NCEMC MICROGRID IMPLEMENTATION REPORT

BUTLER FARMS MICROGRID PROJECT

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PREFACE

PURPOSE

The purpose of this report is to provide detailed documentation of the Butler Farms microgrid project implementation. In addition, it is to provide an electric cooperative with guidance that will help them design and implement its own microgrid project.

SCOPE

The scope of this report is to document NCEMC's experience implementing the Butler Farms microgrid. This report is not meant to be a set of instructions for microgrid implementation. Thus, the report envelops how the microgrid at Butler Farms was designed and implemented, as well as the results from testing the different use cases of this project. For the benefit of the industry, future work, possible improvements, and opportunities for development are also discussed.

AUDIENCE

This report is written for key staff, ranging from engineers to board members, at any cooperative in the United States.

EXECUTIVE SUMMARY

This report details how NCEMC implemented a microgrid project at Butler Farms. It intends to provide reference material for electric cooperatives interested in developing a microgrid on their systems, so as to expedite the development of future projects.

Microgrids are systems that integrate emerging technologies to help modernize the electrical grid. A microgrid is a small electric system that combines local energy resources and control technologies to provide power to a defined area. Microgrids typically remain connected to the main grid but can operate independently.

Microgrids can offer benefits to an electric system. By making use of local energy to supply local loads, microgrids can improve resiliency of the system. Microgrids can also optimize deployment of renewable resources. Despite the benefits, there are still obstacles in implementing microgrids, including cost, complex controller design and optimization, complicated engineering design and a lack of established standards and regulations.

Butler Farms is located in Lillington, North Carolina, and is a “finishing operation” pig farm where they raise the pigs to reach market weight. The farm has driven its own sustainability research for the last 10 years by implementing covered lagoons, 20.28kW of solar generation, and 185kW of methane powered electric generation. To further advance their sustainability initiatives, Butler Farms partnered with South River EMC and NCEMC to implement a microgrid project that would not only benefit the farm, but the surrounding residences as well. NCEMC installed two Power Secure Energy Storage Systems utilizing Samsung Lithium-ion batteries each rated at 125kW / 372.5kWh, the microgrid controller, and reclosers to isolate the portion of the feeder to be powered by the microgrid. The project is divided into three phases, where “Phase One” serves to supply the farm in case of outages, “Phase Two” incorporates the surrounding residences on the feeder to be powered by the batteries of the microgrid during outages or maintenance, and “Phase 3” integrates the swine waste methane generator as a resource of the microgrid. When the project is complete and power from the main grid is interrupted, components of the microgrid can work together to help supply the farm and feeder load. Components of the microgrid can be controlled remotely from the NCEMC Integrated Operations Center or South River dispatch center, where several aspects of the system are monitored in real time.

This report and all of its sections are specific to the Butler Farms microgrid and have been written upon the completion of “Phase One”.

NOMENCLATURE

COG – Consumer Owned Generation

EPC – Engineering, Procurement, and Construction

ESS – Energy Storage System

NC DOL – North Carolina Department of Labor

NCEMC – North Carolina Electric Membership Corporation

OSHA - Occupational Safety and Health Plans

PPA – Power Purchase Agreement

SCADA - Supervisory control and data acquisition

South River EMC – South River Electric Membership Cooperative

US DOE – United States Department of Energy

VRTU – Virtual Remote Terminal Unit

INTRODUCTION TO INVOLVED COMPANIES

NCEMC

North Carolina's electric cooperatives provide reliable, safe and affordable energy and related services to approximately one million households and businesses in 93 of North Carolina's 100 counties. Each of its 26 cooperatives is member-owned, not-for-profit and overseen by a board of directors elected by the membership.

North Carolina Electric Membership Corporation (NCEMC) is one of the largest generation and transmission cooperatives in the nation and is responsible for electricity purchase contracts and transmission.[1]

SOUTH RIVER EMC

South River Electric Membership Cooperative (South River EMC) is an electric distribution cooperative whose headquarters is in Dunn, North Carolina. It also has a District Operations Center in Fayetteville for the convenience of their membership. South River EMC serves over 43,000 members in Harnett, Cumberland, Sampson, Johnston and Bladen counties, has 104 employees, and is owned and operated by the consumer/members who use its services.

South River EMC is a non-profit organization chartered in 1940. The cooperative's electric plant is valued in excess of $215 million. The cooperative has just over 4,569 miles of energized distribution and transmission lines and 38 substations.[2] On part of this distribution system lies Butler Farms and its microgrid.

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[1] http://www.ncelectriccooperatives.com/about/who.htm

[2] http://www.sremc.com/content/about-us-0

INTRODUCTION TO MICROGRIDS

WHAT IS A MICROGRID?

The United State Department of Energy (US DOE) defines a microgrid as:

''A group of **interconnected loads and distributed energy resources** within clearly defined electrical boundaries that **acts as a single controllable entity** with respect to the grid. A microgrid can **connect** **and** **disconnect from the grid** to enable it to operate in both grid-connected or island mode.''

NCEMC defines it as such:

"A microgrid is a small electric system that **combines local energy resources and control technologies** to provide power to a **defined area**. Microgrids typically remain connected to the main grid but **can operate independently**."

As long as the requirements are met, there can be different levels of microgrids, as well as layers of microgrids within a system. This is shown by *Figure 1* below:

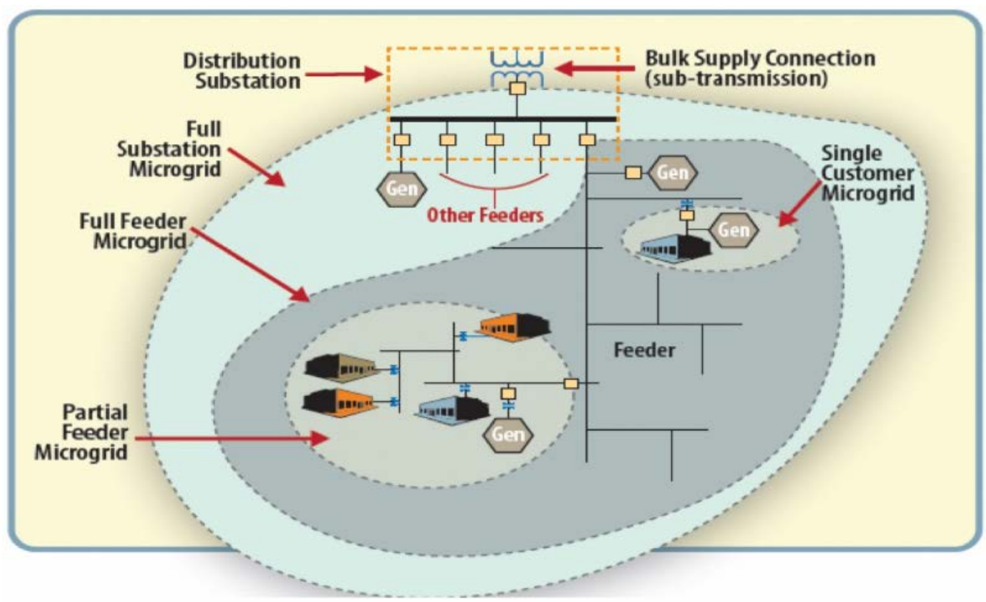

Figure 1 - Generic Microgrid Layout
US DOE | The Role of Microgrids

The Butler Farms microgrid described in this report is a **single customer** microgrid as it is primarily to service the farm and is on the farm's property.

BENEFITS OF MICROGRIDS

There are many reasons why a cooperative would want to implement a microgrid on their system.

1) Microgrids make use of ***local energy*** to supply ***local loads***. Therefore, there is less reliance upon long distribution lines that are susceptible to hazards and that accrue losses.
2) As microgrids can involve storage and active loads, they enable ***reducing the peak demand*** of the system. Also, peak demand can be supplied by the distributed generation of the microgrid instead of the grid itself, potentially resulting in lower energy costs.
3) A microgrid is another way of managing system upgrades. Placing microgrid components downstream in the system can ***prolong distribution asset life*** by avoiding component upgrades.
4) Microgrids assist with the ***optimized deployment of different renewable resources***. By enabling more renewable resources, microgrids may help ***reduce carbon emissions***.
5) Operating on a small scale, microgrids are more ***scalable*** than the existing grid.
6) ***Resiliency*** is the capacity to recover quickly from difficulties. As distribution, or even transmission, lines go down during severe weather conditions, microgrids, as small-scales systems, allow for power to come back up quickly for its service area.

MICROGRID CHALLENGES & DEVELOPMENT

There are, however, challenges in designing and implementing microgrids.

1) A ***lack of standards and regulations*** makes it difficult to implement the rapidly-developing microgrid technology across the country.
2) As ***each microgrid is unique***, there is not yet plug-and-play equipment and no efficient way of designing a system. This makes the development of standards and regulations difficult.
3) Microgrids can change the way the electric grid is designed due to the reverse flow of power from the DERs.
4) The controller at the center of each microgrid has to be designed for each microgrid's specific mode of operation. Thus, controllers are time-consuming to install, integrate, and optimize with a microgrid.

THE BUTLER FARM PROJECT

The Butler Farm microgrid is a joint project between Butler Farms, a Pork and Bio-Energy producer, and the electric providers – South River EMC and NCEMC.

The Butler Farms microgrid will consist of the customer owned solar photovoltaic panel, a diesel electric generator, a methane powered electric generator, and a NCEMC-owned battery energy storage system (ESS) located on the Butler Farms property. The generation elements will be electrically connected to South River EMC's electric distribution grid. The NCEMC microgrid controller is capable of both human operation and automatic operation in both grid-connected and islanded operating modes.

PROJECT GOAL

The ultimate goal of the Butler Farms microgrid is to provide enhanced electric service reliability for the customer and surrounding electrical power distribution infrastructure (distribution feeder) as well as to reduce the customer's and electric provider's peak electricity costs.

The project will also act as an educational pilot project to support greater understanding of microgrid techniques and technologies to provide an alternative to the deployment of standby or emergency diesel generators, and further NCEMC's development of microgrid controllers.

ORIGIN

In late 2016, NCEMC was looking for a home for its second microgrid. The goal of the project was to develop a microgrid that expanded on the knowledge gained from the Ocracoke project and to increase the complexity by merging utility-owned generation with customer-owner generation. NCEMC's desire was to find a project that would highlight the coordination between two of North Carolina's most important industries: agri-business and energy.

South River EMC approached NCEMC with the idea of placing the microgrid at Butler Farms as it would be a natural fit with the farm's existing generation resources. Additionally, the owner, Tom Butler, was focused on environmental stewardship and energy conservation. After the first site visit, the parties knew this would be a natural fit and the concept of the Butler Farms Microgrid was born.

DESIGN

Prior to the implementation of the microgrid, Butler Farms had its own set of renewable energy generation. The "Design" section of this report is therefore split into before and after sections to get an understanding of why the microgrid is beneficial to the farm.

BEFORE

Existing generation on the site (owned by Butler Farms):

- 185kW Methane Powered Electric Generator
- 20.28kW Solar
- 100kW Diesel Generator – Participates in NCEMC Consumer Owned Generation (COG) Program

The majority of generation at Butler Farms is based on the thousands of gallons of waste produced by the farm's swine population to produce electricity. With the use of a digester and covered lagoons, Butler Farms is able to capture the methane produced from the waste and use it to generate electricity. When running, all power produced is sent to the South River EMC distribution system under a Power Purchase Agreement (PPA). Similarly, the grid-tied solar array implemented shortly after the biogas generator are under a separate PPA.

In case of outages, the farm uses the diesel generator as backup to keep essential loads operating. For a hog farm, their primary concern is air flow through the houses. During the summer time the temperature inside the houses can rise rapidly without proper air circulation.

Figure 2 - Butler Farms Layout

AFTER

Added microgrid components:

- 2 – Power Secure Energy Storage System (ESS) with Samsung Lithium-ion batteries rated at 125kW / 372.5 kWh each
- Microgrid Controller
- Reclosers on distribution feeder

A diagram of components is provided below in *Figure 3.*

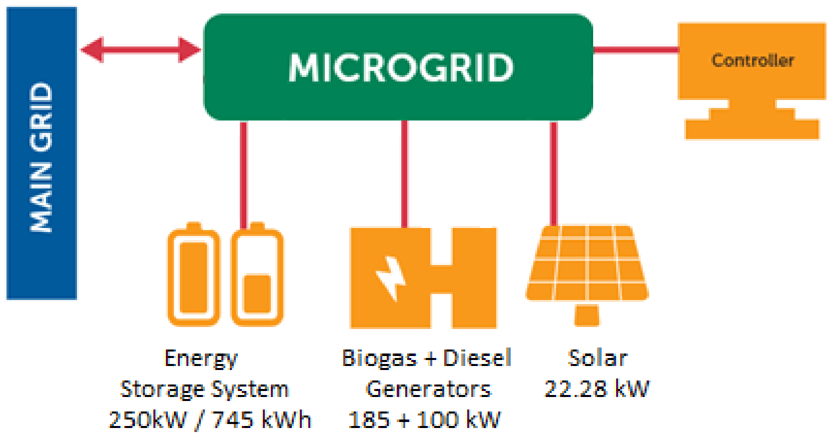

Figure 3 - Design Diagram

The controller was programmed by PowerSecure as part of their turnkey EPC contract to integrate the new resources with the existing utility system and distributed energy resources according to the specified operation, as discussed in the next section. The controller communicates to each component and manages the systems based on the desired output. The system is being manually optimized by the Integrated Operations Center at NCEMC and by ACES (24/7 operations) based on the resources available. South River is able to control the reclosers on the distribution feeder and microgrid mode transition.

This system should prevent Butler Farms from having to use their diesel generator during outages. By using the power provided by the microgrid instead, Mr. Butler should be able to save fuel therefore fuel cost over time.

MODES OF OPERATION AND CONTROL

The Butler Farms project is divided into three phases of construction:

- "Phase One" aims for the microgrid to operate in Grid Tie mode (grid connected) and transition to and from Farm Island mode (supporting only Butler Farms) using only the battery.
- "Phase Two" adds the ability to transition to and from Feeder Island mode, where the microgrid would be supporting the farm and feeder section using only the battery.

- “Phase Three” goes further by enabling the dispatching of the Butler Farm generation resources in both Farm and Feeder Island modes.

PROJECT REQUIREMENTS

Phase One:

- The microgrid shall reduce NCEMC’s peak electricity costs through operation of the ESS in a grid connected mode.
- The microgrid shall have appropriate local disconnects and overrides to support system maintenance.
- The microgrid shall provide enhanced electric service reliability by autonomously transitioning to Farm Island mode during planned or forced grid outages to support Butler Farms.
- The microgrid shall be capable of supporting Butler Farms core electricity needs in Farm Island mode utilizing only the ESS battery for a minimum of four hours.
- The ESS shall provide black start support for the microgrid in the event of an unsuccessful seamless transition.
- The microgrid shall be capable of autonomously reconnecting the microgrid to the South River EMC distribution electric grid.

Phase Two:

- The microgrid shall be capable of supporting both Butler Farms’ and the sectionalized portion of the South River EMC distribution feeder’s core electricity needs for a minimum of four hours in Feeder Island mode utilizing only the ESS battery.
- The microgrid shall be capable of autonomously detecting the sectionalized portion of the South River EMC distribution feeder load and shall be capable of transitioning from Farm Island to Feeder Island mode.

Phase Three:

- The microgrid shall be capable of dispatching the Butler Farm biogas and diesel generators to support the microgrid and to serve more neighboring load.

To summarize, the ESS component of the Butler Farms microgrid will feed into the South River EMC distribution system during the monthly load peak and will remain idle the rest of the time unless called upon during an outage. During an outage, the microgrid will initially provide power to the farm for at least 4 hours. It is currently in development to eventually provide this same functionality to nearby residences on the distribution system.

NCEMC Energy Operations staff is responsible for the daily dispatch of the Butler Farms microgrid during Grid Tie and Farm Island mode.

LOCAL COOPERATIVE INVOLVEMENT

South River EMC owns the solar and biogas meters, as well as the three reclosers (the microgrid recloser and the two line reclosers). They also installed the fiber communication for the microgrid. Upon completion of “Phase Two”, South River EMC will have the ability coordinate with NCEMC to remotely transition the microgrid to Feeder Island mode through their virtual remote terminal unit (VRTU) to control the reclosers.

BUTLER FARMS INVOLVEMENT

Butler Farms owns the solar and methane powered electric generator and are in charge of maintenance. They do not have any operational control of the system, as written in the operating agreement.

COMMUNICATION

Data is transferred over three different media at Butler Farms: telecom data circuit, Ethernet and fiber.

The telecom data circuit provides a secure way for NCEMC and Butler Farms to communicate securely over a distance of 50 miles.

The microgrid and its components on the island are connected by wire. As seen in *Figure 4,* most components are connected with fiber. Fiber offers better performance over long distances, as well as electrical separation that protects components from damage caused by surges following lightning strikes. The Point of Common Coupling meter, and the battery meter (a meter for both ESS enclosures) are connected via Ethernet because they are located in the same enclosure as the microgrid controller.

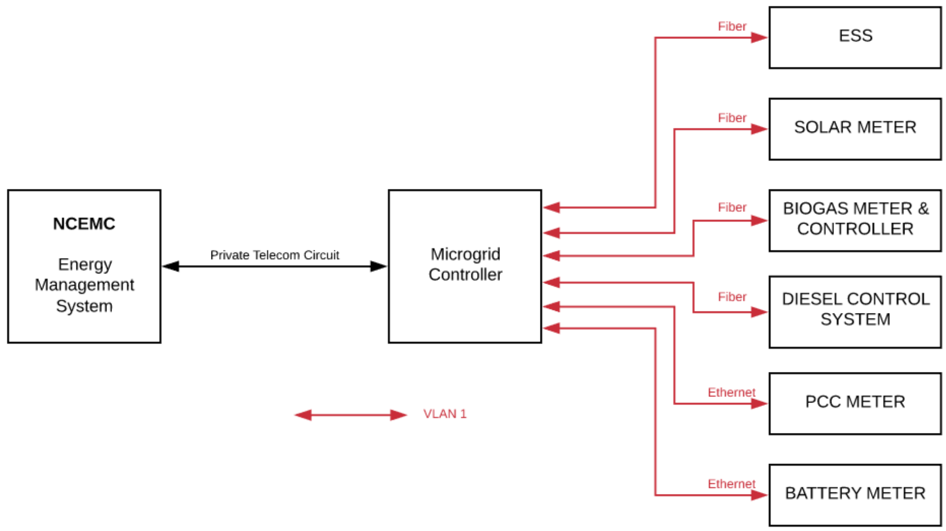

Figure 4 - Communications Diagram

PROCESS

1. INITIATION

A microgrid implementation should start with two major components: a business case, and a feasibility study. The business case identifies high-level project details to show the value of the project both financially and for the benefit of members (financially and in terms of reliability). A feasibility study is indispensable as the microgrid needs to be able to be fully integrate with the existing system without causing any issues. Once the Butler Farms project was approved, a project manager was identified, a project charter was developed and executed, and a project team was appointed. Another key aspect of the initiation process is to identify the measure of success. This sets realistic goals to keep in mind during construction that the implementation needs to meet when finished. The final phase of initiation is the meet with the distribution cooperative and site owner (in this case Tom Butler) to discuss high-level scope, aesthetic requirements, and the interconnection process.

2. PLANNING

As the microgrid was to be built on the Butler Farms property, a ground lease agreement with the site owner (Mr. Butler) was required. Additionally, county zoning and permitting requirements were identified. For thorough planning of a project to meet the requirements of everyone involved, the stakeholders were identified and a communication plan was developed to make sure no one was being left out of the process. To be certain of project expectations and goals, project scenario analysis requirements were developed, along with technical and business project requirement, and a scope document. The final step was to develop a work order with the selected EPC company, where NCEMC provided a copy of the project scope, deliverables, and communication requirements, while the EPC provided the environmental plan, permits, safety, and project schedule.

3. EXECUTION

Execution began by establishing a safety and physical security plan. NCEMC has an obligation to discuss hazards as they relate to their system, such as: tie-ins, cutovers, etc. Other than that the EPC is on their own and obligated to NC DOL/ OSHA. Additionally, the Safety Data Sheets for the batteries and other NCEMC owned equipment had to be provided to the Environmental group to perform a Tier II environmental calculation. For microgrid operation, coordination with NCEMC IT was needed to develop network security, communication model, and IP scheme, as well as coordination with NCEMC Energy Operations and the EMS APP group on data point needs, mapping, and storages.

Operating agreements were developed and executed with the site owner and the distribution cooperative. An operating agreement with the site owner is necessary if there is customer-owned generation to be controlled by the microgrid. The operating agreement with Butler Farms describes how the microgrid will operate and what the farm should expect during outages. For future phases, it describes how the microgrid will interact with the methane powered electric generator and emergency diesel generator. An operating agreement with the distribution cooperative is needed if there is equipment owned by the distribution cooperative to be controlled by the microgrid. The Operating Agreement with South River describes the business rules on who will operate the equipment owned by South River but used by the microgrid. Finally, an interconnection agreement was developed with South River EMC which describes the business rules for the physical connection of the microgrid components to the South River distribution system.

4. CONSTRUCTION

Although construction is done by the selected contractor, it is important to monitor the project by performing site visits to document project; reviewing and distributing contractor status reports; and reviewing the commissioning procedure. These items reduce the risk of unexpected events that may delay the project. To avoid miscommunication in terms of project goals, all parties should sign-off on project scenario analysis requirements for the commissioning of the project. The final step of the construction phase was to develop an

Operating Strategy guide with Portfolio Management to make sure the microgrid is up and running upon completion of the project.

5. CLOSURE

Before turning the project over to the Microgrid Manager, Energy Operations, and IT, it is important to establish field training for technicians and distribution cooperative staff during closure of the project because unplanned events could occur as soon as the first day of operation. This will provide proper maintenance practices to avoid unnecessary damage to components or to the system.

CONCLUSION & RECOMMENDATIONS

NCEMC is constantly working to improve the microgrid process. This report provides information on the process of designing and implementing a microgrid. The Butler Farms project is a continuation of the microgrid initiative taken by NCEMC that began with the Ocracoke Island pilot project. The Butler Farms microgrid is an additional asset to the membership both in gaining operational experience and as a benefit to the surrounding community. It is also a model for consumer sustainability initiative in North Carolina.

This report was written upon the completion of “Phase One” and prior to a cybersecurity analysis and use case study. Once completed, these will be written in detail in separate documentation.

CREDITS

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