivated. During the multi-day outage, the two islanding events provided roughly 12.3 hours of service for about 400 customers in the islanded area for about 295 thousand avoided Customer Minutes of Interruption. However, the multiple islanding events drove up Customer Interruptions due to the power going on and back out twice once batteries were depleted. Such a negative impact on Customer Interruptions only occurs when the outage is significant enough to exceed the capability of the solar and battery storage resources in the microgrid.

Grid Parallel Operation

The Hot Springs Microgrid ran in the grid parallel mode 99.85% of the time. The performance parameters are presented both graphically and tabular form.

Energy

Figure 3 provides a breakdown of the monthly energy generation/use by component.

As observed in Figure 3 and the subsequent tables, the solar component of the microgrid exports a significant amount of energy to the grid while providing 82% of the energy the batteries have received, meaning that DEP expects the Hot Springs battery to be eligible for the legacy Investment Tax Credit (“ITC”).

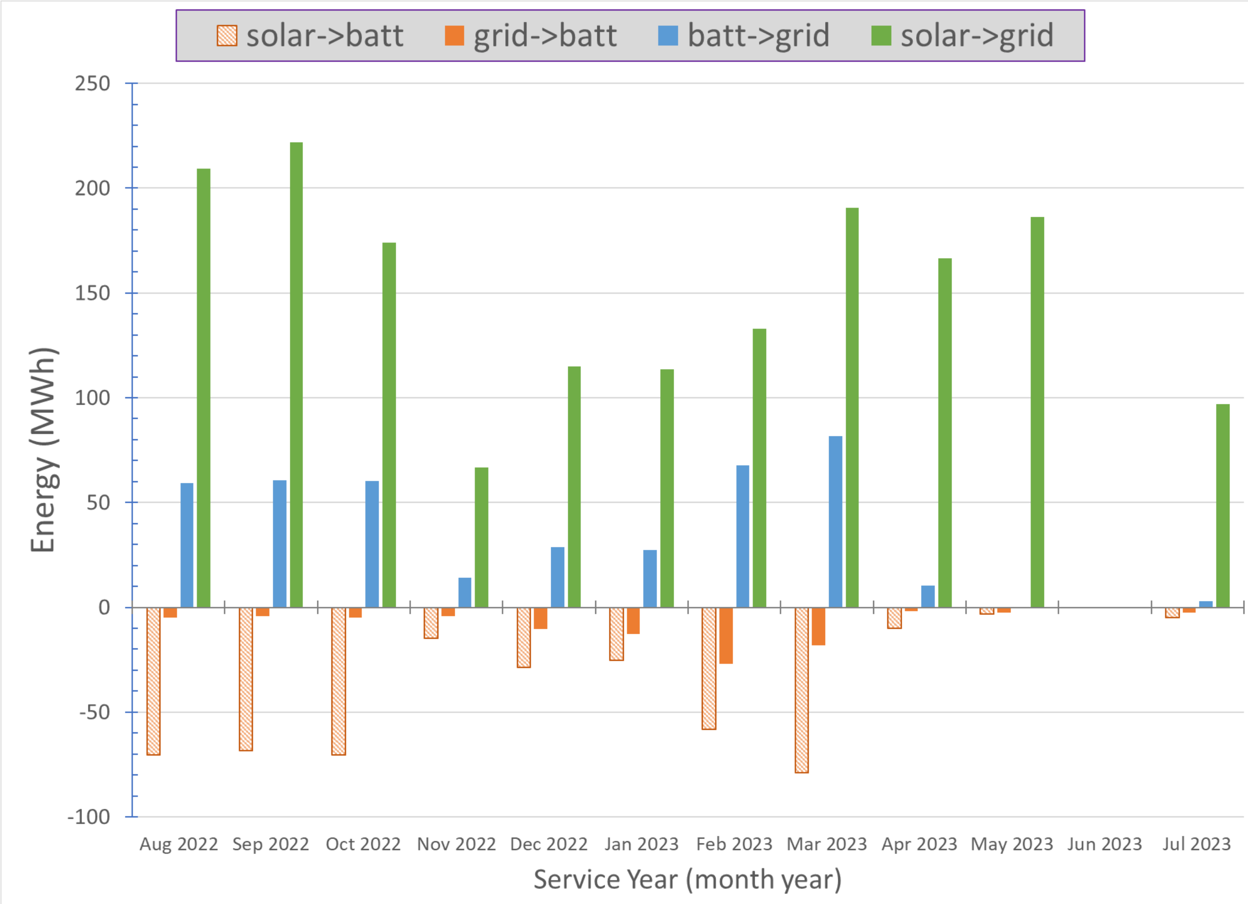

Figure 3: Hot Springs energy flow by month

Table 3, which provides a breakdown of solar generation for the performance year reported in megawatt hour (MWh), addresses the following requirement from the CPCN Order:

> An annual summary of Hot Springs Microgrid operations, including hourly data, with enough specificity to determine: i. Where solar PV energy was directed (to grid or to battery), including the percentage of energy sent to each source.[8]

Table 3: Solar generation breakdown

MWh	Solar Generation	solar->grid	solar->batt	solar->aux	% Solar to Grid	% Solar to Battery	% Solar to Aux loads
Year Total	2170.5	1673.3	433.2	64.1	77%	20%	3%
August 2022	290.4	209.3	70.4	10.7	72%	24%	4%
September 2022	300.5	221.8	68.4	10.3	74%	23%	3%
October 2022	257.5	174.0	70.3	13.3	68%	27%	5%
November 2022	85.0	66.8	14.7	3.5	79%	17%	4%
December 2022	147.0	114.8	28.6	3.6	78%	19%	2%

[8] CPCN Order at 14.

MWh	Solar Generation	solar->grid	solar->batt	solar->aux	% Solar to Grid	% Solar to Battery	% Solar to Aux loads
January 2023	142.2	113.5	25.4	3.3	80%	18%	2%
February 2023	195.1	132.8	58.2	4.1	68%	30%	2%
March 2023	275.6	190.8	79.0	5.9	69%	29%	2%
April 2023	180.5	166.6	9.9	3.9	92%	6%	2%
May 2023	192.8	186.1	3.3	3.4	97%	2%	2%
June 2023	0.0	0.0	0.0	0.0			
July 2023	104.0	96.9	5.0	2.1	93%	5%	2%

Table 4, which provides a breakdown of the battery charging and discharging for the performance year reported in megawatt hour (MWh), addresses the following requirement from the CPCN Order:

> An annual summary of Hot Springs Microgrid operations, including hourly data, with enough specificity to determine: ii. How the battery was charged (from the solar PV system or the grid), including the percentage of total energy from each source.[9]

Table 4: Battery charge and discharge breakdown

MWh	Batt Charge	Batt Discharge	solar->batt	grid->batt	batt->grid	batt->aux	% batt from solar	% batt from grid	% batt to grid	% batt to Aux
Year Total	526.1	418.0	433.2	92.9	413.2	4.8	82%	18%	99%	1%
Aug 2022	75.2	59.9	70.4	4.8	59.4	0.5	94%	6%	99%	1%
Sep 2022	72.5	61.0	68.4	4.2	60.5	0.5	94%	6%	99%	1%
Oct 2022	75.1	61.6	70.3	4.8	60.3	1.2	94%	6%	98%	2%
Nov 2022	18.9	14.7	14.7	4.2	14.2	0.5	78%	22%	97%	3%
Dec 2022	39.1	29.3	28.6	10.4	28.8	0.5	73%	27%	98%	2%
Jan 2023	38.0	27.5	25.4	12.7	27.2	0.3	67%	33%	99%	1%
Feb 2023	85.2	68.1	58.2	27.0	67.7	0.4	68%	32%	99%	1%
Mar2023	97.1	82.4	79.0	18.1	81.8	0.6	81%	19%	99%	1%
Apr 2023	11.7	10.6	9.9	1.8	10.3	0.3	85%	15%	97%	3%
May 2023	5.7	0.0	3.3	2.4	0.0	0.0	58%	42%		
Jun 2023	0.0	0.0	0.0	0.0	0.0	0.0				
Jul 2023	7.6	3.0	5.0	2.6	3.0	0.0	66%	34%	100%	0%

[9] CPCN Order at 14.

Grid parallel operation resulted in 133 charge/discharge cycles in the first service year.[10] The typical state of charge cycled between 30% to 80 % as shown in Figure 1.

Table 5, which provides the distribution of energy that support the auxiliary loads, is provided in response to the following requirement from the CPCN Order:

> An annual summary of Hot Springs Microgrid operations, including hourly data, with enough specificity to determine: iv. Quantification of energy losses from the battery, including energy used as station power for the battery storage and any other on-site devices that use power.[11]

The solar system provides 58% of the load required by the auxiliary loads while the grid supplies 37% and the battery system provides 4%.

Table 5: Energy distribution among components

MWh	batt->aux	solar->aux	grid->aux	Aux Load total	% batt to Aux	% Solar to Aux	% Grid to Aux
Year Total	4.8	64.1	40.7	109.7	4.4%	58.4%	37.1%
August 2022	0.5	10.7	4.7	15.9	3.3%	67.0%	29.7%
September 2022	0.5	10.3	4.2	15.0	3.2%	68.8%	28.1%
October 2022	1.2	13.3	5.5	20.0	6.0%	66.3%	27.7%
November 2022	0.5	3.5	2.2	6.2	7.9%	56.7%	35.5%
December 2022	0.5	3.6	5.2	9.3	5.3%	38.4%	56.3%
January 2023	0.3	3.3	4.7	8.2	3.6%	39.8%	56.6%
February 2023	0.4	4.1	3.4	7.9	5.2%	51.9%	42.9%
March 2023	0.6	5.9	3.6	10.1	6.1%	58.3%	35.6%
April 2023	0.3	3.9	3.3	7.6	4.4%	52.0%	43.6%
May 2023	0.0	3.4	2.6	6.0	0.0%	57.0%	43.0%
June 2023	0.0	0.0	0.0	0.0			
July 2023	0.0	2.1	1.3	3.4	0.0%	62.6%	37.4%

In the Spring of 2023, the site experienced two extended outages that reduced ability to use the battery storage system. The circuit protective devices incorporated in the design worked to prevent catastrophic damage to major components. However, the deep dive investigation to find the root cause of the failures took several weeks. The Company was very cautious returning the system

[10] The total number of charge/discharge cycles is being provided along with the tables in this section to address the following requirement from the CPCN Order at 14: "An annual summary of Hot Springs Microgrid operations, including hourly data, with enough specificity to determine: iii. How the battery was discharged, and for what purpose (islanding, ancillary services, etc.), including the total number of charge/discharge cycles, typical depth of discharge, hourly state of charge, and any other recorded characteristics". The Quantification of Benefits section of this of the Detailed Study of Ancillary Service Benefits discusses the energy values based on the first year of operations and explains how its capacity value is determined.

[11] CPCN Order at 14. Table 5 also addresses the requirement from the CPCN Order at 14 for DEP to provide: "A quantification of energy use consumed by the Hot Springs Microgrid (station power)".

to operation aware of supply chain issues if the broader grid experienced damage, e.g., transformer lead times. The Company did not want to return to service and unknowingly put major components at risk. As the first service year came to end the site was not operational due to root cause analysis and supply chain issues obtaining parts. At the time of this report, DEP is still awaiting delivery of parts.

Capacity Testing

To maintain the warranty coverage, an annual capacity test is run. The capacity test operates the system from a fully discharged state to a fully charged state and then back to a fully discharged state to measure the battery's capacity. The test is run at the allowed maximum charge and discharge power. For Hot Springs that is 1 MW. This testing is found in the following requirement from the CPCN Order, noting that the "ability to provide ancillary services" has been addressed elsewhere:

> A description of how the battery system has degraded over time to include loss of: (1) storage capacity, (2) output capacity, and (3) ability to provide ancillary services.[12]

The capacity testing was not able to be run at the end of the first service year due to hardware problem that kept the system from operating. However, the capacity test results from other battery storage systems indicate DEP should not have an issue meeting the minimum acceptable capacity value. As an example, Table 6 provides the capacity test results from our Asheville Rock Hill Site which uses similar technology and equipment.

Table 6: Capacity test results from our Asheville Rock Hill battery storage site

Service year ending		2021	2022
Guaranteed Energy at POI (AC)	MWh	8.8	8.8
Installed DC Capacity, includes expected yearly degradation	MWh	12.61	12.32
Average DC Capacity measured	MWh	12.77	12.74
Average AC Capacity measured	MWh	12.76	12.67
Efficiency, Charging	%	97.4	98.2
Efficiency, Discharging	%	97.4	96.9
Normalized DC Capacity		1.013	1.034

The capacity meets the minimum requirement. The normalized capacity is the measured capacity over the minimum acceptable capacity for that service year. This allows Duke Energy to compare the capacity among our sites.

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[12] CPCN Order at 14.

Maintenance

The availability of the site averaged 74.6% for the operation year ending July 31, 2023. The target availability was 97%. Availability loss due to vendor responsibility was 9.3%. The availability loss due to issues outside the responsibility of the vendor was 16.1%.

Many maintenance costs associated with this site are rolled up in a confidential long-term service agreement (LTSA) with a vendor. The confidential addendum to this report provides a breakdown of the costs associated with the LTSA and other costs associated with maintaining the site, in compliance with the following requirement from the CPCN Order:

> Operations and maintenance costs, by FERC account and with descriptive footnotes explaining purpose (ongoing maintenance, specific repairs, etc.).[13]

There was a performance decline in May, June, July of 2023 due to the previously mentioned site outages. Surge arrestors in the site transformer were activated which took the site off-line. Time was spent to investigate the root cause and determine if any site component integrity was compromised. This resulted in an extended outage in those months. Thankfully the outages at the Hot Springs site in that time frame did not adversely affect the town of Hot Springs supply of energy. The town did not have any other power outages during the Hot Springs Microgrid's first year of service.

Lessons Learned

The lessons learned from this pilot program covers all aspects in the project; from development all the way through to routine maintenance. Discussion of these learnings addresses the following requirements from the CPCN Order:

> A discussion of how, if at all, the actual Hot Springs Microgrid operations deviated from projections made in this docket...
>
> A summary of how the Hot Springs Microgrid enhanced economic operations and how it was beneficial to DEP's operational knowledge (i.e., lessons from design engineers regarding programming the device or maintenance personnel regarding operations and management costs; Hot Springs Microgrid behavior in light of bulk system dynamics, etc.).[14]

Here are some of the key lessons learned:

- During the commissioning stage, a 1 MW export limit was included in the interconnection agreement. This wrinkle altered the way the site would operate. As explained in the Detailed Study of Ancillary Service Benefits, the

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[13] CPCN Order at 14. The CPCN Order also requires DEP to provide, "Costs of installed capital upgrades and retirements, in the same format as for initial costs of construction", but no such costs were incurred within the first year of operations.
[14] CPCN Order at 14.

Company describes the value energy arbitrage added to the project due to the 1 MW export limit. The interconnection limit issue has been discussed within Duke Energy to ensure future projects look more closely at the proposed use cases and any barriers that may exist operating to the proposed used cases.

- Design improvements are being incorporated into future battery projects to reduce the effort bringing the site back on-line after grid perturbations take the site off-line. Specifically, the circuitry that powers the battery systems and the auxiliary loads need to be decoupled. Decoupling these two systems would allow the power to auxiliary loads (HVAC, communications, camera, controls system) to come back on-line much quicker especially if the battery systems needed to be off-line for repairs.
- Thorough testing of automation needs to be done before full implementation is completed. The Company found gaps during original automation testing that are being addressed. Lab/bench testing could eliminate the need for some of the field testing.
- For islanding, the control software needs to be modified to allow staggering the start of inverters when multiple inverters are utilized as a grid forming source. This modification will fix the issue observed in our April islanding events.
- To reduce total harmonic distortion, DEP is implementing a pulse shifting of the inverters when multiple inverters are available for grid forming.
- Implementation of emergency stop (fast-stop) on storage inverters upon OPEN/TRIP operation of upstream devices prevents Load Rejection Overvoltage events at the site.
- Site backup (UPS) batteries throughout the site should be rated and designed for multiple deep discharge operations. There are four different UPS battery systems within the microgrid that support the various sub systems. Those sub systems include the site control center, each container, each fire detection system within a container, and each gas detection system within a container.
- DEP’s experience indicates the maintenance contracts with liquidated damages do not actually deliver the best response and best availability. Due to vendor priorities, subcontractor availability, and site location, the vendor accepts and pays the liquidated damages. This may improve Duke Energy’s operations and maintenance budget, but it does not serve our customer well if the site is not available when needed. Duke Energy has been moving toward a maintenance model that will reduce costs and improve availability.
- Parts availability has become a critical path for system operations. The inability for the vendor to supply parts in a timely manner to restore operations has been a major barrier to Hot Springs Microgrid operations. Our experience at Hot Springs has shown the UPS batteries need replacing more frequently than manufacturer recommendations. In the future, Duke

Energy will investigate a sparing strategy to improve battery fleet performance.

- First-of-a-kind studies necessary to enable islanding capability were undertaken for the Hot Springs Microgrid. The Company now understands how these islanding studies relate to generator interconnection processes. The Company learned what modifications to engineering design and schedule may be required because of these first-of-a-kind islanding studies. The study process also allowed a market survey of vendors available to perform these studies and knowledge of how the utility may self-perform to save study costs.

Required Study of Ancillary Service Benefits

Background

In addition to the Annual Report on Operations discussed previously, the Hot Springs CPCN Order required the following:

> DEP shall perform a study, either by contracting with a third party or as part of Its integrated systems and optimization planning initiative, to estimate the ancillary service benefits battery storage can provide DEP's system, using sub-hourly modeling techniques similar to the Astrape Solar Integration Cost Study in Docket No. E-100, Sub 158, and use the results to help quantify the success of the Hot Springs Microgrid. In addition, the results could be used in future battery storage proposals, providing more confidence that estimated benefits used to justify battery storage projects would actually be realized by DEP ratepayers. This study should aim to quantify and value separately the various ancillary services batteries can provide, such as spinning and frequency reserves. If possible, this study should analyze different energy storage technologies of varying durations to determine the most cost-effective energy storage technology and duration for each type of ancillary service provided. The study shall be completed within 15 months after commercial operation of the Hot Springs Microgrid commences.[15]

That requirement was intended to address two main concerns: the need to value ancillary services within DEP's own system and the reflection of how the Hot Springs Microgrid could help meet those system needs. During the CPCN proceeding, DEP developed a cost-benefit analysis (CBA) that included an estimate for ancillary services the battery storage component of the microgrid could provide as a secondary use case to its primary reliability function. At the time, DEP had to use frequency regulation values from MISO to represent potential ancillary service benefits, since no such valuation had been developed for the DEP system. Since then, DEP has developed its own ancillary service requirements and a process to quantify their value through production cost modeling. While interconnection limits for the Hot Springs Microgrid have resulted in a shift of the secondary use case from ancillary services to energy arbitrage, there are learnings from Hot Springs regarding ancillary services that will inform future energy storage resources.

This section of the Hot Springs 15 Month Report addresses the Detailed Study requirement as follows:

- Share how DEP calculated its system ancillary service requirements and incorporated them as constraints in production cost modeling for Integrated Resource Planning

[15] CPCN Order at 14-15

- Describe how DEP systemwide ancillary values in the production cost model are allocated to individual projects using a proxy value methodology
- Estimate ancillary values for Hot Springs absent interconnection constraints at the site, as compared to ancillary values in the Hot Springs CPCN CBA
- Explain how Hot Springs is operating and share learnings for future project evaluations

As discussed previously, DEP learned of interconnection limits for the Hot Springs Microgrid during the interconnection process, after the CPCN was approved. This resulted in a change of the secondary use case for the battery storage component of the microgrid from providing ancillary services to performing energy arbitrage or storing solar energy production in excess of the interconnection limit and discharging that energy at other times of the day. Section 3 of the CPCN requires the quantification of the ancillary services the microgrid provides and in the recent DEP NC rate case (Docket No. E-2, Sub 1300) Public Staff requested an update to the Hot Springs cost benefit analysis based on that interconnection limit. The change in secondary use case means that DEP cannot demonstrate ancillary services offered at Hot Springs. However, the Company believes there is still great value in sharing: (1) how DEP has defined ancillary service needs for its system, (2) how DEP developed a process to show how individual resources can meet those needs, and (3) what learnings about ancillary values are still gained through this Hot Springs 15-month report. Pursuant to the Final Order in the DEP NC Rate Case[16], DEP met with Public Staff in September 2023 to discuss this approach and reached consensus. At the request of Public Staff, DEP used its proxy value process to compare hypothetical DEP-based ancillary benefits to benefits assumed in the CPCN application process for Hot Springs if interconnection limitations did not exist.

The Path from Ancillary Service Requirements to Individual Project Evaluations

NERC defines ancillary services as: “Those services that are necessary to support the transmission of capacity and energy from resources to loads while maintaining reliable operation of the Transmission Service Provider’s transmission system in accordance with good utility practice.”[17] Since the CPCN, Duke Energy has developed an ancillary requirements model for the DEP and Duke Energy Carolinas, LLC (“DEC”) systems based on sub hourly data and incorporated those requirements into the IRP production cost model – Encompass – as hourly constraints. The quantile regression-based ancillary reserves requirement model defines needs for balancing reserves, and regulating reserves, with regulating reserves representing 10-minute variability in net load. This work is described in the “System Reliability Requirements” section of the ISOP Appendix to the 2023 Carolinas Resource Plan.

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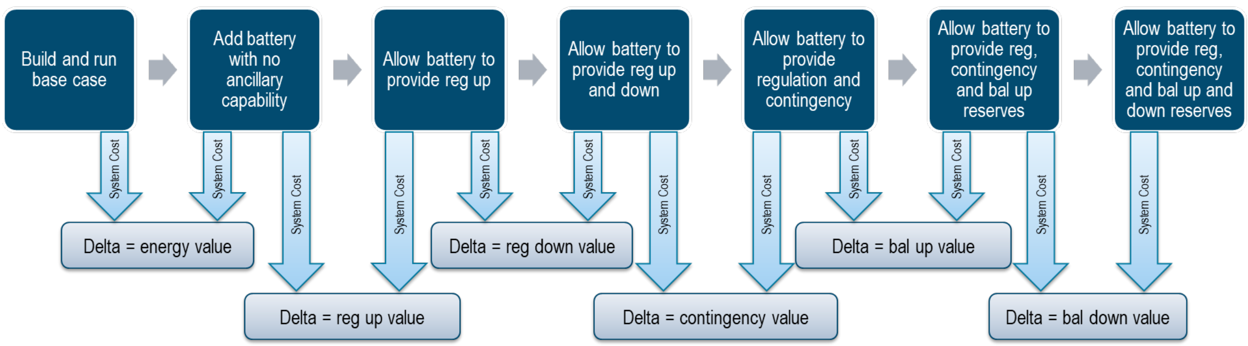
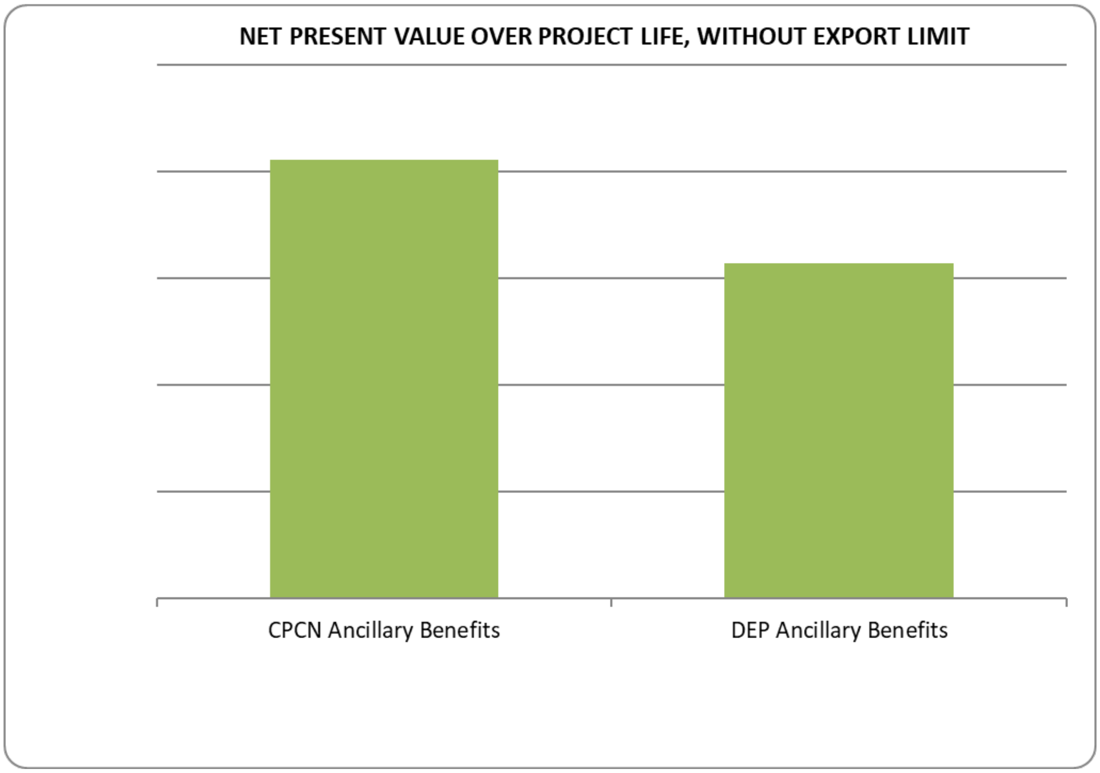
[16] See Pages 85-86 of the NCUC’s August 18, 2023, *Order Accepting Stipulations, Granting Partial Rate Increase, and Requiring Public Notice* in Docket No. E-2, Sub 1300.
[17] https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf

Encompass is used for Integrated Resource Planning (IRP), and Duke Energy recognized the need to reflect those IRP values in the evaluation of individual resources. To do so, the Integrated System & Operations Planning (ISOP) team at Duke Energy developed a proxy value process that allows for flexible, consistent application of production value across generation, transmission, and distribution planning. The ISOP team performs multiple, sequential Encompass model runs to reflect the value provided by a 200 MW storage resource of a given duration that can offer energy arbitrage; then energy and frequency regulation; then energy, frequency regulation and contingency; and finally, energy, frequency regulation, contingency, and balancing. This is performed sequentially to ensure there is no double-counting of services provided. The sequence is depicted below:



The bulk system proxy values, for capacity and energy in addition to ancillary services, are applied to individual projects by the ISOP team based on the size, duration, and other technical details of a storage project. This allows the Company to assign a value of ancillary services at various durations to smaller resources (e.g. 1 MW) proportionally from those calculated for larger (i.e. 200 MW) resources. This is necessary because the value of small resources may not register clearly in a production cost model at the full IRP scale. While DEP is not providing ancillary services with the Hot Springs battery, the Company calculated ancillary benefit values in the event no interconnection limits existed. DEP performed this analysis at the request of the Public Staff to understand how the export limit impacted the overall Hot Springs Microgrid CBA. Since the CBA performed in the CPCN proceeding and DEP's proxy values are confidential, the ISOP team prepared the graphic below to compare the MISO-derived frequency regulation benefit to the hypothetical ancillary values of the Hot Springs battery as a 4.4 MW resource in a way that can be shared publicly:



As can be seen in the graphic above, DEP's ancillary values are lower than the ancillary values that were used in the Hot Springs CBA developed during the CPCN proceeding. Since DEP is not providing ancillary services from Hot Springs at all, the CBA would be negatively impacted in that manner. However, performing energy arbitrage means the Hot Springs battery charges mostly from a renewable resource that makes it eligible for the legacy storage ITC.[18] Also, DEP's capacity needs are greater than they were at the time of the CPCN. These factors were also not considered as part of the CBA developed during the CPCN proceeding. Those additional benefits are secondary to the main purpose of microgrids like Hot Springs: improving reliability for customers in remote parts of Duke Energy's service territory. That said, two key learnings from Hot Springs will inform future projects based on this experience. First, the proxy value process helps provide DEP a reflection of the value small resources can provide for needs on DEP's own system. Second, Duke Energy has greater awareness of potential interconnection limits and can quickly evaluate the impact of potential interconnection limits, or the benefit of paying upgrade costs to address them, using the proxy value process.

Regarding services that Hot Springs is providing today, below are quantifications of non-ancillary services from the battery's first year in operation.

[18] The legacy storage ITC requires the BESS to be charged at least 75% by a renewable resource. As discussed in the Annual Report on Operations, the Hot Springs BESS was charged 82% from the Hot Springs Solar facility.

Quantification of Benefits

The CPCN Order requires the following in the Annual Report on Operations, but those topics are being discussed in the Detailed Report on Ancillary Service Benefits to best organize content in this report:

> A quantification of the total ancillary services provided to the grid by the Hot Springs Microgrid (in both capacity and energy), including what types of services were provided (spinning reserve, regulation up or down, etc.) and whether these services displaced ancillary services traditionally provided by thermal plants.[19]

While the Hot Springs BESS is not providing the ancillary services calculated through the ISOP proxy value methodology (regulation, contingency, and balancing), it is providing other valuable benefits to DEP customers.[20] Namely, the Hot Springs BESS provides quantifiable benefits in energy arbitrage, capacity, frequency response (not to be confused with frequency regulation), voltage, and – most importantly – reliability to the town of Hot Springs. Those quantifiable benefits are discussed below.

Energy Arbitrage

Once the 1 MW export limit was identified it was decided that using this battery for energy arbitrage instead of ancillary services was a more valuable way to utilize the battery. Energy arbitrage is the shifting of energy from low value hours to higher value hours. Since solar output to the grid is also impacted by the export limit shifting to energy arbitrage allows the capture of significant solar energy that would have been curtailed if not for the presence of the Hot Springs battery.

As mentioned above the Hot Springs battery received 82% of its charging energy from the local solar during the 7/31/22-7/30/23 timeframe. The remaining charging energy that was sourced from the grid (92.9 MWH) was produced at a cost of $4,282. Including the solar energy used to charge the battery results in an average charging cost of 8.14 $/MWH. The value of the energy discharged from the battery during the same period was $28,927 or 69.20 $/MWH. This valuation is based on the incremental costs that are also used for valuation of purchases and sales involving DEP.

Capacity

There are two resources within the Hot Springs Microgrid that could be capable of providing Bulk System Capacity when in Grid-Tied mode- the 4.4 MW / 4.4 MWh battery as well as the 1.961 MW Solar Plant (PV). There is also a 1.0 MVA at unity power factor (1 MW) grid-tied discharge limit for the microgrid. Duke Energy

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[19] CPCN Order at 14.

[20] The CPCN Order at 14 requires "To the extent possible, an estimate of any savings realized from the energy storage system's ancillary services". As stated previously, DEP is not providing ancillary services with the Hot Springs BESS.

worked with Astrape Consulting to develop the Effective Load Carrying Capability (ELCC) of limited duration energy storage devices. It should be noted that the Hot Springs Microgrid does not exactly match the configurations studied in ELCC study (e.g., battery storage to PV ratios, PV to storage configuration assumptions may differ, etc.), but the study is a reasonable reference for the purposes of this report.

With the Hot Springs Microgrid being in DEP, and DEP currently having less than 450 MWs of batteries installed – using the numbers from the April 2022 study, it is currently estimated that a 4-hour battery paired with solar could provide 93.7% capacity from the 4-hour storage device and 4.7% marginal capacity from the paired solar.[21]

Table 6. DEP Winter Marginal Values

Solar	Battery	Duration	Marginal Battery including any synergistic values	Marginal Solar including any synergistic values
3,000	300	2	100.0%	[redacted]
4,500	600	2	85.1%	[redacted]
6,000	900	2	70.2%	[redacted]
7,500	1,200	2	55.4%	[redacted]
3,000	450	4	93.7%	4.7%
4,500	900	4	86.8%	3.2%
6,000	1,800	4	73.1%	1.7%
7,500	3,600	4	45.8%	1.7%
9,000	4,800	4	27.5%	1.6%

Converting the 1-hour 4.4 MW / 4.4 MWh battery to an equivalent 4-hour battery yields a 1.1MW/4.4MWh resource. Applying the ELCC numbers from the April 2022 results a MW capacity of (1.1 * 93.7%) + (1.961 * 4.7%) = ~1.22 MWs of capacity. Applying the 1 MW ONAN mitigation constraint on the microgrid, for a 4-hour battery the capacity reduction at Hot Springs would be 1.22 – 1 = .22 MWs. Once there are enough batteries on the system that DEP needs to move to 6-hour battery capacity planning, the battery would be become a 0.73MW/4.4MWh resource and the ONAN mitigation reduction would be reduced to 0 MW.

Frequency Response

NERC defines frequency response as "(Equipment) The ability of a system or elements of the system to react or respond to a change in system frequency".[22] To provide Frequency Response, the Hot Springs BESS has been installed and configured with the ability to respond to system frequency (Eastern Interconnect)

[21] DEC and DEP Effective Load Carrying Capability (ELCC) Study: https://starw1.ncuc.gov/NCUC/ViewFile.aspx?Id=4ff77646-b2b8-44fd-859d-a1da38e65d30
[22] https://www.nerc.com/pa/Stand/Glossary%20of%20Terms/Glossary_of_Terms.pdf

deviations. The Hot Springs Microgrid was installed with a Power Plant Controller (PPC) with a rule-engine type algorithm. The active power portion of the algorithm simultaneously implements various control modes through a single MW setpoint – one of the control inputs being the Frequency Response component of the Hot Springs MW setpoint.

The Frequency Response component of the Hot Springs BESS controls was set up – in accordance with the NERC Reliability Guideline on Primary Frequency Control – with a 5% frequency droop response with a +/- 0.036 Hz deadband. As the Hot Springs BESS is neither a Steam Turbine nor a Combustion Turbine, Hot Springs was configured per the "All Others" maximum deadband settings.[23]

Table 3.1: Eastern Interconnection Deadband Settings	
Generator Type	**Maximum Deadband Setting**
All Generating Units	+/- 0.036 Hz

Table 3.2: Eastern Interconnection Droop Settings	
Generator Type	**Maximum Deadband Setting**
All Others	5%

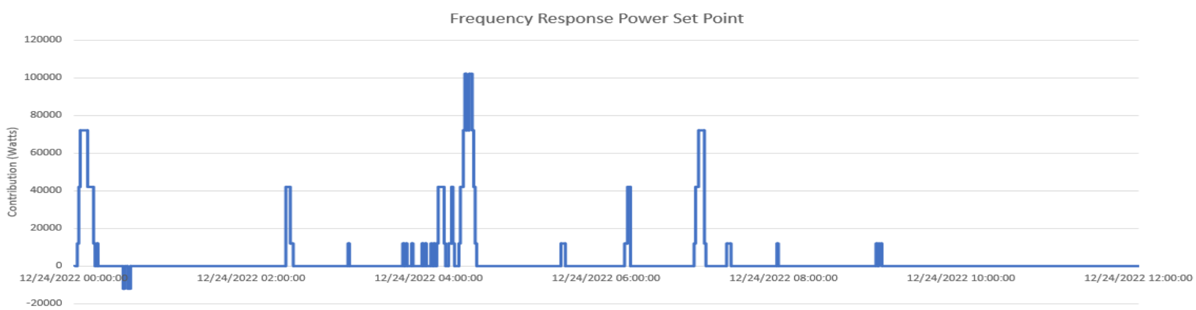
Using the maximum frequency deadband setting of +/- 0.036 Hz, the Frequency Response of generators in the Eastern Interconnection are generally, infrequently called upon to respond to frequency disturbances. One recent date with significant frequency deviation from the Eastern Interconnection scheduled frequency of 60.00 Hz was December 24th, 2022.

As discussed under NCUC Docket M-100, Sub 163, both the DEP & DEC regions served by Duke Energy experienced a severe cold snap during Winter Storm Elliot the morning of December 24th, 2022. A chart of both the Eastern Interconnection Frequency (measured within Duke Energy's service territory) and the contribution of primary Frequency Response to the Hot Springs BESS setpoint during the first 12 hours of December 24th, 2022 are included below. The Eastern Interconnection Frequency was significantly low just after midnight and again around 04:24. The Hot Springs BESS setpoint responded in both instances, as well as during several other deviations that morning. Just after 00:30 in the morning, the Eastern Interconnection Frequency went above the 0.036 Hz deadband for a short period, and the Hot Springs BESS setpoint also responded as designed during that event, consuming energy (charging) during that period, as illustrated when the Eastern Interconnection Frequency exceeded 60.02 Hz in the first chart and the Hot Springs BESS setpoint provided a negative contribution in Watts in the second chart.

[23] https://www.nerc.com/comm/OC/RS_GOP_Survey_DL/PFC_Reliability_Guideline_rev20190501_v2_final.pdf

Eastern Interconnection Frequency on 12/24/2022 from 00:00 - 12:00 (PM):

Contribution of Primary Response to the Hot Springs Battery Setpoint on 12/24/2022 (00:00-12:00):



Frequency Response provides an essential grid service by increasing the primary frequency response of the Eastern Interconnection. With Frequency Response being a requirement of bulk system generators- it is uncommon for generators to receive revenue for providing Frequency Response. PJM refers to Frequency Response ("Primary Frequency Response") as being a "non-market ancillary service".[24] Valuation of Frequency Response is impracticable as there is not an alternative configuration to compare one bulk system generator providing Frequency Response against another bulk system generator that is not providing Frequency Response. The value of providing Frequency Response comes from a more resilient and reliable bulk system electric grid from the increased primary frequency response during system disturbances.

[24] https://pjm.com/-/media/committees-groups/task-forces/rmdstf/2022/20220322/20220322-item-04-regulation-overview-education.ashx#:~:text=Primary%20frequency%20response%20(PFR)%20is,getting%20paid%20for%20providing%20PFR

Voltage

The Hot Springs site has the capability and is utilized for voltage support in certain conditions while in grid parallel mode operation. While operating in grid parallel, the Hot Springs facility is required to adhere to the 1MVA, unity power factor (1MW) discharge constraint. For charging operations, the Hot Springs facility can charge up to 1,350kVA at unity power factor. Above the 1,350kVA charging setpoint, the Hot Springs facility will operate at an off-unity power factor to maintain voltage within an allowable range at the Point of Interconnection. From 1,350kVA up to 2,100kVA, the battery will inject reactive power from unity to 0.98 leading power factor, respectively, to maintain allowable voltage limits.

For islanding operation, the Hot Springs facility is the sole source for maintaining voltage on the distribution circuit. The Hot Springs BESS inverters will operate in grid-forming, voltage source mode of operation. As the voltage deviates from the nominal setpoint, the battery storage inverters will inject or absorb reactive power to maintain the nominal voltage at the inverter terminals.

Reliability

The primary purpose of the Hot Springs Microgrid is to provide backup power to the town of Hot Springs if the distribution feeder serving the town experiences an outage. The Marshall feeder serving customers in the town of Hot Springs is routed through rough terrain that makes access to equipment for repairs difficult, resulting in long duration outages.

In the event the feeder is out of service due to an event/failure between the intentional islanding device back towards the substation, the Hot Springs facility will shut down and begin the process for starting the system in grid forming, voltage source operation. Once established, the Hot Springs facility can provide power to all customers downstream of the intentional islanding device until either the circuit is restored, or the batteries are depleted. Islanding operations were discussed in the Annual Report on Operations.

Conclusion

The Annual Operational Report covered the islanding activity, operational performance, maintenance costs, the lessons learned, and the ancillary services. This report provided the details from its first year following COD; August 1, 2022, through July 31, 2023. In that operation year the Hot Springs Microgrid attained an overall availability of 74.6%. Availability loss due to vendor responsibility was 9.3%. The availability loss due to issues outside the responsibility of the vendor was 16.1%. It experienced 3 islanding events, of which two required human intervention to be successful. The total islanding time was 13.0 hours, with a total energy export of 12.0 MWh; 8.7 MWh from the battery, 3.3 MWh from the PV. This availability is expected to increase with increased operational experience.

The energy generation from the different system components were provided. The PV system provided 82% of the battery's energy needs in the first year. The auxiliary loads received 58% of their energy from the PV system.

With the 1 MW export limit introduced after the initial system proposal, DEP had to shift from ancillary services to energy arbitrage as its secondary use case when islanding was not in play. The energy arbitrage was valued. The report also discussed Frequency Response, Capacity, Voltage, and Reliability.

The Company has learned a great deal from the first year of operation. Issues relating to development, design, site configuration, rule engine operations, support personnel quality, and parts availability all play a part optimizing the value the assets will bring to our customers. All these lessons learned will continue to optimize performance of Hot Springs Microgrid as well as future Duke Energy microgrids.

Confidential Addendum **[BEGIN CONFIDENTIAL]**

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DUKE ENERGY PROGRESS, LLC

Confidential Hourly Data
Hot Springs 15-Month Report

FILED UNDER SEAL

DOCKET NO. E-2, SUB 1185

CERTIFICATE OF SERVICE

I certify that a copy of Duke Energy Progress, LLC's Hot Springs 15-Month Report, in Docket No. E-2, Sub 1185, has been served by electronic mail, hand delivery or by depositing a copy in the United States mail, postage prepaid, to parties of record.

This the 31st day of October, 2023.

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