# 83 - City of Jamestown

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OBG

REPORT

# NY Prize Community Grid Competition – Stage 1 Feasibility Assessment



**New York State Energy and Research Development Authority**
**Albany, NY**

December 2015

## EXECUTIVE SUMMARY

The Jamestown Board of Public Utilities (JBPU) has been providing safe, reliable electric services for nearly 100 years. Throughout this period the JBPU has continuously evolved to stay current with technologies used to generate, transmit, and deliver electricity to a community of over 40,000 people. As New York State continues to explore and advance new policies and regulation through initiatives like NY Prize and Reforming the Energy Vision (REV), NYSERDA and the Public Service Commission are seeking premiere and highly scalable models to demonstrate the latest in energy resource capabilities and management, in particular, the NY Prize initiative to develop microgrids.

The city of Jamestown has several characteristics which make it unique when compared to other locations.

***Energy Resource Assets -*** JBPU already possesses a natural gas-fired electric generator unit which can be utilized as the source of energy for a microgrid that could serve approximately 40 MW of customer load.

***Supply Resiliency -*** The unit's natural gas fuel supply is provided from a natural gas engine driven compressor station located in a rural area approximately twenty eight miles west of Jamestown. This facility's operation inherently creates a robust and resilient source of fuel for the 40 MW generator.

***Hardened Infrastructure*** - There are several underground resilient distribution feeders already in service within Jamestown's distribution system which provide electricity to numerous customers who provide vital services to the community that would be greatly needed in a regional electrical disruption.

***Thermal Infrastructure & Capabilities –*** Existing natural gas-fired hot water thermal energy generators enable JBPU to provide District Heating service to the foundation of customer buildings in the envisioned microgrid area.

***Centralized Services –*** The infrastructure needed for the distribution of both thermal and electrical systems originates and is controlled from the Carlson Station. Therefore, the capital cost of a microgrid distribution and communication system build out will not be significant as the majority of the infrastructure is already in place.

***Utility Led*** – JBPU, as the project host entity and provider of other public works services for the community including water and wastewater facilities, is well positioned to manage, coordinate, and execute constraints. The JBPU's involvement will thus significantly reduce microgrid implementation challenges because many areas of information and decision authority will be performed by a single organization that is already highly respected and integral to the community.

When all these assets are taken together, most components of a "Jamestown Microgrid" currently exist thus eliminating the need for major investment and construction to demonstrate a community project that is aligned to the overall goals of the NY Prize competition. A benefit-cost analysis performed for this conceptual system shows the benefit/cost ratio of 18.

These characteristics make the Jamestown microgrid one of the best candidates for microgrid implementation within a short period of time and with minimal impact or risk. The Jamestown area serves as a central hub for the western NY region beyond Buffalo, providing societal services such as police protection, fire department protection, emergency room medical treatment, health care, food distribution, community shelters, and etc. Considering the discussed unique characteristics of Jamestown, the proposed microgrid represents a viable, practical, economical, and scalable solution to improve the resiliency of the regional energy infrastructure.

Despite the advantages of the Jamestown microgrid, there are several challenges which must be overcome in order for it to be implemented.

***Regulatory Change -*** In the absence of supportive market structures for microgrids, cost recovery is a major challenge. Current rate structures do not favor a microgrid installation from both an investment and operational cost recovery perspective. Without an adequate cost recovery mechanism, the JBPU is unlikely to proceed with the envisioned project, and the wide array of benefits this solution offers shall be unrealized.

***Valuing Reliability –*** JBPU prides itself on providing reliable services to its customers and those customers generally perceive the services they receive as having very good reliability. Considering the high reliability of JBPU's existing infrastructure, convincing the New York State Public Service Commission to allow the JBPU to include a project of this nature in its rate base could be a major challenge. Moreover, electric customers will have to be convinced that the rate impacts related to improving reliability by a very small amount holds merit. In many cases, implementation of reliability improvement measures only occurs after major events or disruptions. Therefore, implementation of the envisioned microgrid is only likely if there is financial and regulatory support from NYSERDA, the New York Public Service Commission, and the New York Power Authority.

In conclusion, OBG has determined that developing a microgrid applicable to the goals of the NY Prize program within the JBPU service area is highly feasible and a project could readily be executed that would help NYSERDA to achieve that goal. There are more than 40 municipal utilities in NY State which have varying degrees of similar characteristics to the JBPU system studied. The unique communication and control system architecture that OBG describes as being needed to control a Jamestown microgrid, represents a technological advancement that could be widely applied to those municipal systems. This would position the state as the most robust and resilient in the entire country. Other local utility companies could then mimic the approach to implement a common understanding of a microgrid in their territories, resulting in a more active and dynamic energy system, compatible with the wider REV initiative.

# TABLE OF CONTENTS

# Task 1

## INTRODUCTION

On June 24, 2015 the City of Jamestown through its Board of Public Utilities ("JBPU") and the New York State Energy Research and Development Authority ("NYSERDA") entered into Agreement #65527 for a NY Prize RFP 3044 Stage 1 Feasibility Assessment. As the electricity utility serving the greater Jamestown, NY area, the JBPU was awarded funding from NYSERDA to perform a study of the JBPU municipal electrical system. The objective of the study is to determine the feasibility of reconfiguring the physical infrastructure associated with the existing electrical system into a "microgrid" that could improve utility service reliability and resiliency in situations where a major event such as a widespread wind or ice storm disrupts the regional supply of electricity.

JBPU has retained OBG Engineers to conduct this feasibility study following the suggested guidelines from NYSERDA RFP 3044, as well as additional capabilities as deemed appropriate from the team.

## TASK 1 – DESCRIPTION OF MICROGRID CAPABILITIES

### 1.1. BACKGROUND

The City of Jamestown began providing electric service in 1891 and in 1923 established an independent arm of the city, the Jamestown Board of Public Utilities (JBPU). JBPU is one of the oldest municipal power systems in the country and is one of the largest municipally owned and operated utilities in New York State. The utility consists of five divisions: Electric, Water (potable), Wastewater (sewage), Solid Waste (refuse disposal), and District Heat (underground hot water for space heating).

The JBPU's Electric Division serves a geographic area that includes the City of Jamestown, the Villages of Celoron and Falconer, and portions of the Town of Ellicott. The 23 square mile service area has approximately 48,000 inhabitants and 19,800 customer locations.

The JBPU is a preference power customer of the New York Power Authority (NYPA). Hydropower generated at the Niagara Power Plant is transmitted to National Grid's (NGrid) Falconer Substation, from which two 115kV overhead lines connect directly to the JBPU's adjacent Dow Street Substation. The JBPU system is the largest single point load on NGrid's 115kV loop that serves most of Chautauqua and Cattaraugus Counties.

Approximately 55% of the JBPU customer load is served directly from the Dow Street Substation (Falconer, NY), while the remaining 45% of the JBPU customer load is served through a 15 kV substation located at the other primary electrical facility in the JBPU system, the Samuel A. Carlson Generating Station (Carlson Station). Carlson Station has long served the community with locally produced energy. Once a coal fired facility with a capacity of approximately 48 Mw, Carlson Station was modified in 1984 to enable it to simultaneously generate hot water. In recent years the station has been converted to use natural gas as its exclusive fuel. At the heart of the facility is a General Electric LM6000 gas turbine generator which was commissioned in 2001 and is designated as "Unit #7" or "G7". Unit #7 is configured to allow it to operate with a simple cycle capacity of 43 Mw. Through the use of a heat recovery steam generator (HRSG) and the older steam turbines located at the site, Unit #7 can be operated in combined cycle configuration. The HRSG steam can also be supplemented with the output from two of the facility's converted gas fired steam boilers. With all units in operation, Carlson Station has an electrical capacity of approximately 78 MW and a thermal capacity of 80 million btu/hr. It is a critical combined heat and power (CHP) resource for 73 buildings in the immediate downtown area.

The JBPU's service area is located in Western New York. Not only do extreme weather events including heavy lake effect snow regularly occur, the NGrid 115kV electrical transmission system has a history of causing outages that have significantly impacted all JBPU customers including:

- August 14, 2003 - The NGrid 115 kV system was out for a time during a blackout in the Northeast. The JBPU used Carlson Station to self-generate most of the system load for the next approximately 2.5 days while other statewide restoration efforts were completed.
- October 29, 2007 – The JBPU system was tripped by low 115 kV system voltage experienced when NGrid had a switching problem during maintenance at the Dunkirk power generating facility.

- June 2, 2010 - The JBPU system was tripped by low 115 kV system voltage experienced when NGrid had a relay testing problem during maintenance at the Dunkirk facility.

The JBPU has long recognized the importance of utility service reliability within its service area. A microgrid concept, defined as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that act as single controllable entity with respect to the grid" is a promising approach to improve system reliability. Because of the unique presence of Carlson Station and its direct interconnection to the JBPU's service area, the creation of a community microgrid is highly feasible and almost exists within the JBPU system. The primary items preventing microgrid operation are appropriate control systems and relay schemes specifically designed to enable the safe and reliable disconnection and reconnection of selected areas of the JBPU distribution system to take place in an emergency event. In addition, a small black start generator is needed to support the operation of Unit #7 in certain circumstances.

The Jamestown Microgrid concept involves utilizing the power generation equipment located in the JBPU's service area to power a resilient network of underground electrical distribution circuitry ensuring a high level of utility service reliability in the core area of downtown Jamestown, independent of the NGrid 115 kV system.

The OBG study will provide a comprehensive overview to identify the specific technology and costs to construct and commission a proposed Jamestown Microgrid. This microgrid will enable the JBPU to provide a large number of its customers with a wide array of benefits stemming from a robust and resilient electric power system able to withstand extreme weather events and a regional power disruption. From the establishment of a secure microgrid, numerous functions essential to the support of the community as well as the State of New York will be achieved including the following:

- The core area of downtown Jamestown will either remain in electrical and thermal service or experience only a brief outage in a disruptive event. This will enable the majority of community's first responders and critical medical services to operate more efficiently including the Jamestown Police Department, the Jamestown Fire Department, the Jamestown Department of Public Works Department including Streets and Parks and highway maintenance, the JBPU Electric Division line department (critical for additional power restoration), Alstar EMS Ambulance Service, WCA Hospital, Urgent Care Medical Facility, public vehicle petroleum refueling station and several large community host shelters.
- The wider area that the Jamestown Microgrid will support, includes additional EMS service providers, the Smith Avenue Water Pump Station, the South and Center Chautauqua Lake waste water treatment plant, numerous waste water pump stations, numerous commercial locations such as Wegman's, Sam's Club, Home Depot, public fueling stations, etc.
- The wider service area also includes up to approximately 45% of the overall load served by the JBPU representing over ten thousand residential and small commercial customers.
- A quick turnaround community project demonstrating real world microgrid technology for the state to showcase as a successful project implementation under the NY Prize program.

## 1.2. THE JAMESTOWN MICROGRID CONCEPT

A Microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that act as single controllable entity with respect to the grid. The goal of microgrid implementation in Jamestown is to support designated loads inside the Jamestown service area.

During any outage event when the JBPU's electric system is disconnected from NGrid's 115 kV system, the LM6000 gas turbine generator will be the primary source of the Jamestown Microgrid. . The Jamestown Microgrid will utilize existing generator G7 at Carlson Station, along with the Station's on-site electrical distribution substation, to power a resilient network of existing underground and overhead electrical feeders serving downtown Jamestown and the surrounding community to ensure a high level of utility service reliability independent of the NGrid 115kV system. The electricity produced by G7 will also allow Carlson Station to operate the equipment located there needed to supply the thermal demand of the microgrid. In what follows, a detailed description of the Jamestown existing electrical system and proposed microgrid is provided.

## 1.3. ELECTRICAL AND THERMAL INFRASTRUCTURE CHARACTERIZATIONS

The existing JBPU electric distribution system consists of three main substations. At the interconnection point to National Grid in Falconer, NY, JBPU's Dow Street Substation receives power at 115 kV via two National Grid 115 kV feeders from the adjacent National Grid Falconer Substation. At Dow Street, power is stepped down to 13.8 kV for distribution to a portion of the JBPU customer base and also to 34.5 kV for sub transmission to the Chadakoin Substation and Carlson Station. Chadakoin is a new substation with minimal load on it at this time. Carlson Station, which is the hub of the Jamestown Microgrid, is comprised of 13.8 kV generation facilities and a major distribution substation feeding customers through distribution transformer T9. FIGURE 1.1 shows the single line diagram of the overall JBPU electrical system.

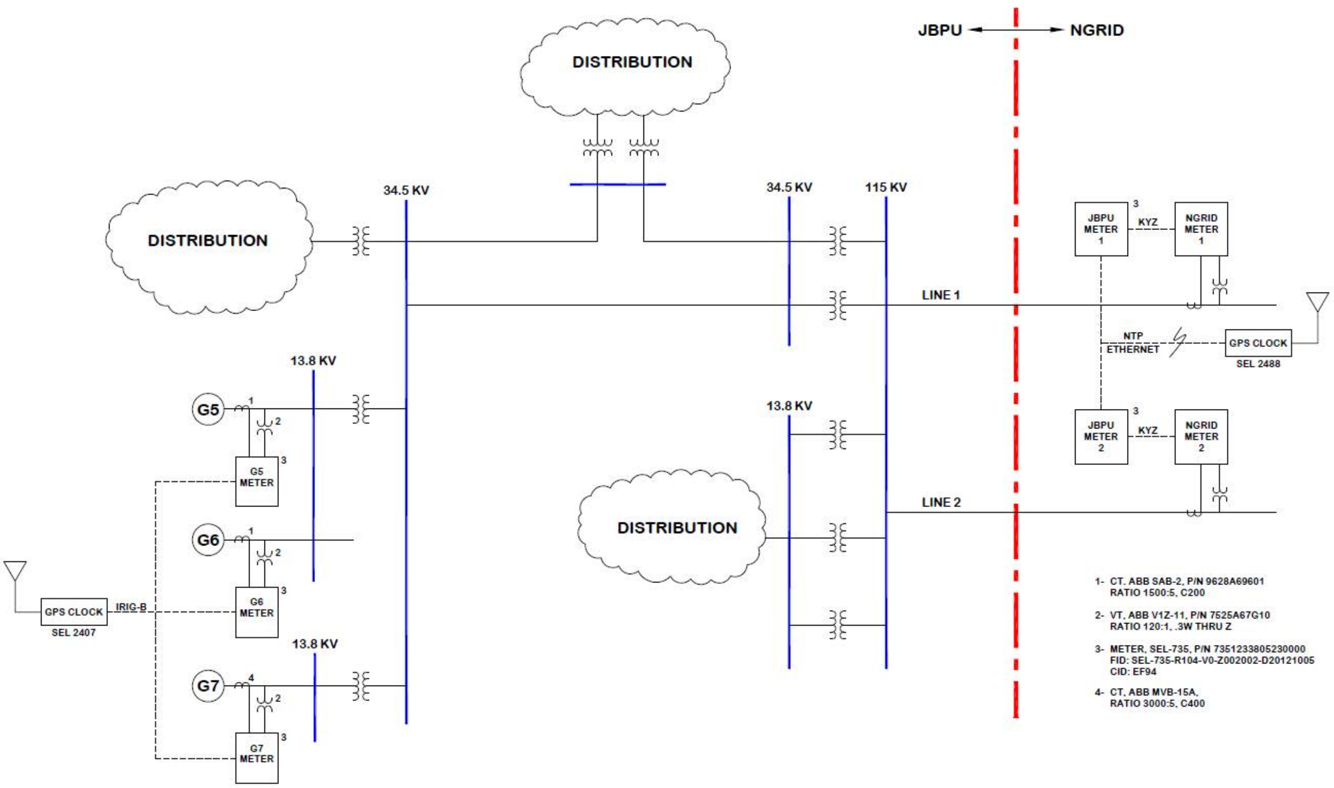



**Figure 1.1: Existing JBPU Electrical System**

The distribution substation located within Carlson Station will be the main hub of the microgrid. It delivers power to many public services and critical facilities located in the central and western portions of the JBPU service area, including but not limited to:

- Two hospitals
- Public services including city hall, police, fire, and Department of Public Works (DPW)
- Shelters/areas of refuge
- Schools
- Water and wastewater treatment plant
- Banks
- Gas stations
- Hotels
- Housing (elderly, low-income senior, and residential)
- Retail (Wegmans, Tops markets, Home Depot, etc.)
- Public communications (telephone, TV, and radio).

This critical distribution system supplies electricity to customers through eleven (11) separate feeders including S703, S704, S705, S709, S710, S711, S712, S715, S902, S903, and S904. An important distinction to the proposed microgrid is that feeders S704, S710, S712, and S904 are resilient underground circuits which supply Jamestown's core downtown area as depicted by FIGURE 1.2 (a list of customers located in that area is provided in FIGURE 1.3). The remaining seven (7) feeders, also part of the microgrid, are less resilient circuits. The area served by these overhead circuits is depicted in FIGURE 1.4.

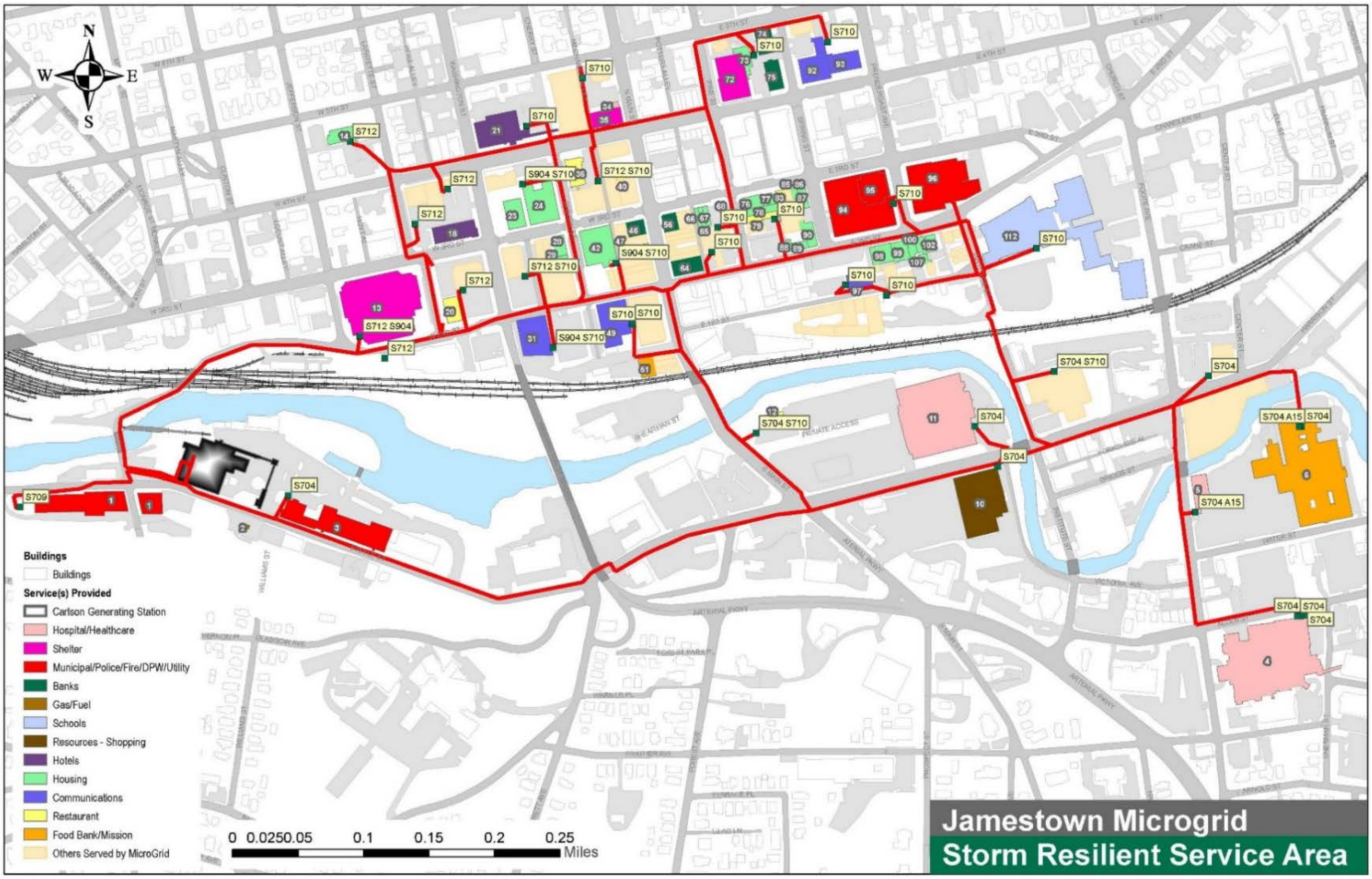



Figure 1.2. Enlargement of the Downtown Jamestown underground electric service area

| JAMESTOWN MICROGRID - STORM RESILIENT SERVICE AREA CUSTOMERS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Map Reference | Service Code | Description | District Heating Customer | Occupancy | Food Service | Backup Generation (kW) | Circuit | BG Fuel Source |
| 1 | 3 | DPW GARAGES | YES | | | | S709 | |
| 2 | 6 | JBPU FUELING STATION | | | | | S709 | |
| 3 | 3 | JBPU UTILITY OPERATION CENTER | YES | | | YES - 180 | S704 | DIESEL |
| 4 | 1 | WCA HOSPITAL | YES | | YES | YES - N/A | S704 | N/A |
| 5 | 1 | CANCER CARE OF WNY | YES | | | YES - N/A | S704 | N/A |
| 6 | 13 | ST SUSAN'S KITCHEN/WNY FOOD BANK | YES | | YES | | S704 | |
| 10 | 8 | BIG LOTS/DOLLAR GENERAL | | | | | S704 | |
| 11 | 1 | JAMESTOWN AREA MEDICAL ASSOCIATES/5 STAR URGENT CARE | YES | | YES | | S704 | |
| 12 | 12 | ORIENTAL STAR RESTAURANT | | | YES | | S710 | |
| 13 | 2 | JSB ICE ARENA | YES | 5,200 | YES | | S712 | |
| 14 | 10 | JAMESTOWN HOUSING AUTHORITY (SENIOR HOUSING) | YES | 101 UNITS | | YES - 45 | S712 | N/A |
| 18 | 9 | BEST WESTERN | YES | 61 ROOMS | | | S712 | |
| 20 | 12 | SHAWBUCK'S | | | YES | | S712 | |
| 21 | 9 | HOLIDAY INN | YES | N/A | YES | YES - N/A | S710 | N/A |
| 23 | 10 | CHADAKOIN BUILDING (RESIDENTIAL) | YES | 32 UNITS | | | S710 | |
| 24 | 10 | HOTEL JAMESTOWN (SENIOR HOUSING) | YES | 115 UNITS | | | S710 | |
| 28 | 10 | WELLMAN BUILDING (RESIDENTIAL) | | | | | S712 | |
| 29 | 10 | WELLMAN BUILDING (RESIDENTIAL) | | 44 UNITS | | | S712 | |
| 31 | 11 | FURNITURE MART BUILDING W/HORIZON WIRELESS | | | | YES - 67 | S710 | N/A |
| 34 | 1 | DENTISTRY | | | | | S710 | |
| 35 | 2 | YWCA | YES | N/A | | | S710 | |
| 36 | 12 | CHERRY LOUNGE | | | YES | | S710 | |
| 40 | 12 | WINE CELLAR | | | YES | | S712 | |
| 42 | 10 | COVENANT MANOR (SENIOR, SECTION 8 HOUSING) | YES | 88 UNITS | | | S710 | |
| 46 | 5 | JAMESTOWN SAVINGS BANK | YES | | | | S710 | |
| 47 | 12 | THE PUB | | | YES | | S710 | |
| 48 | 12 | LISCANDRO'S | | | YES | | S710 | |
| 49 | 11 | THE POST JOURNAL | YES | | | | S710 | |
| 51 | 13 | UNION GOSPEL MISSION | | 22 ROOMS | YES | | S710 | |
| 56 | 5 | M & T BANK | | | | | S710 | |
| 64 | 5 | KEY BANK | YES | | | | S710 | |
| 65 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 66 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 67 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 68 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 72 | 2 | YMCA | YES | N/A | | | S710 | |
| 73 | 10 | YMCA APARTMENTS (LOW INCOME HOUSING) | YES | 19 UNITS | | | S710 | |
| 74 | 5 | NIAGARA BANK | | | | | S710 | |
| 75 | 5 | LAKESHORE SAVINGS BANK | | | | | S710 | |
| 76 | 10 | APARTMENTS (RESIDENTIAL) | | 12 UNITS | | | S710 | |
| 77 | 10 | APARTMENTS (RESIDENTIAL) | | | | | S710 | |
| 78 | 10 | APARTMENTS (RESIDENTIAL) | | | | | S710 | |
| 79 | 12 | 210 PINE | | | YES | | S710 | |
| 83 | 12 | FORTE | YES | | YES | | S710 | |
| 85 | 10 | APARTMENTS (RESIDENTIAL) | YES | 1-10 UNITS | | | S710 | |
| 86 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 87 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 88 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 89 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 90 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 92 | 11 | WINDSTREAM | YES | | | YES - N/A | S710 | N/A |
| 93 | 11 | WINDSTREAM | YES | | | | S710 | |
| 94 | 3 | JAMESTOWN POLICE/FIRE | YES | | | YES - N/A | S710 | N/A |
| 95 | 3 | CITY HALL (VERIZON CELL TOWER) | | | | YES - N/A | S710 | N/A |
| 96 | 3 | FEDERAL BUILDING | YES | | | | S710 | |
| 97 | 11 | TIME WARNER CABLE | YES | | | YES - N/A | S710 | N/A |
| 98 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 99 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 100 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 101 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 102 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 107 | 10 | APARTMENTS (RESIDENTIAL) | | 1-10 UNITS | | | S710 | |
| 112 | 7 | JAMESTOWN HIGH SCHOOL | YES | | YES | YES - 200 | S710 | N/A |

**Figure 1.3. Jamestown Microgrid Downtown Service Area Customers**

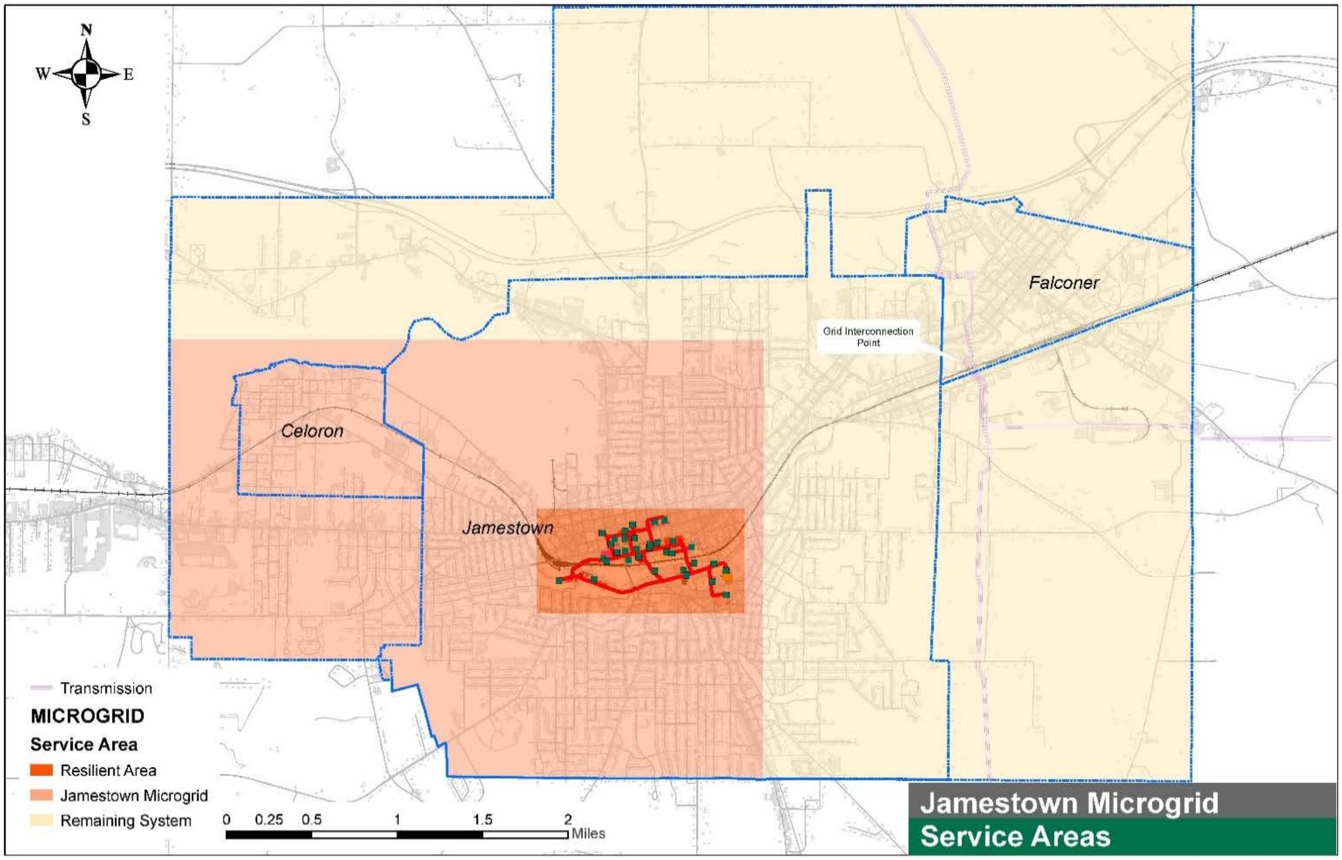



**Figure 1.4: Jamestown Microgrid Service Area (Carlson Area) as compared to overall JBPU service area.**

As mentioned earlier, Jamestown BPU has an LM6000 natural gas-fired electric generator commissioned in 2001 which possesses a simple cycle capacity of 43 MW. In addition, two steam turbine generators each with a capacity of 22 MW can be operated in different configurations using combined cycle steam produced by the LM6000 exhaust or by steam produced with natural gas-fired boilers. The facility also houses two natural gas-fired hot water thermal energy generators making it a combined heat and power (CHP) resource for 73 buildings in the immediate downtown area. All of these units are connected to the Carlson Substation. FIGURE 1.5 shows a single line schematic of the primary electrical and thermal generation resources located at Carlson Station.

District heating is a proven technology for supplying space and process heat from a central source and transporting it through a closed loop piping distribution system to individual buildings. It is a thermal energy network carrying hot water or steam from a central production station to service the energy requirements of commercial, residential, institutional and industrial buildings.

JBPU presently provides District Heating service via a network of underground piping which extends to the perimeter foundation wall of each customer's building. Appropriate shut off valves exist to separate each building from the main distribution network to support operational and maintenance activities. The building owner has the responsibility to install all necessary hydronic equipment and connections to the utility's piping network and then distribute the heat provided throughout their structure. This equipment typically includes a heat exchanger, expansion tank, circulation pumps and control system. JBPU is responsible for the installation and monitoring of a BTU meter which is used to measure and bill the customer for their thermal consumption. A map of the district heat/chilling system is shown in FIGURE 1.6. Note that much of this area overlaps the core of the resilient downtown Jamestown microgrid.

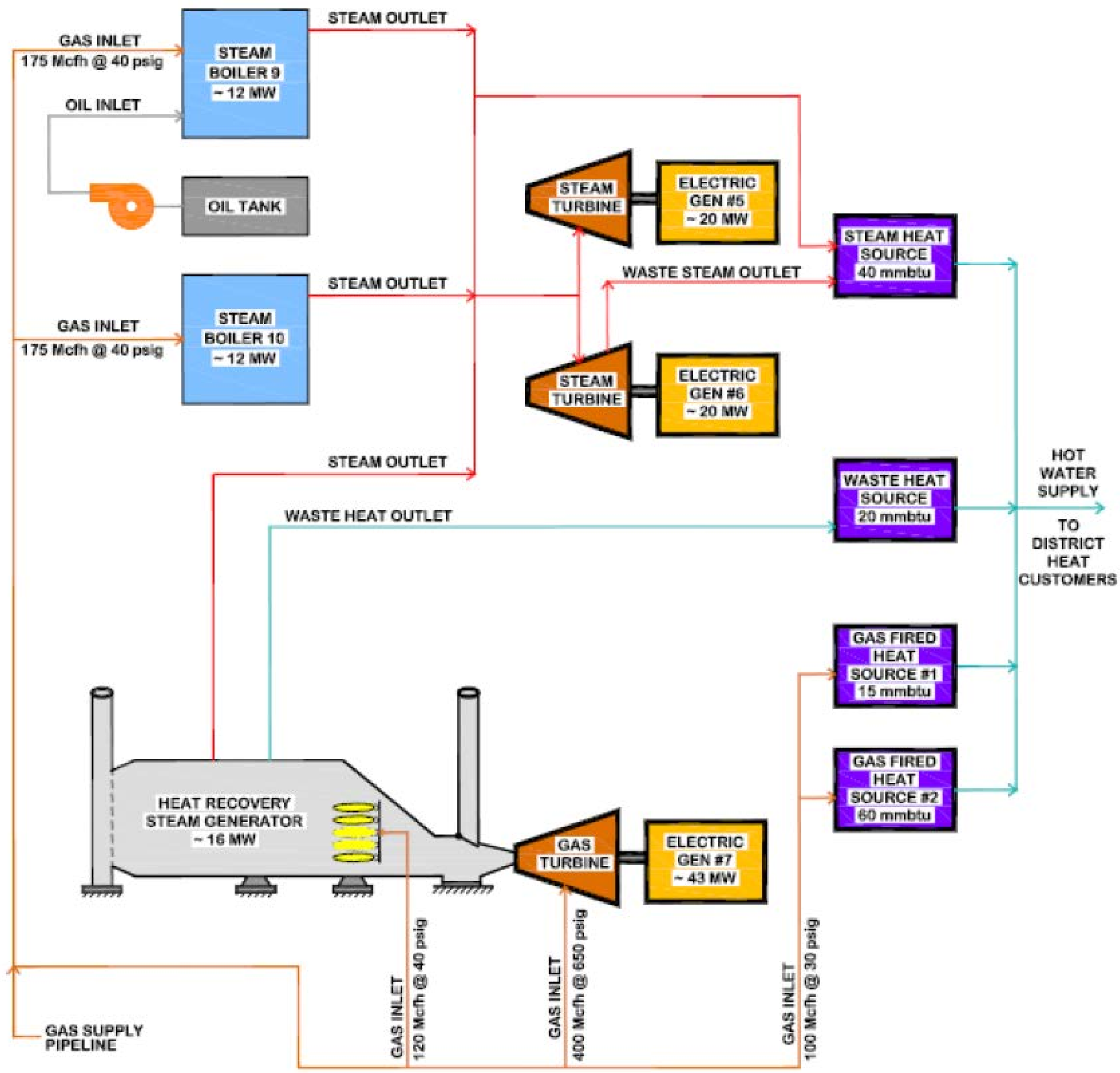



**Figure 1.5: Single line diagram of the Carlson generation station.**

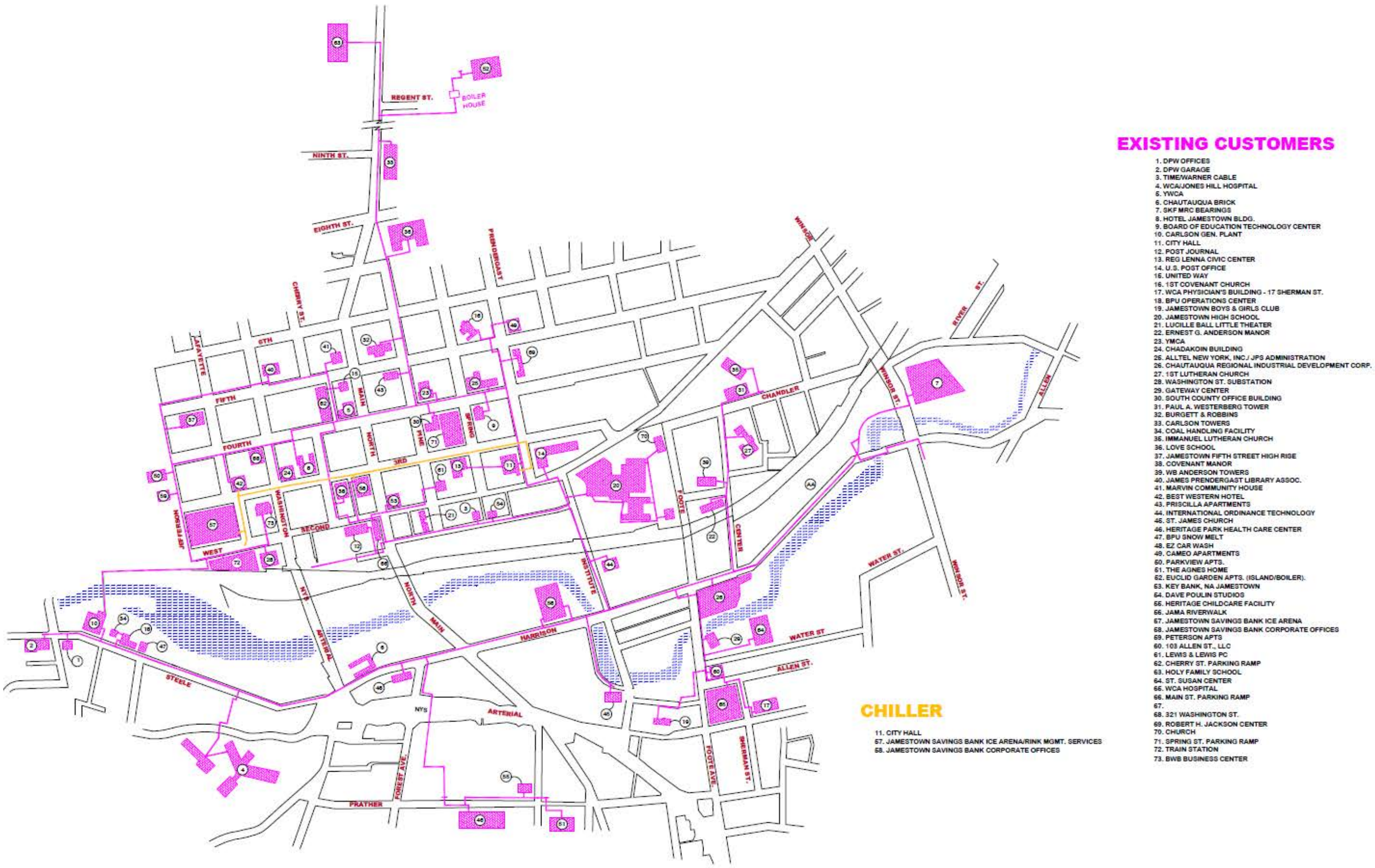



**Figure 1.6: Jamestown ditrivt heat/chilling service area.**

The thermal energy is produced from five sources: DH LPDH, DH 11th Stg, DH #6 Aux, DH Aux 1, and DH Aux 2. TABLE 1.1 lists the share of each source in sullying the thermal load of the system.

**Table 1.1. Share of each thermal source in the district heat/chilling system.**

| | LPDH | 11th Stg | #6 Aux | Aux 1 | Aux 2 |
|---|---|---|---|---|---|
| **2014 YTD (MMBtu)** | 67216 | 32601 | 25176 | 16394 | 53592 |
| **% of Total** | 34 | 17 | 13 | 8 | 27 |
| **Maximum/hr. (MMBtu)** | 28 | 20 | 29 | 17 | 46 |

## 1.4. MICROGRID CAPABILITIES

The Jamestown Microgrid will encompass defining characteristics/features as defined by the Department of Energy including:

- Geographically delimited or enclosed
- Connected to the main utility grid at one point of common coupling (PCC)
- Fed from a single substation
- Can automatically transition to/from and operate islanded
  - Operates in a synchronized and/or current-sourced mode when utility-interconnected
  - Is compatible with system protection devices and coordination
  - Can be electrically established from local/black-start generation resources
- Includes Demand Response (DR) and generator agnostics to support customer needs as applicable such as
  - Renewables (inverter interfaced)
  - Fossil fuel based emergency generators
  - Integrated energy storage
  - Includes an Energy Management System (EMS) to balance real time generation supply with distribution system demand
- Includes informational exchanges that can take place across the PCC in real time.

To expand the capabilities of the Jamestown Microgrid to encompass goals which extend beyond the primary objective of increased reliability and resiliency, the feasibility assessment has identified opportunities in areas of customer engagement, energy storage, load factor improvement and expanded CHP generation. These technologies are intended to leverage existing capabilities. For example, the JBPU currently uses a GIS (Graphic Information System) to accurately track infrastructure throughout its distribution system. In addition, the JBPU also maintains a customer database that controls billing and contact information for customers (CIS). An outcome of the Jamestown Microgrid project could be to connect actual customer contact/consumption information from the CIS database to service points in GIS. This connection would create opportunities to improve public outreach, energy efficiency, reliability and power quality. This system could also be leveraged in the future with smart meters and customer portals as they are implemented. This would enable the utility to create new electric rate structures designed to provide incentives for individual customers to modify their behavior in a manner that promotes system load factor improvement. Separately, the current utilization of generation equipment at the Carlson Station includes periods during the spring and fall months during which maintenance is performed on G7 which potentially reduces microgrid reliability. An enhancement of the Jamestown Microgrid could feasibly include the installation of additional fossil fuel based CHP equipment. A CHP unit with an electrical capacity of 9 Mw and a thermal capacity of 18 mmbtu/hr would greatly alleviate these concerns, provide energy output closely aligned to the core needs of downtown and provide a highly efficient source of locally created energy.

Customer knowledge and interaction is a critical goal for microgrid implementation within the REV: Reforming the Energy Vision environment, and is something that we feel can be enabled within the JBPU system. In addition to providing robust and resilient electricity to the JBPU customers served by the Jamestown Microgrid, our intent is to provide a cleaner, more efficient and affordable energy system for all JBPU customers. With a focus on the following objectives, also aligned with Performance Excellence in Electricity Renewal (PEER), it is feasible, given adequate resources, that a truly 'smart grid' could be created in conjunction with the Jamestown Microgrid and achieve improvements in the areas of:

- Reliability and resiliency
- Energy efficiency and environment
- Operational effectiveness
- Customer contribution and engagement

Paramount to a microgrid's success, safety and stability management requires the proper coordination of numerous power actors. In TABLE 1.2, these power actors are listed. In what follows, a brief description of each actor is provided.

**Table 1.2. Power actors in the microgrid control system.**

| Role | Actor |
|---|---|
| **Monitoring and Control** | Energy Management System (EMS)<br>Human-Machine Interface (HMI)<br>HMI Server |
| **Protection** | Intelligent Electronic Device (IED)<br>Protective Relay<br>Breaker<br>Fuse |
| **Generation** | Generator<br>Generator Controller<br>Black Start Generator<br>Automatic Transfer Switch<br>Clean and Renewable Technologies* |
| **Load** | Load Controller<br>Smart Meter |
| **Distribution** | Remote Terminal Unit (RTU)<br>Phasor Measurement Unit (PMU)<br>Point of Common Coupling Relay*<br>Distribution Transformer<br>Grounding Transformer<br>Disconnect Switch |
| **Storage** | Energy Storage*<br>Energy Storage Controller*<br>Plug-in Electric Vehicle*<br>Electric Vehicle Supply Equipment* |

* Assets for future consideration.

### A. Energy Management System

EMS is the central or distributed control system which monitors, controls, and optimizes the operation of the microgrid. The EMS serves several major functions:

- Control the import/export of real and reactive power from the utility by controlling the output of G7 generator;
- Provide automatic bus transfer control that will automatically close tie breakers (if applicable) to restore power to a feeder which has lost his power;
- Automatically shed load (with an EMS response time less than a threshold which will be calculated) upon loss of main grid;
- Automatically shed load to maintain a minimum generation capacity reserve;
- Display the open/closed status and power levels of 115 kV, 34.5 kV, and 13.8 kV switches and breakers;
- Allow operators to trip and close tie breakers and utility intertie breakers.

Usually the EMS has a network connection to all other network-connected controllers.

### B. Historian

Historian is a database application that logs and record microgrid operation data. It has network connection which enables sending and receiving data to/from EMS.

### C. Human-Machine Interface

Human-machine interface (HMI) is a console where a human can interact with EMS, including manual operation and control of microgrid. Through the network connection, HMI accesses HMI server to display operational data. HMI server is an information system that parses and formats EMS data to be viewed on HMI. Therefore it must receive from EMS and sends data to HMI.

### D. IED

Intelligent electronic device (IED) is a general term that encompasses relays, microgrid controllers, or any microprocessor-based power system controller for power system equipment. IEDs send power data to EMS for control functions. Based on the protection relay functionalities, some of them do not possess network connection capabilities.

### E. Relay

Protection relay is an electromagnetic device that monitors flow in an electrical circuit and trips circuit breakers when a fault is detected. Based on the protection relay functionalities, some of them do not possess network connection capabilities

### F. Breaker

Breaker is an automated electrical switch that protects circuits and devices from damage caused by a fault. Breakers do not possess network connection capabilities.

### G. Fuse

Fuse is a sacrificial device that protects equipment and lines from fault current by allowing conductive material to melt and disrupt current. Fuses do not possess network connection capabilities.

### H. Generator

Generator is a non-renewable electrical generation device, including diesel generators, gas generators, natural gas generators, and liquid petroleum gas generators. Generators do not possess network connection capabilities.

### I. Generator Controller

Generator controller is a device that controls generator power output, voltage, and frequency based on set points or commanded EMS values. EMS can monitor generator controller data and dynamically change controller set points.

### J. Black Start Generator

Black Start Generator is a generator used for restoring a power station to operation without relying on the external electric power system. A new 750kW natural gas-fired generator will be installed adjacent to G7 to provide black-start capability in the event G7 is offline during utility power loss.

### K. Automatic Transfer Switch

Automatic transfer switch (ATS) is an electrical switch installed where a backup generator is located. ATS automatically switches load from utility source to backup generator source when power loss is detected. Some ATS have network connectivity functionality but it may not be utilized.

### L. Renewable Generator

Any generator that produces energy from a natural source, such as PV arrays, wind turbine, and geothermal resources is considered as renewable energy generator. Renewable energy generator do not possess network connection capabilities.

### M. Renewable Generator Controller

Renewable energy controller is a device that controls renewable power output, voltage, and frequency based on available natural resources or on commanded EMS values. EMS can monitor the controller data and dynamically change the controller set points.

### N. Building Management System

Building management system (BMS) is a control system installed in a building that controls and monitors the building's electrical and mechanical equipment, such as lighting and environmental systems. EMS can monitor building energy consumption and change operational parameters, such as temperature set points.

### O. Load Controller

Load controller is a device that monitors and controls the amount of energy loads consumed by shedding, adding, or shifting load based on predetermined set points or by EMS commands. Load controller must be able to send load data to EMS and receives EMS commands.

### P. Smart Meter

Smart meters provide a digital link between the utility and the customer and opens the door for energy management. Services that the utility provides to customers using smart meter include:

- Budget setting and high usage alerts;
- Online portals with easy to understand graphics;
- Home energy reports and easily downloadable energy usage data which customers can upload into their preferred app.

- Smart meter sends energy information to EMS and historian. In order to apply different tariff structure, smart meter must be able to receive tariff information from the utility.
- In the Jamestown Microgrid project, by applying appropriate funding programs, smart meters could be installed for customers based on load characteristics (size, flexibility and criticality). Smart meters enable advanced load forecasting, consumer engagement, and demand response, as well as linkages to smart thermostats, solar inverters, electric vehicle chargers and other key distributed energy assets (if applicable).

**Q. Remote Terminal Unit**

Remote terminal unit (RTU) is an equipment that monitors digital and analog field devices. RTU transmits data to EMS.

**R. Phasor Measurement Unit**

Phasor measurement unit (PMU) is a device that measures electrical waveforms in the microgrid using synchro phasors to assess the state of the electrical system and manage power quality. PMU sends phasor data to EMS to adjust generation and load set points.

**S. Point of Common Coupling Synchronizing Relay**

Point of common coupling (PCC) synchronizing relay ensures the microgrid and the main grid are isolated when necessary and properly synchronized before reconnection. PCC synchronizing relay sends connection information and flow data to EMS.

**T. Distribution Transformer**

Distribution transformer is a transformer that converts electrical energy from one voltage to another. Depending on the location and type of the transformer, some of them have tap changer that allow finer voltage control and may allow tap settings to be changed remotely.

**U. Grounding Transformer**

Grounding transformer is a transformer that establishes an earth reference point for an ungrounded microgrid. Grounding transformers do not possess network connection capabilities.

**V. Disconnect Switch**

Disconnect switch is a manually operated device to disconnect power system components from the power system after power circuit has been interrupted by some other means. Some of the disconnect switches can be manually operated from a remote location.

**W. Energy Storage**

Energy storage system is an equipment components, such as batteries, flywheel, and pumped hydro, which stores some form of energy for conversion into electrical energy at a later time. Energy storage systems do not possess network connection capabilities.

There are four categories of storage technologies: mechanical energy storage; electrochemical (and chemical) energy storage; electrical and magnetic field energy storage; and thermal energy storage. FIGURE 1.7 shows these categories. Also TABLE 1.3 presents some estimates of technical and economical characteristics of different battery technologies, considering available/published technical characteristics of battery technologies and implemented projects.

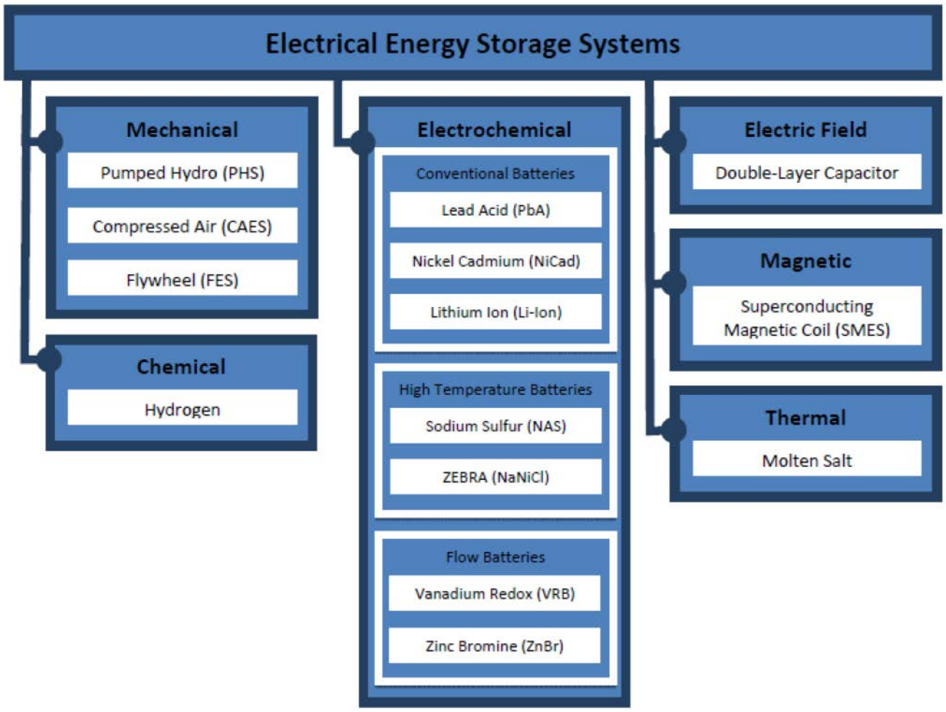



**Figure 1.7. Classification of energy storage according to energy form.**

## Table 1.3. Technical and economical characteristics of battery technologies.

| Technology | Power Cost $/kW | Energy Cost $/kWh | Round-Trip Efficiency % | Energy Density Wh/kg | Energy Density Wh/l |
|---|---|---|---|---|---|
| **Advanced Lead-Acid** | 1700-4900 | 425-980 | 75-90 | 33-42 | 60-110 |
| **Lithium-Ion** | 1000-4100 | 500-1500 | 85-95 | 65 | 140-210 |
| **Nickel-Cadmium** | - | - | 70-90 | 40-60 | 50-150 |
| **Sodium-Sulfur** | 3000-4000 | 445-555 | 75-86 | 150 | 140-170 |
| **Vanadium Redox** | 3000-3700 | 620-830 | 65-75 | 10-20 | 15-25 |
| **Zinc-Bromine** | 2300 | 875 | 65 | 35.5 | 80 |
| **Sodium Nickle Chloride** | - | - | 91 | 90-120 | 166 |

**X. Energy Storage Controller**

Energy storage controller is a device that controls low level charging and discharging flow rates and reports voltage, current, and state of charge information to EMS. EMS can control charging and discharging schemes to optimize energy usage or improve power quality.

**Y. Plug-In Electric Vehicle**

Plug-in electric vehicle (PEV) is a motor vehicle that stores and uses electricity in rechargeable battery packs to propel or assist in propelling the vehicle. EMS may have network connection to vehicle, but some only interface with electric vehicle supply equipment.

**Z. Electric Vehicle Supply Equipment**

Electric vehicle supply equipment (EVSE) is an equipment that supplies electric energy for the charging/discharging of PEVs. ESVS sends connection status and charging/discharging information to EMS.


The control and communication architecture of the proposed microgrid is designed using the components introduced above. Active network control of the proposed microgrid is performed by the EMS. At low level, the load controllers and the generator controller, control the assigned load and generation. However, the load controllers are enabled to perform energy efficiency and demand response program. At high level, the EMS monitors the entire system, using advanced metering technologies such as PMU and smart meters, and coordinate load and generator controllers accordingly. The existence of smart meter enables customer interaction and their participation in different energy efficiency and demand response programs.

Our preliminary evaluation of the Jamestown existing assets and infrastructure indicates that the Jamestown BPU is a superior candidate for microgrid implementation. The next section identifies necessary components to achieve the microgrid with minimum cost – in fact it is our opinion that Jamestown is very close to establishing a resilient energy infrastructure in a short time frame. The major components required for the Jamestown Microgrid are voltage transformers, current transformers, breakers, Relays, EMS and black start generator.

# Task 2

# TASK 2 – DEVELOP PRELIMINARY TECHNICAL DESIGN AND CONFIGURATION

## 2.1. PROPOSED MICROGRID INFRASTRUCTURE AND OPERATION

The implementation of a microgrid requires the integration of certain communications to enable the control architecture necessary to address safety, security, reliability, sustainability, and cost-effectiveness. Control system networks implemented for microgrids will leverage the Internet protocol suite of communications protocols, including communications at the link, internet, transport, and application layers. The Internet protocol suite is commonly known as Transmission Control Protocol/Internet Protocol (TCP/IP); however, microgrid control system networks generally employ several different protocols to enable communication between the many types of power and cyber actors.

Analysis of the historical load profile for distribution transformer T9 at Carlson Station confirms that existing generator G7 is sized appropriately for the overall load seen by T9 for the majority of the year. As demonstrated in FIGURE 2.1, Utilizing G7 as the primary generation source for the proposed Jamestown Microgrid, along with the 34.5 kV infrastructure at Carlson Station, we intend to island Carlson Station from the rest of JBPU's electrical system at circuit breakers S505 & S507, and operate in microgrid mode through the generation of G7 and the existing electric distribution downstream of transformer T9.

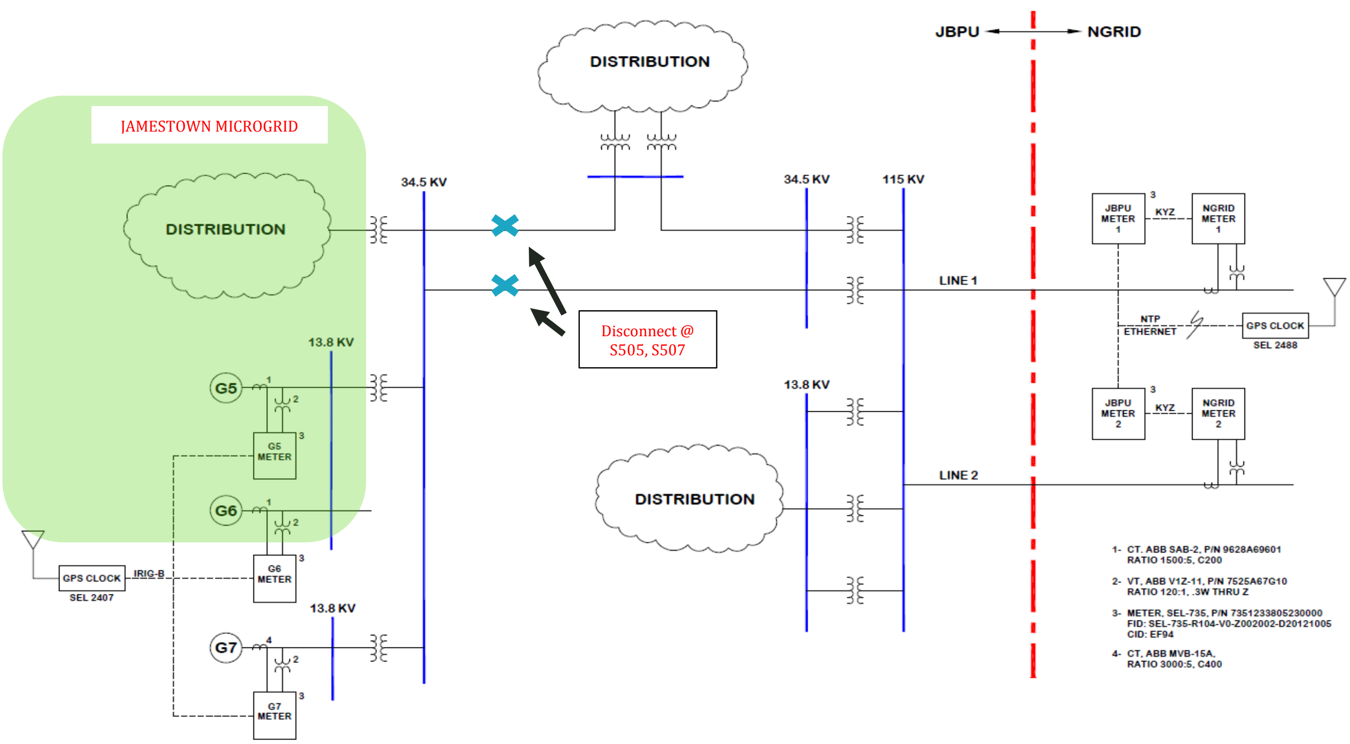



**Figure 2.1: Proposed Jamestown Microgrid**

FIGURE 2.2 represents an enlarged basic single-line diagram of the existing electrical infrastructure at Carlson Station. The proposed microgrid includes feeders S703, S704, S705, S709, S710, S712, S715, S902, S903, and S904. The critical customers served by the Jamestown Microgrid and the service code for customer chart are identified in FIGURE 2.3 and FIGURE 2.4, respectively. Using underground feeders, all critical loads would be energized during any event such as severe weather condition. This would increase the resiliency of the Jamestown Microgrid greatly.

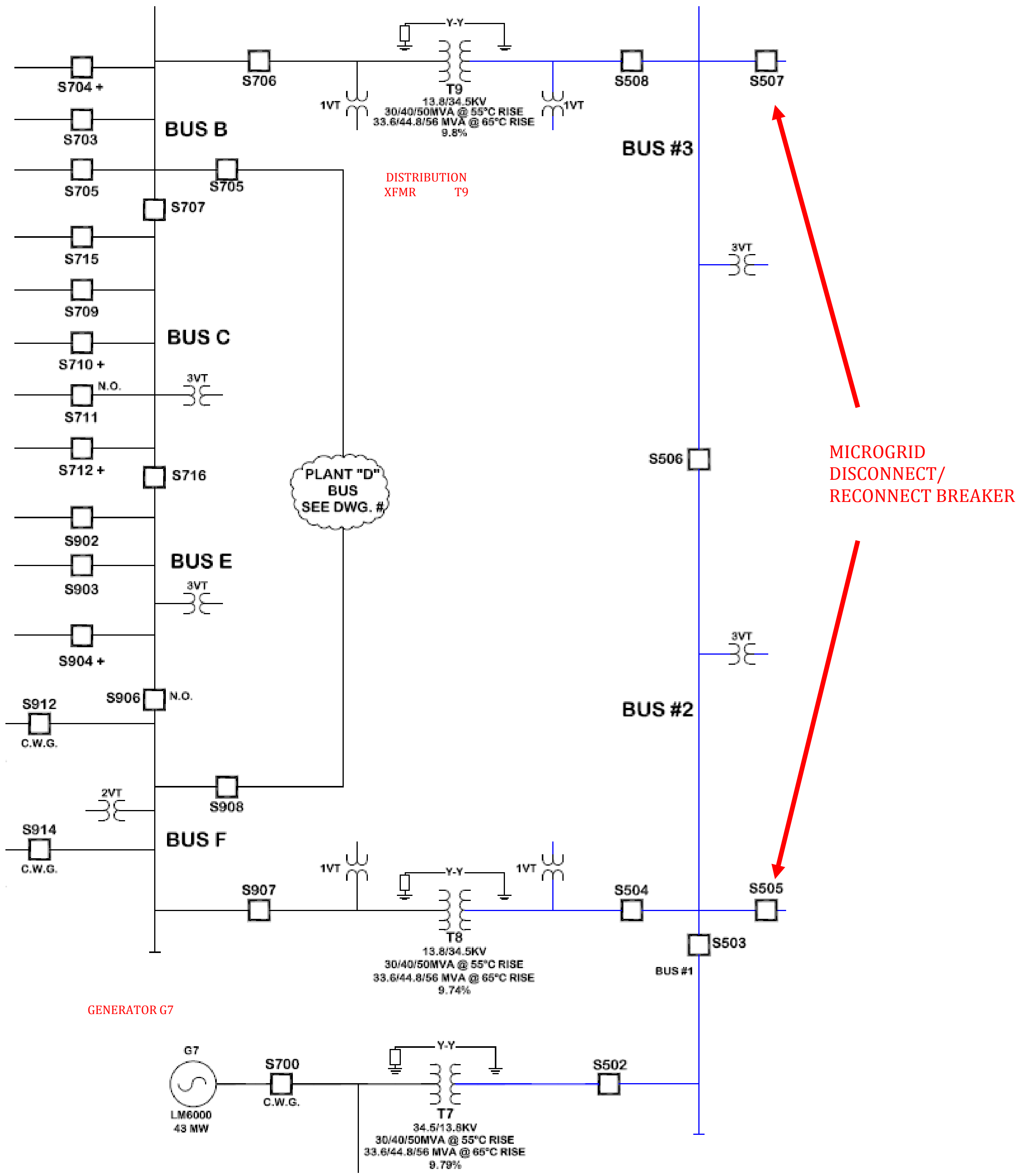



**Figure 2.2: Enlargement of Proposed Jamestown Microgrid Existing Infrastructure**

| JAMESTOWN MICROGRID - CRITICAL CUSTOMERS IN SERVICE AREA | | |
|---|---|---|
| Service Code | Description | Circuit |
| 1 | The Resource Center (2) | S703 |
| 1 | Alstar EMS Ambulance Service | E4 |
| 3 | Jamestown Fire Dept. Station 4 | P3 |
| 3 | Lakewood Water Pumpstation | H14 |
| 3 | Smith Ave. Water Pumpstation | P2 |
| 3 | Orr St. Water Pumpstation | H4 |
| 4 | Chautauqua County South and Center Sewer Treatment Plant | S703 |
| 4 | Sewer Lift Stations (Multiple) | MANY |
| 5 | Banks (Multiple) | MANY |
| 6 | Fueling Stations (Multiple) | MANY |
| 7 | Southwestern Central School (Elementary, Middle, High Schools) | H14 |
| 8 | Sam's Club | H14 |
| 8 | Wegman's | H14 |
| 8 | Home Depot | H14 |
| 8 | TOPS Market's | P4 |
| 8 | KMART | H14 |
| 10 | Tanglewood Manor (Elderly) | H14 |
| 10 | Apartments (Multiple) | MANY |
| 12 | Restaurants (Multiple) | MANY |

**Figure 2.3: Additional critical customers**

| SERVICE CODES | |
|---|---|
| Code | Description |
| 1 | Hospital/Healthcare |
| 2 | Shelter |
| 3 | Municipal/Police/Fire/DPW/Utility |
| 4 | Water Treatment |
| 5 | Banks |
| 6 | Gas/Fuel |
| 7 | Schools |
| 8 | Resources - Shopping |
| 9 | Hotels |
| 10 | Housing |
| 11 | Communications |
| 12 | Restaurant |
| 13 | Food Bank/Mission |

**Figure 2.4: Service code for the customer chart**

FIGURE 2.5 shows the control architecture of the Jamestown Microgrid. Black solid lines, blue and green dotted lines represent electrical connections, control signal, and measurement signal, respectively. Based on the proposed control structure, four operational states can be observed: Normal operation; Normal-to-island transition; Island operation; and Island-to-normal transition. FIGURE 2.6 shows the operational states and their relationship.

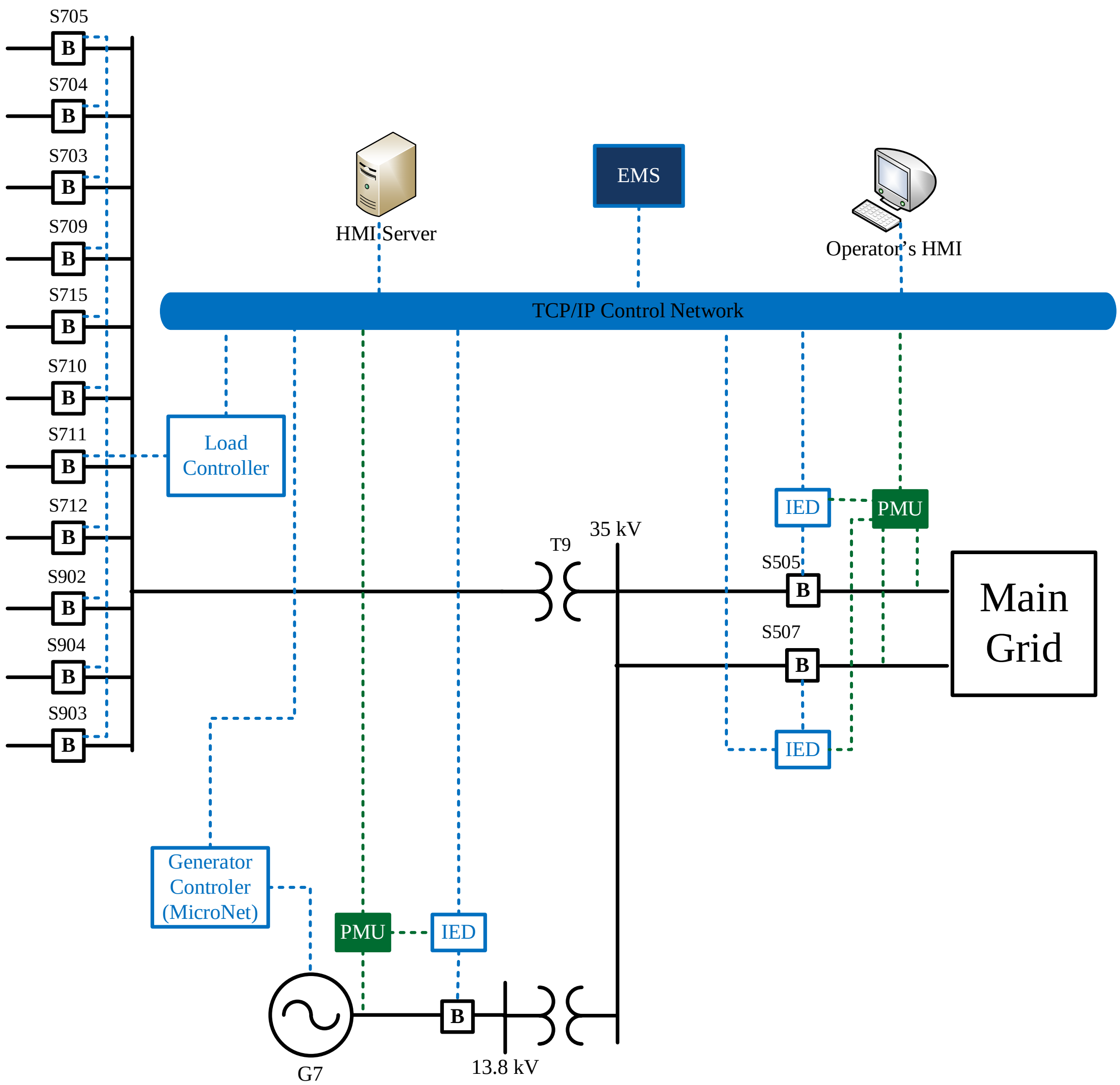



**Figure 2.5. Control architecture of the proposed Jamestown Microgrid.**

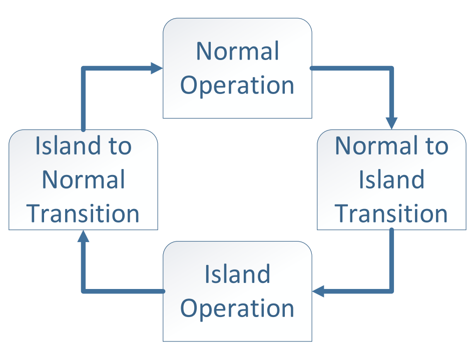



**Figure 2.6. Operational states.**

### 2.1.1. Normal Operation

In normal operation, the Jamestown system is connected to National Grid's 115 Kv substation in Falconer (Main Grid). Frequency and voltage references are thus provided by the Main Grid. The phase angle of the Carlson Station generator G7 will vary against the reference phasor because of fluctuations in system demand and local site loads. Upon the loss-of-main grid condition being detected, the Jamestown Microgrid control system moves to a normal-to-island transition state.

### 2.1.2. Normal-to-Island Transition

To ensure that real world microgrid capability does not detract from overall system reliability, it is vital that the loss-of-main grid detection system be able to determine the typical phase variation at the embedded generator site and respond only when anomalous behavior is identified. Thus, a prototype detector is proposed, as represented by the schematic diagram in FIGURE 2.7, to prevent unnecessary microgrid transitions to island mode from occurring.

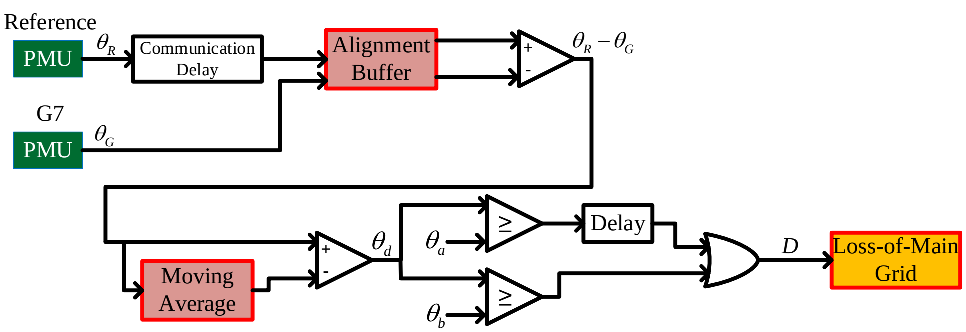



**Figure 2.7. Prototype synchrophasor loss-of-main grid detector schematic.**

*The principle of operation of the prototype is as follows:*

The detector acquires the phase angle of the generator and from a reference site via a synchrophasor. The reference synchrophasor arrives via Internet telecoms and therefore experiences a non-deterministic delay. An alignment buffer is used to ensure the algorithm is fed the most current synchrophasors with matching time stamps. The alignment buffer operates by feeding both the reference synchrophasor and generator synchrophasor into an array indexed by the time stamp of the synchrophasor. This array of synchronized data is then employed within the detector algorithm. The phase of the generator, $\theta_G$, with respect to the reference, $\theta_R$, is calculated, and a moving average of period, $t_{avg}$, normalizes the phase difference of the generator, $\theta_R$, about $0^o$. The period of the moving average is somewhat arbitrary, but should be several orders of magnitude more than the islanding detection time (seconds) and of the same timescale as normal network load variation (i.e. several thousand seconds). The detector outputs a binary signal, $D$, if either of two events happens. If the generator phase difference, $\theta_d$, exceeds the threshold for delay, $\theta_a$, for more than the delay time, $t_d$, and then the detector detects the loss-of-main grid. If $\theta_d$ exceeds the threshold $\theta_b$ then the relay detector responds immediately. This allows for the generator to have a temporary phase excursion following a system wide transient provided that it is brief in duration and not excessively large.

After detection of loss-of-main grid, EMS must switch from gird-tied operation mode to island operation mode, seamlessly. This transition must be done within a certain time frame before the generator's protections are activated. Those protections are mainly over/under voltage relay and over/under frequency relay. In order to keep voltage and frequency within the normal range, load and generation in the island must be matched. EMS provides the load-generation match in the island using the load controller and the generator controller. This task will be done by appropriate load shedding in the case of load exceeding generation capacity, or by adjusting the generator output in the case of generation capacity exceeding load, or both in some circumstances. If EMS fails to match the load and generation within the predefined time frame, the generator will be tripped, requiring the use of the black start generation unit to reestablish G7 operation and complete the transition.

### 2.1.3. Island Operation

Upon disconnecting, the distributed generator must immediately switch from "synchronized mode" to "autonomous mode" engaging controls to regulate voltage and frequency. Therefore in island operation, the generator G7 is responsible for two actions:

- Control the busbar voltage to the required nominal level;
- Supply the load with the required reactive power and respond fast to any load changes to meet the demand at any time.

The generator's automatic voltage regulator (AVR) controls may need to switch over immediately to operate in a different mode. For example, if the AVR was operated in a power factor control (PFC) mode when connected to the main grid, it will need to switch to the voltage control mode. In addition to the generator configuration, the settings of various protective relays will likely need to be different in islanded mode, or separate relays employed, since small generators typically produce less fault current than large generators on the main grid and voltage or frequency tolerances may need to be broader in island mode [4]. In this state, EMS keeps the load and generation match in the island using load controller and generator controller.

### 2.1.4. Island-to-Normal Transition

In this state, the grid connection is still available. However, in order to reconnect the islanded section to the main grid, the generator G7 must be synchronized to the main grid. Traditionally, power plants include a synchronizing panel to indicate what adjustments the operator should make to the governor and exciter and when it is acceptable for the operator to close the breaker. In many cases, the process is automated using an automatic synchronizer with manual control available as a backup. The synchronizing system must perform the following functions:

- Control the governor to match speed;
- Control the exciter to match voltage;
- Close the breaker as close to a zero-degree angle difference as possible.

An automatic synchronizer is a device that can perform all or part of the functions required to synchronize a generator. It can provide control signals to the generator and exciter to match the frequency and voltage to the system, and it can also close the breaker.

## 2.2. LOAD CHARACTERIZATION

For electrical loads, hourly measured active loads of the transformer at the feeders were available at the time of preparing this report. Therefore, this set of data represents the hourly aggregated active load of feeders S703, S704, S705, S709, S710, S711, S712, S715, S902, S903, and S904. For thermal loads, a set of measured data points were available at the time of preparing this report. The hourly measured data included five sources of thermal energy: DH LPDH, DH 11th Stg, DH #6 Aux, DH Aux 1, and DH Aux 2.

FIGURE 2.8 shows the aggregated hourly thermal and electrical load of the system for 2014. From Figure 2.8, it can be inferred that both thermal and electrical load are affected by monthly and seasonal weather conditions. Therefore, FIGURE 2.9 which shows the average monthly thermal and electrical load of the system, can indicate a better understanding of the load pattern.

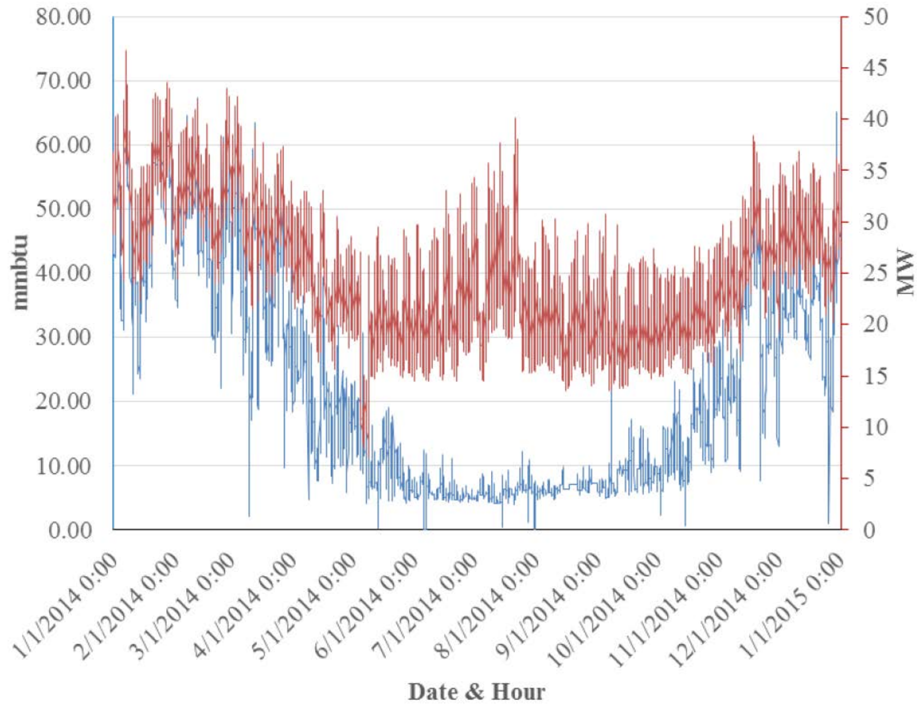



**Figure 2.8. Aggregated hourly thermal and electrical load for year 2014.**

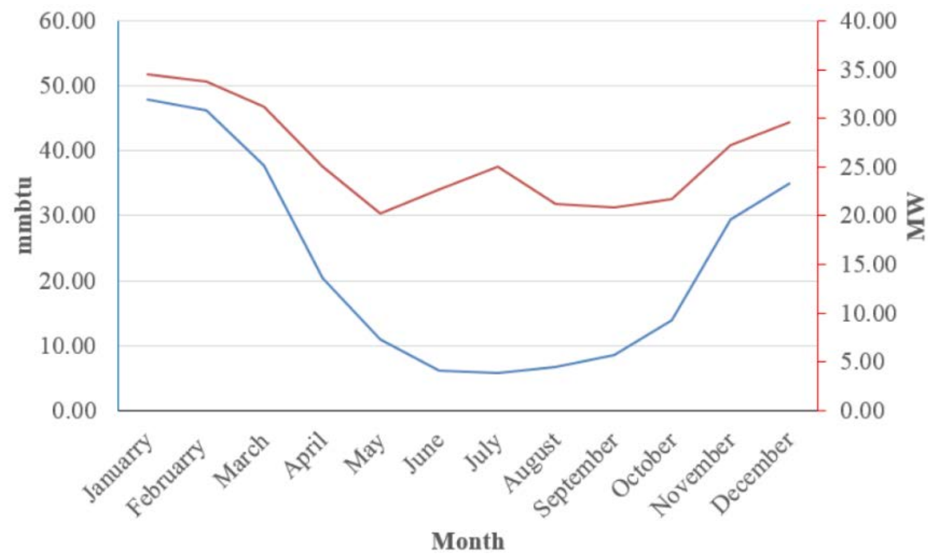



**Figure 2.9. Average monthly thermal and electrical load for year 2014.**

As can be seen from Figure 2.8 and Figure 2.9, thermal peak load occurs during winter. The thermal load decreases drastically during summer. Similarly, the electrical peak load occurs during winter. However, during summer, due to the use of electricity for cooling purposes, we observe growth in some electrical load during summer. In order to achieve a reliable daily load profile, thermal and electrical load, we then analyzed the thermal and electrical load data as shown in the following sections.

### 2.2.1. Electrical Load

TABLE 2.1 lists the hourly electrical load summary of the feeders in the proposed Jamestown Microgrid for 2014. It should be noted that there was unreliable measured data for the period of May 5*th* to May 9*th* of 2014. The measured data for those days was therefore eliminated from the data set.

**Table 2.1. Hourly electrical load summary of the feeders in the proposed microgrid for year 2014.**

| Month | Minimum (kWh) | Maximum (kWh) | Mean (kWh) |
|---|---|---|---|
| January | 22,408 | 46,736 | 34,476 |
| February | 24,019 | 43,031 | 33,750 |
| March | 21,414 | 42,234 | 31,139 |
| April | 15,675 | 33,081 | 25,061 |
| May | 14,758 | 29,536 | 21,516 |
| June | 14,497 | 33,739 | 22,647 |
| July | 14,536 | 40,155 | 25,023 |
| August | 13,591 | 30,283 | 21,235 |
| September | 13,591 | 30,783 | 20,803 |
| October | 14,936 | 27,894 | 21,732 |
| November | 16,984 | 38,417 | 27,228 |
| December | 19,329 | 36,884 | 29,569 |

A set of measured data for electrical load included 15-minute measured active and reactive load on each feeder S703, S704, S705, S709, S710, S711, S712, S715, S902, S903, and S904, were available at the time of preparing this report. The data set covered the measurement for the last 10 years. For this load analysis purpose, we used the data for the year 2014. In order to process the measured data, two typical days have been defined: Working day and Weekend/holiday. The daily load profile, for each typical day, for every 15-minute interval, was then analyzed for each season. The season is defined based on the geographical location of Jamestown which is:

- Spring - from March 21st to June 21st
- Summer - from June 22nd to September 22nd
- Fall - from September 23rd to December 21st
- Winter - from December 22nd to March 20th.

After observing the raw data, some points appeared to differ from the rest of data. In some cases, it is reasonable to consider such outliers, or data values that appear to be inconsistent with the rest of the data. Those outliers have been detected and removed from the data set using a defined criterion (an outlier is defined as a value that is more than two standard deviation away from the mean).

In what follows, the aggregated daily load analysis of the underground feeders (S704, S710, S712, and S904), overhead feeders (S703, S705, S709, S711, S715, S902, and S903), and aggregated feeders in the proposed microgrid is presented for each typical day within 15-minute intervals.

### A. Underground Feeders

The underground feeders in the proposed microgrid considered in this section are S704, S710, S712, and S904. As explained earlier, the analysis has been performed for two typical days, working day and weekend/holiday, for each season. FIGURE 2.10 shows the aggregated daily load profile, for every 15-minute interval, for each typical day of each season. From the figure, it can be seen that there is a peak in load profile during a working day starting at 8 a.m. and ending at 5 p.m. which represents residential/commercial loads. The load profile has a smoother pattern in a weekend/holiday.

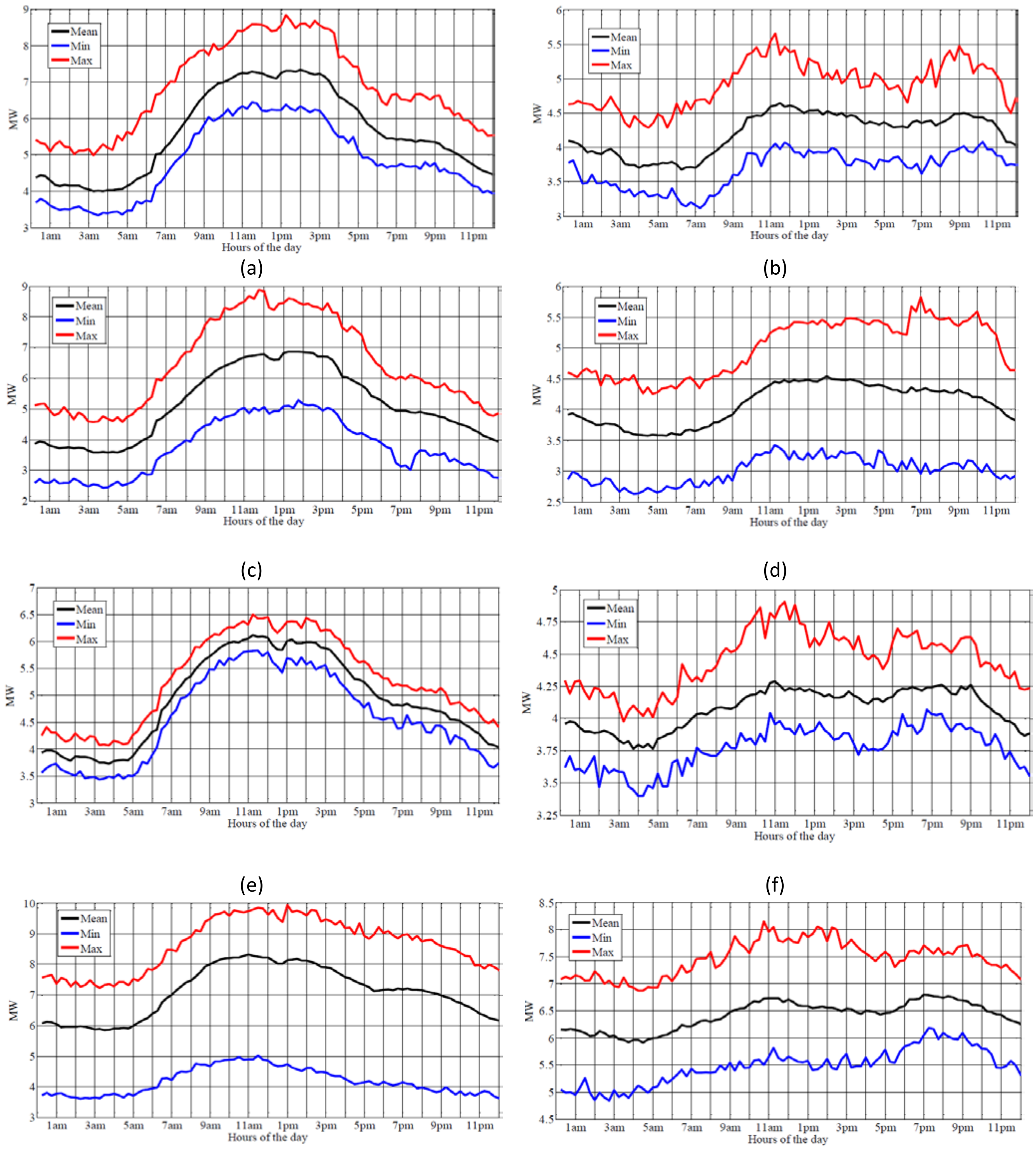



**Figure 2.10. Aggregated daily load profile of the underground feeders of the proposed microgrid for: (a) Working day in spring; (b) Weekend/holiday in spring; (c) Working day in summer; (d) Weekend/holiday in summer; (e) Working day in fall; (f) Weekend/holiday in fall; (g) Working day in winter; (h) Weekend/holiday in winter.**

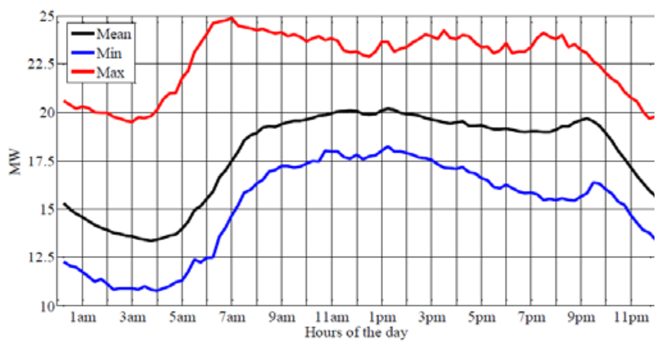
TABLE 2.2 summarizes the minimum and maximum values of load on aggregated underground feeders. The minimum and maximum aggregated load on the underground feeders are 2432 kW and 9943 kW, respectively. The minimum and maximum load happened in a working day of summer and a working day of winter, respectively.

**Table 2.2. Aggregated load summary of the underground feeders in the proposed microgrid for year 2014.**

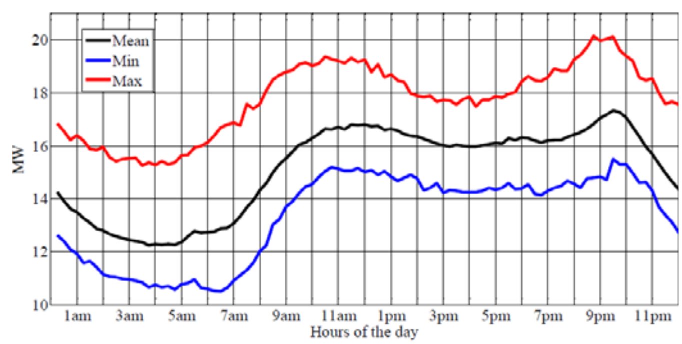
| Season | Working Day | | Weekend/Holiday | |
|---|---|---|---|---|
| | Min (kW) | Max (kW) | Min (kW) | Max(kW) |
| **Spring** | 3,330 | 8,846 | 3,117 | 5,654 |
| **Summer** | 2,432 | 8,876 | 2,628 | 5,826 |
| **Fall** | 3,436 | 6,502 | 3,396 | 4,905 |
| **Winter** | 3,607 | 9,943 | 4,843 | 8,156 |

### B. Overhead Feeders

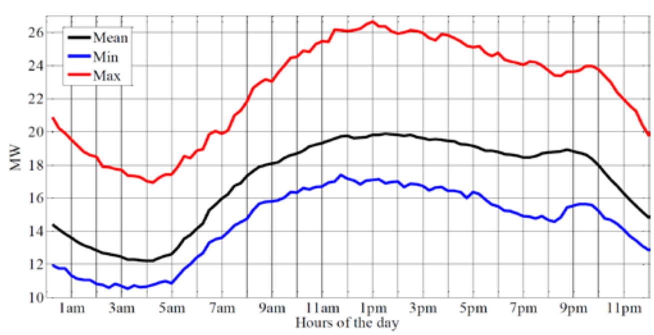
The overhead feeders of the proposed microgrid considered in this section are S703, S705, S709, S711, S715, S902, and S903. FIGURE 2.11 shows the aggregated daily load profile, for every 15-minute interval, for each typical day of each season. From the figure, it can be seen that in summer, there is a deep valley and hill in the load profile. However, during other seasons, the load profile is smoother which shows the effect of using electricity for heating purposes.



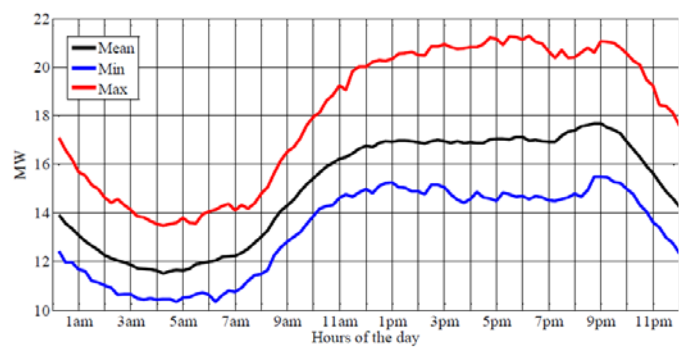

(a)



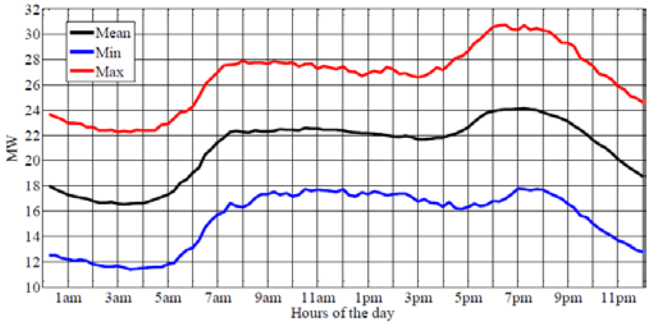

(b)



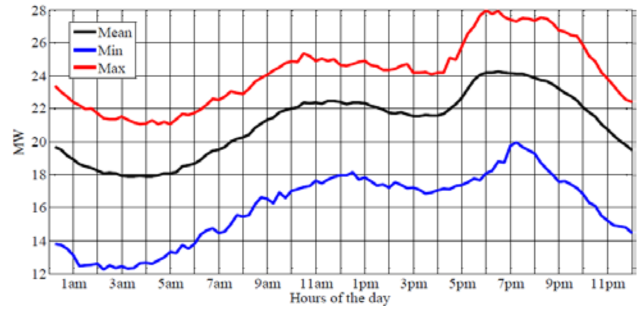

(c)



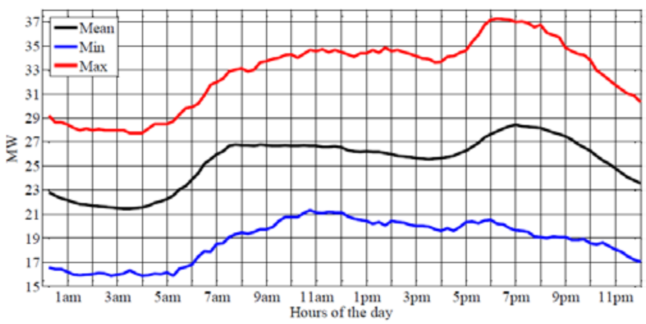

(d)



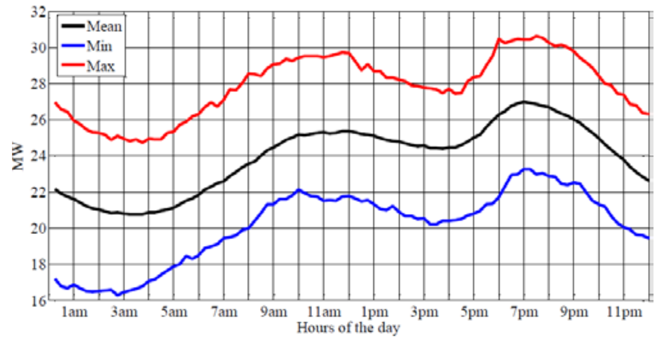

(e)




(f)




(g)




(h)

**Figure 2.11. Aggregated daily load profile of the overhead feeders of the proposed microgrid for: (a) Working day in spring; (b) Weekend/holiday in spring; (c) Working day in summer; (d) Weekend/holiday in summer; (e) Working day in fall; (f) Weekend/holiday in fall; (g) Working day in winter; (h) Weekend/holiday in winter.**

TABLE 2.3 summarizes the minimum and maximum values of aggregated loads of the overhead feeders in the proposed microgrid. The minimum and maximum aggregated loads of the substation are 10,326 kW and 37,293 kW, respectively. The minimum and maximum load happened in a weekend/holiday of summer and a working day of winter, respectively.

### Table 2.3. Aggregated load summary of the overhead feeders in the proposed microgrid for year 2014.

| Season | Working Day | | Weekend/Holiday | |
|---|---|---|---|---|
| | Min (kW) | Max (kW) | Min (kW) | Max(kW) |
| **Spring** | 10,782 | 24,871 | 10,503 | 20,135 |
| **Summer** | 10,513 | 26,646 | 10,326 | 21,278 |
| **Fall** | 11,412 | 30,733 | 12,230 | 27,936 |
| **Winter** | 15,876 | 37,293 | 16,272 | 30,611 |

### C. Aggregated Feeders

FIGURE 2.12 shows the annual load curve duration of the proposed microgrid. The curve is for year 2014. Notice that the aggregated hours projected in the figure is below 8760 hours because some measurements were filtered due to noise in measurements and other concerns. FIGURE 2.13 shows the aggregated daily load profile of the proposed microgrid, for every 15-minute interval, for each typical day of each season. Since majority of the load are connected to the overhead feeders, the same effect of the thermal load on the load profiles can be observed from the figure.

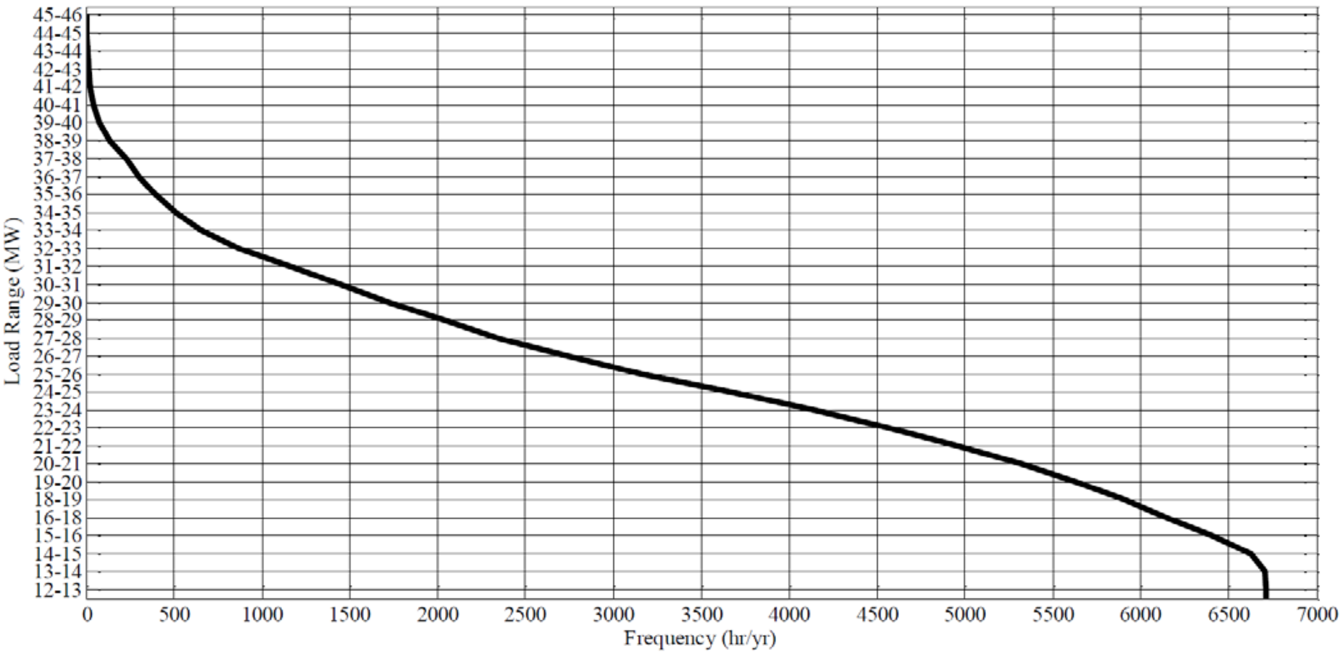



**Figure 2.12. Annual load curve duration of the proposed microgrid.**

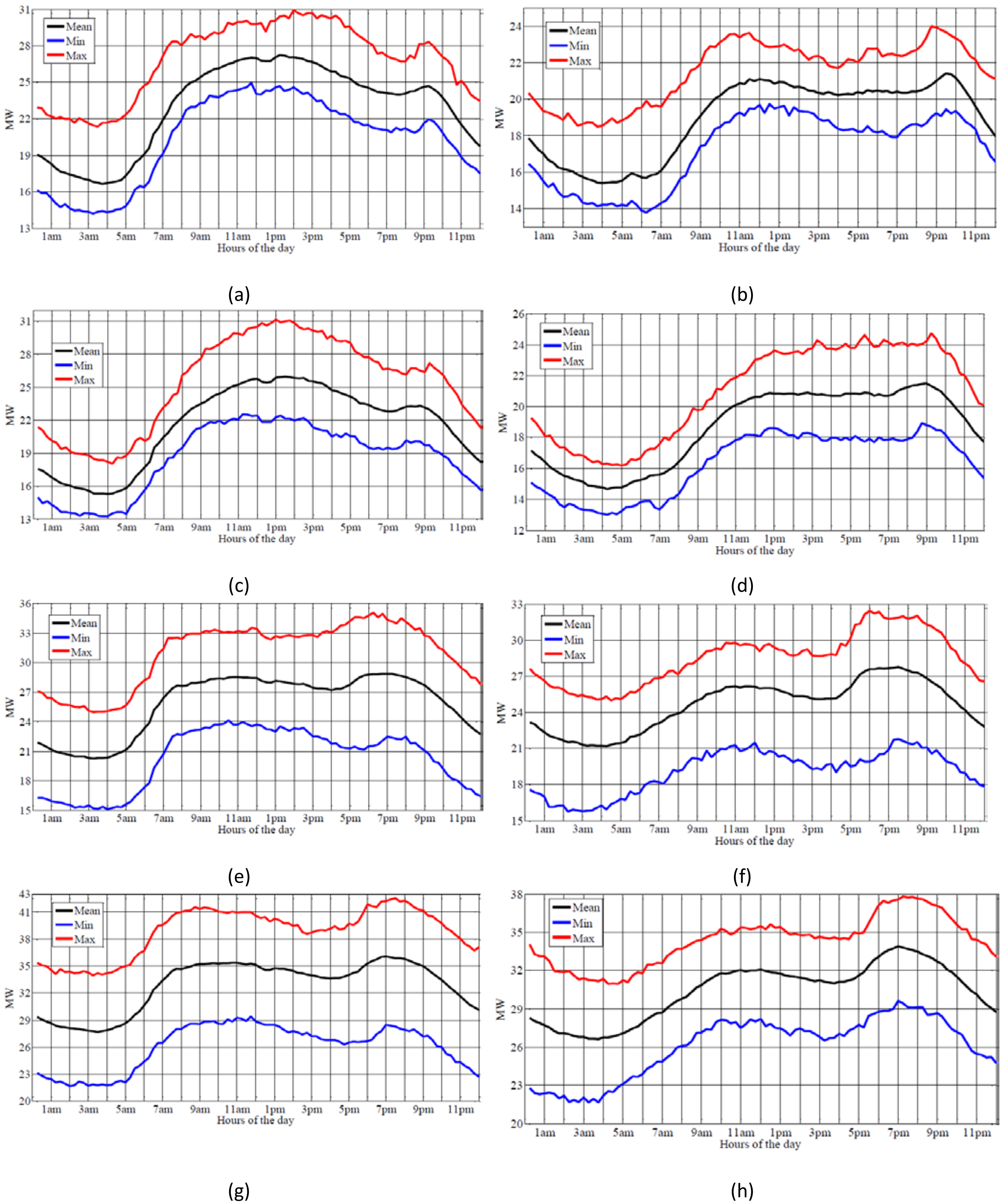



**Figure 2.13. Aggregated daily load profile of the proposed microgrid for: (a) Working day in spring; (b) Weekend/holiday in spring; (c) Working day in summer; (d) Weekend/holiday in summer; (e) Working day in fall; (f) Weekend/holiday in fall; (g) Working day in winter; (h) Weekend/holiday in winter.**

TABLE 2.4 summarizes the minimum and maximum values of aggregated load of the proposed microgrid. The minimum and maximum aggregated load of the substation are 13012 kW and 42563 kW, respectively. The minimum and maximum load happened in a weekend/holiday of summer and a working day of winter, respectively.

**Table 2.4. Aggregated load summary of the proposed microgrid for year 2014.**

| Season | Working Day | | Weekend/Holiday | |
|---|---|---|---|---|
| | Min (kW) | Max (kW) | Min (kW) | Max(kW) |
| **Spring** | 14,211 | 30,900 | 13,790 | 23,982 |
| **Summer** | 13,260 | 31,165 | 13,012 | 24,727 |
| **Fall** | 15,106 | 35,091 | 15,738 | 32,385 |
| **Winter** | 21,656 | 42,563 | 21,662 | 37,791 |

### 2.2.2. Thermal Load

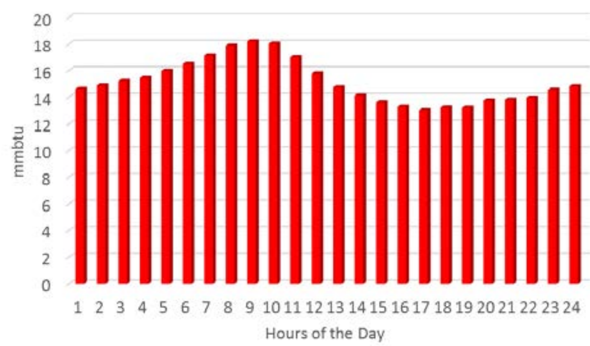
With a favorable report from Burns & Roe Co. of Oradell, New Jersey, Jamestown began seeking sources to fund a detailed engineering report to actually construct a District Heating system. The New York State Energy Research and Development Authority agreed with the Burns & Roe preliminary engineering report and sponsored a $350,000 second phase project. The City committed an additional $100,000 to complete the engineering design.

Based upon the favorable report to re-implement District Heating, JBPU presently provides this service to the foundation of the customer's building with shut off valves to separate the building from the main distribution system. The building owner has the responsibility to install all necessary hydronic equipment to utility District Heating. This would include heat exchanger, expansion tank, pumps, and control system. JBPU is responsible to install and monitor the BTU meter and the flow meter. TABLE 2.5 lists the aggregated hourly thermal load summary of the district heat/chilling system for 2014.

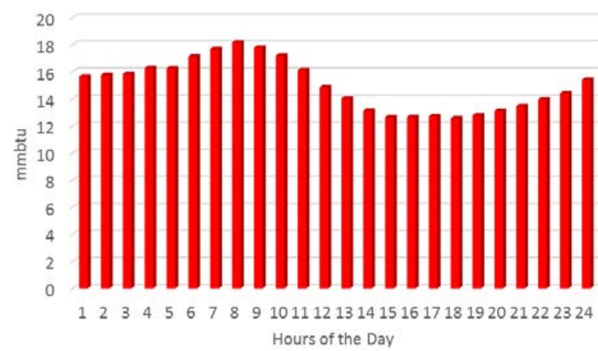
**Table 2.5. Aggregated hourly thermal load summary of the district heating/chilling system in the proposed microgrid for year 2014.**

| Month | Maximum (MMBtu) | Mean (MMBtu) |
|---|---|---|
| **January** | 70.49 | 47.95 |
| **February** | 64.34 | 46.25 |
| **March** | 63.55 | 37.57 |
| **April** | 39.43 | 20.35 |
| **May** | 30.81 | 10.88 |
| **June** | 12.48 | 6.08 |
| **July** | 12.34 | 5.86 |
| **August** | 10.06 | 6.65 |
| **September** | 25.43 | 8.49 |
| **October** | 28.54 | 14.04 |
| **November** | 55.03 | 29.38 |
| **December** | 65.21 | 35.09 |

This thermal energy is produced from five sources: DH LPDH, DH 11th Stg, DH #6 Aux, DH Aux 1, and DH Aux 2. Using hourly measured thermal loads for 2014, the daily thermal load profile for each typical day (working day and weekend/holiday), was analyzed for each season. The season is defined as the same season for electrical loads. In order to understand the aggregated daily thermal load pattern, we have studied the heat generation profile of each heat source in the district heat system. Therefore, the aggregated generation patterns lead us to the average aggregated load pattern of the district heat system. FIGURE 2.14 shows the aggregated thermal load of this system. From Figure 2.14, it can be inferred that the thermal load in each typical day of each season follows a relatively consistent pattern. During the working day of each season, a peak can be observed at 8 a.m. when people start working. For the rest of the day, the thermal load is almost constant. However, during weekend/holiday, the thermal load follows flatter pattern. That implies that people use constant thermal energy during weekend/holiday.




(a)

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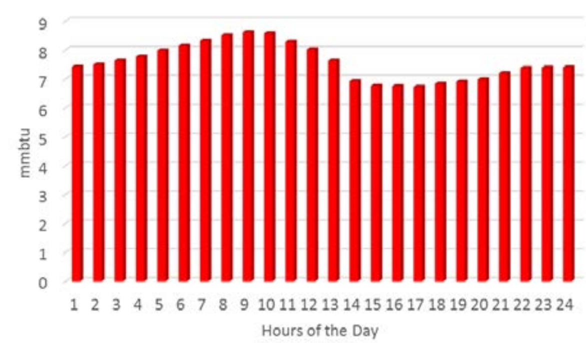


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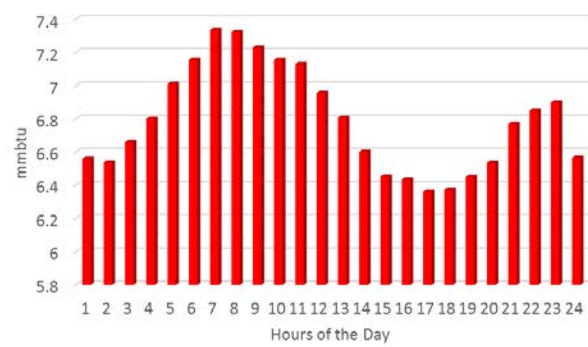


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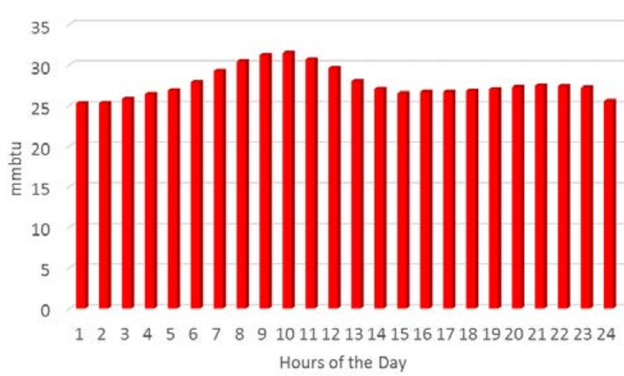


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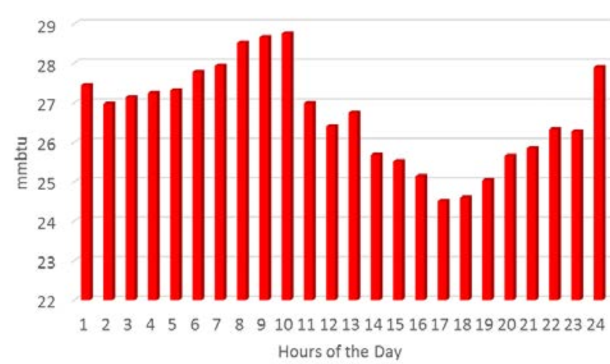
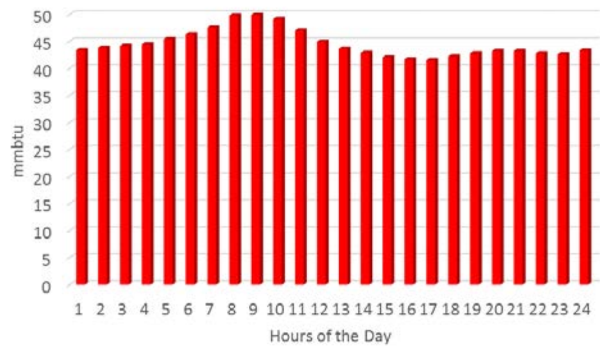
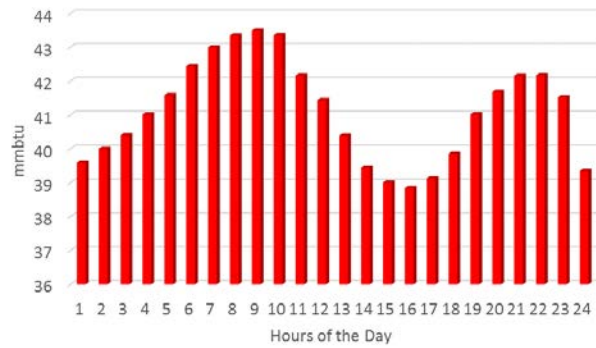



(f)




(g)




(h)

**Figure 2.14. Average aggregated daily profile of the thermal load for: (a) Working day in spring; (b) Weekend/holiday in spring; (c) Working day in summer; (d) Weekend/holiday in summer; (e) Working day in fall; (f) Weekend/holiday in fall; (g) Working day in winter; (h) Weekend/holiday in winter.**

## 2.3. DISTRIBUTED ENERGY RESOURCES CHARACTERIZATION

Carlson Station's existing primary power-generating resource is a GE LM6000 natural gas-fired electric generator, commissioned in 2001, having a simple cycle capacity of 43 MW. The generator (G7) delivers electricity to the Station's on-site 34.5kV/13.8kV electrical distribution substation, which then distributes power to up to seven of the ten substations operated by the JBPU for its customers. The gas turbine is coupled to a Deltak heat recovery steam generator (HRSG) which uses the exhaust heat from the LM6000, and some additional gas firing, to produce steam to power a steam turbine generator, which already exists. The gas turbine can be run in simple cycle, with the HRSG, with an efficient operating range between approximately 21.5 and 43 megawatts. The gas turbine can be run in combined cycle, with the HRSG, to add approximately 22 megawatts of additional gas-produced electricity.

G7's natural gas fuel supply is provided from a compressor station located in a rural area approximately twenty eight miles west of Jamestown. This compressor station receives natural gas from both local wells and the interstate Tennessee Gas Pipeline. The compressor station operates from natural gas fired engines and is therefore not reliant upon the regional electrical grid to provide a reliable and continuous fuel supply to the Carlson Station. In island operation state, G7 is the source of power. Considering the load patterns, G7 can supply all underground feeders. Depending of the time of the day, the day of the week, and the season, some of the overhead feeders (up to total load of 43 MW) can be supplied by G7 in the proposed microgrid.

Due to the air pollution control and economic considerations, G7 is not running throughout the whole year. Based on the generation scheduling of G7 for the year 2014, 3,774 hours of the year the generator was offline. FIGURE 2.15 shows the generation schedule of G7 for the year 2014. Considering the control characteristics of G7, the generator is not able to decrease its generation more than 50%, in a fast ramp-down manner. The load analysis and generation schedules of G7 conclude 84 hours of the year when the electrical load of the proposed microgrid is below 50% of the G7's output power. Therefore during those time periods of the year when G7 is offline or the electrical load of the proposed microgrid is below 50%, which is 3,858 hours total, we will have to use a black-start generator to bring G7 online in the proposed Jamestown microgrid. The district heating/chilling system will supply the thermal demand, using G7 and boiler Aux 2. During severe weather conditions, G7 and boiler Aux 2 can still provide electricity and heat for the proposed microgrid. Notice that underground feeders will still feed all connected loads during severe weather conditions.

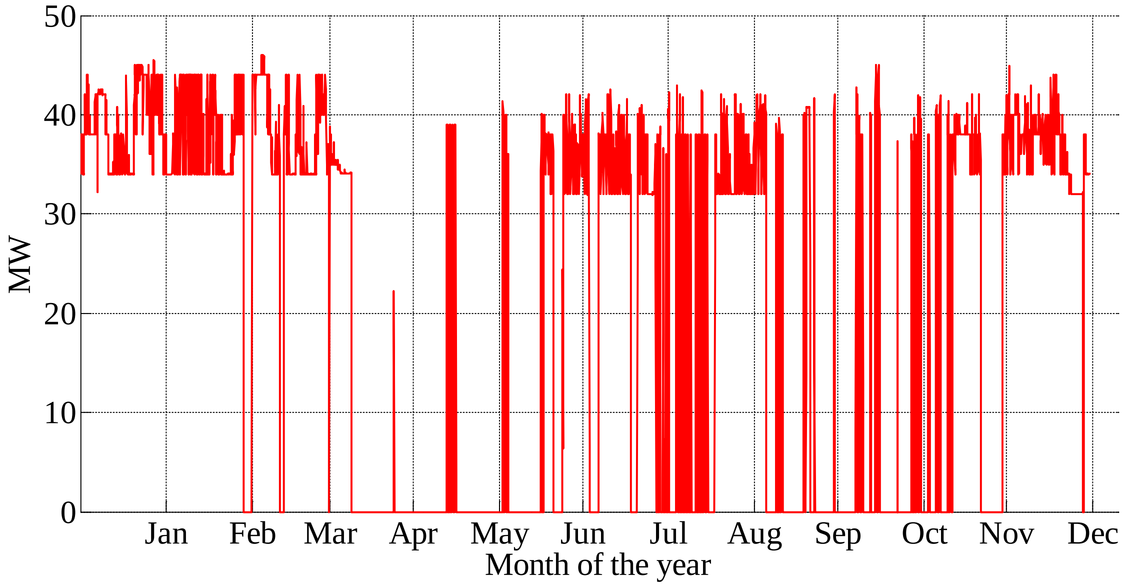



**Figure 2.15. G7 generation schedule for the year 2014.**

In order to investigate the G7 capabilities in different operating states, we define the worst case scenario in which the loss of main grid happens when the system has minimum load. The reason to define loss of main grid at minimum load period is to observe the behavior of G7 when the gap between load and generation in the proposed island is maximum. The values in TABLE 2.7 are assumed are the settings for over voltage/under voltage protection and over frequency/under frequency protection relays of the generator.

**Table 2.7. Voltage and frequency trip set-points of G7.**

| Element | Pickup Range | Time Delay |
|---|---|---|
| **Under Voltage** | 0.5 pu | 160 ms |
| **Under Voltage** | 0.88 pu | 2 s |
| **Over Voltage** | 1.1 pu | 1 s |
| **Over Voltage** | 1.2 pu | 160 ms |
| **Under Frequency** | 57 Hz | 160 ms |
| **Over Frequency** | 60.5 Hz | 160 ms |

Considering the load analysis, the observed minimum load of the system is 13.591 MW. We assume the power factor of G7 to be 0.95 at nominal power. At this operational status, we apply the loss of the main grid. This scenario represents loss of the main grid during minimum load period. After loss of main grid the frequency starts deviating from 60 Hz. Our calculation shows that the over frequency relay is activated at 70 ms after loss of main grid. Therefore, the time frame for transition from grid tied mode to island mode during minimum load period is 70 ms. Therefore, in the worst case scenario, the time frame to ride-through voltage and frequency events in the islanded mode is 70 ms. In order to be prepared for the worst case scenario, the seamless transition scheme from grid tied to island mode, must be as fast as 70 ms.

## 2.4. MICROGRID AND BUILDING CONTROLS CHARACTERIZATION

The JBPU administers an active energy efficiency program which provides a wide array of financial incentives to customers who invest in energy efficiency products. Since 2009, the JBPU program has rebated over $2.3 million dollars to qualifying customers which is estimated to have reduced the JBPU system peak customer demand by 2.5%. The existing JBPU Carlson Station which will provide energy to the microgrid is a combined heat and power facility which operates at a relatively high overall thermal efficiency of approximately 48%.

FIGURE 2.20 shows the decision tree of the EMS. Based on the measured data from PMUs, the EMS can detect the loss of main grid. As soon as the loss of main grid is detected, EMS has to make decision. If G7 is offline, EMS uses the black start generator to start G7. After bringing G7 online, load and generation will be increased until the voltage and frequency are within normal ranges. However, if G7 is operating right before the loss of main grid, the EMS will check the load level. If the load is within 50% of G7's generated power, EMS will be able to adjust G7's output power to perfume load following. In case of over-load, EMS performs load shedding and in case of over-generation, EMS decreases load and/or increases G7's generated power. If the load is not within 50% of G7's generated power, G7 will not be able to do load following. Therefore G7 will be tripped and EMS will have to use the black start generator. Based on the load analysis and G7's generation schedules, if loss of the main grid happens during 3858 hours of the year, the EMS will have to use the black start generator. However during the rest of the year the transition from grid-tied mode to island mode can be accomplished seamlessly. Currently there is no building energy management system (BEMS) in place. However, the EMS enables JBPU to incorporate any future BEMS unit in the decision tree, by considering them as load controllers.

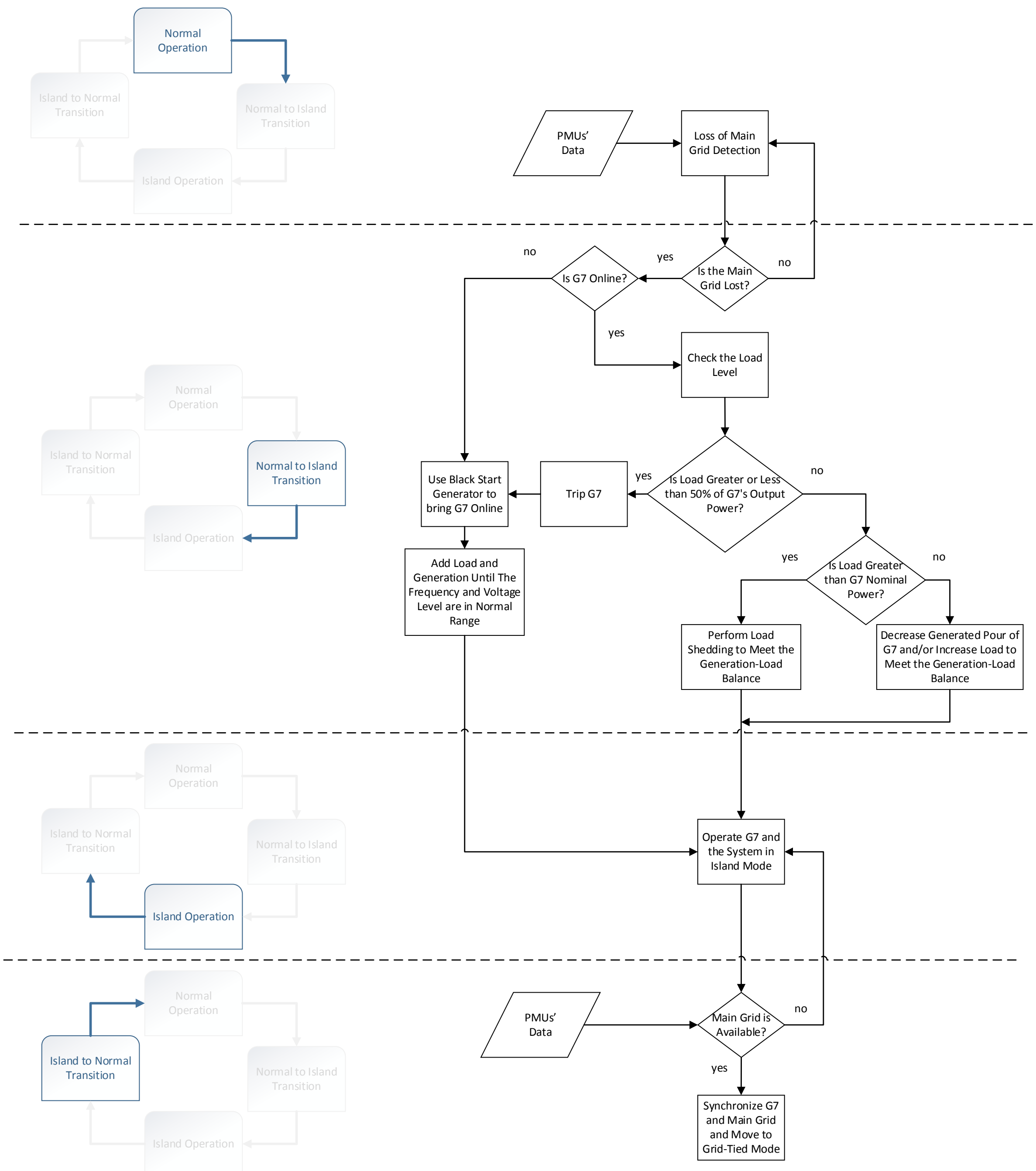



**Figure 2.20. EMS decision tree for microgrid operation.**

## 2.5. IT/TELECOMMUNICATION INFRASTRUCTURE CHARACTERIZATION

Supervisory control and data acquisition (SCADA) is used in Jamestown electric power system for communication and control purposes. The SCADA master station is a Windows server running GE iFix software. Communication from the server to end devices is Ethernet based. The Ethernet network has redundant fiber paths to all substations utilizing Cisco switches and Gigabit connections. Protocols used from the IFix server are DNP and Modbus, both over Ethernet. End devices for monitoring and or control consist of the following:

- Modicon Momentum PLC's connected via Ethernet. I/O options are Digital In, Digital Out, and Analog In. They may be used for alarm status points, breaker status points, and breaker control or misc. analog signal inputs. Breaker control would be a digital out from iFix that pulses a digital out on the PLC that operates a 24VDC relay that operates the breaker. The used protocol is Modbus/TCP.
- SEL 751 relays connected via Ethernet. The system polls and accepts report on exception messages for breaker status, relay target values, analog metering values and physical inputs. Breaker and reclosing function control is achieved via Digital Out blocks from iFix to Remote Bits in the relay that pulse physical outputs to operate the breaker. The used communication is DNP over Ethernet.
- Communication to a SEL 2030 communication processor is via Ethernet. The communication processors then communicate to relays via serial RS232 to the relay, typically at 19200 baud. Relays connected to the 2030 consist of ABB DPU2000, ABB DPU2000R, ABB TPU2000, ABB TPU2000R, SEL 321, SEL 311, SEL 351, SEL 501, and SEL387. Protocol to the 2030 from iFix is DNP over Ethernet.
  - The ABB comms for polling are ASCII Modbus serial commands to the relay, the return messages are parsed and moved to data regions in the SEL 2030. The data region is then polled via Modbus/TCP from the iFix server. Control to ABB relays is a digital out from the iFix server to a remote bit on the SEL2030 that triggers an ASCII Modbus serial message to the relay that pulses a physical output for breaker control.
  - SEL serial comms utilize SEL commands on the 2030 for polling and control, such as 20METER, 20TARGET, FASTMETER, etc. The values are then moved to a data region for polling from the iFix server. Control to SEL relays is a digital out from iFix to a remote bit on the 2030 which triggers a FastOper message to the relay that pulses a physical output for breaker control.
- Most devices at Steele St. and Dow St. are connected via SEL 2030 communication processors. Control is done via a communication message on the serial port as described above. Some breaker control on the 35kV breakers is handled thru a PLC output as described above.

The implementation of a microgrid requires the integration of communications to enable the control architecture necessary for safety, security, reliability, sustainability, and cost-effectiveness. Control system networks implemented for microgrids will leverage the Internet protocol suite of communications protocols, including communications at the link, internet, transport, and application layers. The Internet protocol suite is commonly known as Transmission Control Protocol/Internet Protocol (TCP/IP); however, microgrid control system networks employ several different protocols to enable communication between the many types of power and cyber actors. TABLE 2.9 describes the purpose of communication at each layer in the protocol stack and presents the various protocols that may be found in a microgrid control system network. Additionally, security protocols, such as TLS/SSL, may be used at any layer to protect data sent between applications and hosts.

Application layer protocols support process-to-process communication and rely on transport and internet layer protocols to establish and maintain the host-to-host connections between hosts running the processes. The microgrid control system network will include both SCADA application protocols and other general-use application protocols. Many common application protocols, such as DHCP, Domain Name System (DNS), and Network Time Protocol (NTP), are used for network management and are found in typical information technology (IT) networks in addition to control system networks.

Table 2.9. Communication protocol stack.

| Layer | Purpose | Protocols |
|---|---|---|
| **Application** | Process-to-process communication: allows applications on the same or different hosts to share data. | DHCP, DNS, HTTP, NTP, SSH, XML-RPC; Control system-specie: DNP3, Modbus, LonTalk; proprietary protocols developed by vendors of micro-EMSs |
| **Transport** | Host-to-host communication: allows for different hosts to communicate on either the same network or on networks separated by routers. | TCP, UDP |
| **Internet** | Internetwork communication: allows for host-to-host communication across network boundaries through intervening routers. | IP (IPv4, IPv6), IPsec |
| **Link** | Local network communication: allows for host-to-host communication without intervening routers. | Ethernet, serial |

Transport layer protocols support host-to-host communication that is hardware independent. The two most common transport layer protocols are Transmission Control Protocol (TCP), which is connection-oriented, and User Datagram Protocol (UDP), which is considered connectionless. Employment of either TCP or UDP within a microgrid control system network is based primarily on the importance of speed versus reliability and the necessity for error detection.

Internet layer communication protocols support internetworking; they allow for hosts to communicate across network boundaries through intervening routers. The Internet Protocol (IP) is the principal component of the internet layer, and as such, will be employed in the microgrid controls system. IP version 4 (IPv4) is the dominant protocol of the Internet, but its successor, IP version 6 (IPv6) is seeing increased use. IPv6 provides many features that can be useful for the creation of enclaves in a microgrid control system network. The prominent difference between the two IP versions is their respective host addressing systems: IPv4 uses 32-bit addresses while IPv6 uses 128-bit addresses.

Link layer protocols support local network communication, allowing hosts to communicate without intervening routers. For example, communication between an HMI and its server will likely occur over Ethernet, but many power actors, such as generator controllers, may only be able to send data and receive commands via a serial connection. The protocols employed at the link layer will be dependent on the hardware implementation of the microgrid.

## 2.6. MAJOR EQUIPMENT COST

In the previous section, we mentioned that there is a minimum cost to establish the Jamestown Microgrid. Based on the proposed architectures for the Jamestown Microgrid, TABLE 2.10 lists the anticipated major equipment needed to implement the microgrid. The associated cost for each equipment in the table is an estimated cost and does not include the engineering, programming and other soft cost related to installing and operation of the microgrid. The O&M cost in the table is estimated based on the best engineering practices.

| Major Component | Description | Quantity | Total Cost ($) |
|---|---|---|---|
| **Voltage Transformer** | Three 34.5 kV/120 V transformers for each breaker (S505 & S507) | 6 | 80,000 |
| **Current Transformer** | Three 34.5 kV 1200:5 transformers for e each breaker (S505 & S507) | 6 | 78,000 |
| **Energy Management System** | SEL PowerMax – microprocessor based computing platform, communication processor, HMI, load shedding processor, generator control system processor, rugged computer | 1 | 65,000 |
| **Relay** | SEL-751A for S505 & S507 | 2 | 10,000 |
| **Black Start Generator** | 750 kW natural gas | 1 | 195,000 |
| **Hard-Wired Circuit Breaker Control Circuits** | | 1 | 28,000 |
| **Phasor Measurement Unit** | SEL 451-4 & SEL 2407 | 3 | 19,100 |
| **Synchrophasor Vector Processor** | SEL 3378 | 1 | 22,000 |
| **Synchrophasor Data Concentrator** | SEL 3373 | 1 | 9,500 |
| **O&M Cost** | | | 60,000 |
| | | **TOTAL** | **$566,600** |

# Task 3

# TASK 3 – ASSESSMEMT OF MICROGRID'S COMMERCIAL & FINANCIAL FEASIBILITY

## 3.1 COMMERCIAL VIABILITY – JBPU MICROGRID

Key benefits of deploying the microgrid are the improvement of system robustness, resiliency and security during an emergency situation. JBPU is the load serving entity (LSE) responsible to physically deliver electricity throughout the City of Jamestown and the surrounding communities of Celoron, Falconer and the Town of Ellicott. Nearly half of the JBPU customers representing more than 10,000 individuals will be directly connected to the proposed microgrid. Because the microgrid also serves many critical customers directly through resilient underground feeders (S704, S710, S712 and S904), 100% of the JBPU service area including all JBPU customers will directly or indirectly benefit by the microgrid's operation. For example, the population matrix served by the proposed microgrid covers different types of loads including hospital/healthcare, shelter, municipal, police station, fire department, DPW, utility, water treatment, banks, gas/fuel, schools, shopping, hotels, housing, communications, restaurants, food bank/mission and residents. JBPU, as the owner and operator of the microgrid, will serve the widest array of possible customers in the proposed microgrid. In an extended emergency it is feasible that, based on the availability of the overhead feeders and generation capacity, a very high percentage of JBPU customers will be served. The priority list of the loads connected to the overhead feeders will be calculated in a subsequent phase of the project. It is worth mentioning that thermal energy will also be supplied to the microgrid's customers during islanded microgrid operation.

The proposed communication and control structure for the microgrid will not readily enable the JBPU to interact with wholesale electrical energy markets, such as the NYISO, to gain external financial benefits. Though some aspects of a more sophisticated enhanced microgrid could enable JBPU to perform activities like peak shaving or demand response through load shedding, the existing markets do not recognize the financial value of such activities. Therefore, normal microgrid operation will not generally create cost recovery mechanisms directly tied to offset the additional expenses associated with this capability. Though technically feasible, in order to investigate the potential financial benefits of items such as energy storage, load factor improvement strategies and microgrid islanding capabilities, further study and market reforms will be needed.

Assumptions made by the JBPU for the initial microgrid are that the associated installation costs as well as fixed ongoing operation and maintenance expense will be added to the utility's base expense used to calculate rates paid by all customers. When the microgrid is operated in island mode, the variable costs incurred including items such as fossil fuel, shall be charged to all JBPU customers through the current procedures approved by the PSC for variable cost recovery. As such, any impacts to the JBPU and its customers related to new commercial or contractual requirements are expected to be minor. As the JBPU's regulatory authority, the approval of the New York State PSC is expected to be required before the JBPU is able to proceed with microgrid implementation.

## 3.2 COMMERCIAL VIABILITY – VALUE PROPOSITION

The JBPU is a non-profit municipal electric utility directed by a nine (9) member politically appointed Board. The utility falls under the jurisdiction of the New York State Public Service Commission for the purposes of rate structuring and the authorization to charge customers. The JBPU rates are broken into three general components: 1) fixed monthly service charge; 2) energy/demand charges allocated based on metered Kwh/Kw; 3) variable commodity charges allocated based on metered Kwh. Rate components #1 and #2 are intended to allow the JBPU to recover its fixed operating, capital and maintenance costs. Rate component #3 is intended to allow the JBPU to recover its variable costs associated with the procurement of wholesale energy.

The cost impacts of the Jamestown microgrid are expected to be relatively minor when compared to other potential projects capable of serving a similar number of customers. The main infrastructure components needed already exist. That means there will be no major construction activities. For example, the several underground distribution feeders which will be used as a part of the resilient electric power system have been in use for many years and the only added costs required are control equipment related.

The addition of islanding capability to the Jamestown system will create a microgrid that results in enhancements to the reliability and robustness of the electrical distribution system. This proposed microgrid could supply electrical energy to JBPU customers which would be roughly equal to 10,000 individuals as well delivering thermal energy to approximately 73 buildings in the downtown Jamestown area. A portion of the electrical customers will be served by the network of extremely resilient underground feeders encompassing different types of loads including hospital/healthcare, shelter, municipal, police station, fire department, DPW, utility, water treatment, banks, gas/fuel, schools, hotels, housing, communications, restaurants, food bank/mission and residents. As mentioned earlier, most components of the proposed microgrid already exist and are in use. Minor upgrades to the existing electric infrastructure include adding the following items:

- Voltage and current transformers;
- Energy management system;
- Black start generator;
- Relays and circuit breakers;
- Phasor measurement units;
- Synchrophasor vector processor;
- Synchrophasor data concentrator.

The items listed above, totaling approximately $650,000 in capital investment, represent the major cost drivers associated with the implementation of a Jamestown microgrid. Though significant, the nature of these improvements is such that construction related activities and employment will be modest and of short duration with minor overall impact on the local economy.

The proposed microgrid's benefits are not limited merely to improving resiliency of the electrical system and the array of community services that will swell from this resource such as emergency responder support, healthcare service support and community shelter support. The proposed communication and control architecture of this project will enable the JBPU to demonstrate real world solutions associated with synchronizing variable load to generation output in real time dynamic conditions. In addition, as markets reform, the JBPU will be positioned to participate in activities even when the system is in normal condition. As mentioned earlier, the potential addition of energy storage devices (ESD), for example, could not only improve the JBPU's load factor which results in utilization efficiency improvements, but may also allow for cost recovery through other mechanisms and save considerable amounts of money for the JBPU customers.

An analysis for understanding internal and external factors that may support or hinder JBPU's ability to implement the proposed microgrid was performed. The Strengths Weaknesses Opportunities Threats (SWOT) Analysis below highlights the initial findings and will support strategy definition through project maturation. The strategy that results from the SWOT analysis highlights the opportunities and strengths of the project. However there are very few weaknesses and threats which are mostly based on low recovery cost.

<table>
<tr><th>STRENGTHS</th><th>WEAKNESSES</th></tr>
<tr><td>
<ul>
<li>Jamestown is the central hub for the western NY region;</li>
<li>Existence of an easily adaptable electric power system to be islanded by operating few breakers;</li>
<li>Most of the major components of the microgrid are already in place. Therefore the primary cost impacts of the microgrid on JBPU customers is expected to be minor;</li>
<li>Existence of several underground resilient distribution feeders;</li>
<li>Existence of reliable natural gas supply;</li>
<li>Existence of district heat system which enables JBPU to provide thermal energy as well as electrical energy during any emergency events;</li>
<li>Existence of 43 MW generator which can be used as the source of energy for the proposed microgrid;</li>
<li>Since JBPU is the sole owner and operator of the system, no environmental studies or special permits are needed for the project to proceed;</li>
</ul>
</td><td>
<ul>
<li>The operation of the 43 MW generator assigned to the proposed microgrid is limited due to the applicable emission regulations;</li>
</ul>
</td></tr>
<tr><th>OPPORTUNITIES</th><th>THREATS</th></tr>
<tr><td>
<ul>
<li>The proposed microgrid in this project can be used in other municipal utilities in the state;</li>
<li>The proposed microgrid can be a great example to demonstrate NY REV goals;</li>
<li>The proposed microgrid could serve as a national practice for other microgrid programs such as SPIDERS;</li>
<li>Facilitating applying FERC Orders 784 and 755 by accommodating new market mechanisms in NYISO territory.</li>
</ul>
</td><td>
<ul>
<li>Low cost recovery due to lack of supportive market mechanism in NYISO territory;</li>
<li>Current rate structure is not in favor of implementing microgrid.</li>
</ul>
</td></tr>
</table>

The city of Jamestown has several characteristics which make it unique when compared to other locations. JBPU already possesses an LM6000 natural gas-fired electric generator which can be utilized as the source of energy in the proposed microgrid. The unit's natural gas fuel supply is provided from a natural gas engine driven compressor station located in a rural area approximately twenty eight miles west of Jamestown. This facility's operation inherently creates a robust and resilient source of fuel for the LM6000 unit. The Carlson Station also houses two natural gas-fired hot water thermal energy generators making it a combined heat and power (CHP) resource for 73 buildings in the immediate downtown area. Therefore, JBPU will also be able to provide District Heating service to the foundation of customer buildings in the proposed microgrid area. There are several underground resilient distribution feeders already in service within Jamestown's distribution system. When all these assets are taken together, most components of the proposed microgrid currently exist and there is no need for major investment and construction on site. These characteristics make the Jamestown microgrid the best candidate for microgrid implementation within a short period of time and with minimal impact.

The Jamestown area serves as a central hub for the western NY region beyond Buffalo, providing societal services such as health care, jobs and etc. Considering its geographical location, extreme weather events including heavy lake effect snow regularly occur. The NGrid 115kV electrical transmission system has had a history of causing outages that have significantly impacted all JBPU customers. Considering the discussed unique characteristics of Jamestown, the proposed microgrid represents a viable, practical, economical and scalable solution to improve the resiliency of the energy infrastructure.

FIGURE 3.1 shows the scalability of the proposed microgrid at three levels: Local; State; and Federal. There are more than 40 municipal utilities in NY State which have similar characteristics. The proposed communication and control architecture for the Jamestown microgrid can be applied to all areas of them. This would position the state as the most robust and resilient in the entire country. Other local utility companies can mimic the same approach to implement a common understanding of a microgrid in their territories. This contemplates a more active and dynamic energy system where energy sources are more closely located to load. This project is one of the best demonstrations of the vision New York State is trying to achieve through REV. In addition, the project will be well positioned when the NYISO enhances its market mechanisms to accommodate new technologies such as energy storage systems. At the federal level, the proposed microgrid architecture can support FERC's requirements in FERC orders 784 and 755. The Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) Joint Capability Technology Demonstration (JCTD) is another federal level program initiated by the Department of Defense (DoD) and the Department of Energy (DoE) to protect task-critical assets from loss of power due to cyber-attack, integrate renewable and other distributed energy generation concepts to power task-critical assets in times of emergency, sustain critical operations during prolonged power outages, and manage installation electrical power and consumption efficiency to reduce petroleum demand, carbon foot print and cost. The proposed microgrid architecture for Jamestown could be applied as a general practice for all sites in the SPIDERS program.

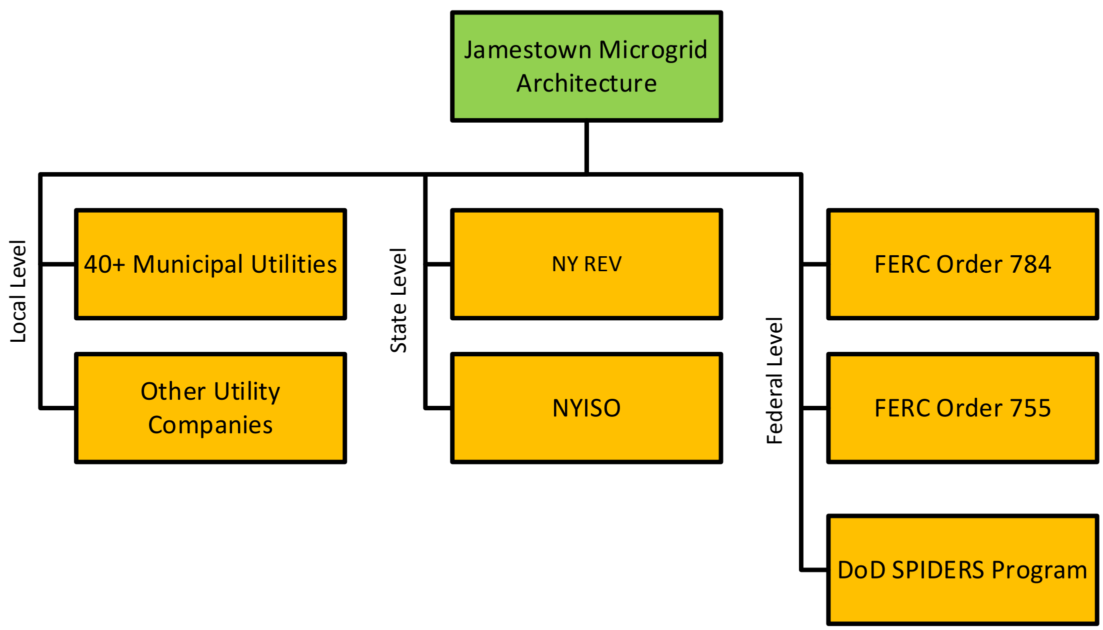



**Figure 3.1. Proposed Jamestown microgrid scalability.**

### 3.3 COMMERCIAL VIABILITY – PROJECT TEAM

In this project, the JBPU will be the sole owner of the microgrid including electrical and thermal generation and distribution systems. As a community owned system the JBPU will be well positioned to engage its customers and leverage their support to maximize the value to the area. Other potential stakeholders include the New York Public Service Department who regulates JBPU rates, and O'Brien and Gere as the engineering contractor who will provide technical support to design and implement the proposed microgrid.

### 3.4 COMMERCIAL VIABILITY – CREATING AND DELIVERING THE VALUE

All of the technologies for the proposed microgrid were chosen based on the list of characteristics delineated in Section 2 of this document. The proposed communication, measurement and control architecture was designed in a way to be fully automated, self-healing, interactive with customers and able to do the transition from grid-tied mode to island mode and vice versa, seamlessly. The proposed architecture is a comprehensive platform which can accommodate any future upgrade in the system such adding new distributed generators (e.g. PV or wind) or new loads.

Since most of the assets required for microgrid implementation already exist, the project would not need major investment and construction. JBPU already possesses an LM6000 natural gas-fired electric generator which can be utilized as the source of energy in the proposed microgrid. The unit's natural gas fuel supply is provided from a resilient compressor station. The facility also houses two natural gas-fired hot water thermal energy generators making it a CHP resource for 73 buildings in the immediate downtown area. The distribution system has several underground resilient feeders which are already in service and will be utilized by the proposed microgrid. Therefore, no environmental studies or special permits are needed for the project to proceed, though prudency justification will need to be demonstrated to customers and the PSC. It is advisable that entities such as National Grid and the NYISO be engaged at an early time to ensure their support and benefit from their input.

Once the microgrid project is approved for potential development, including authorization by the JBPU Board, funding sources shall be sought and when secured, the technical design shall be initiated. Upon receiving final regulatory authorization to proceed, project execution shall involve the competitive bidding of equipment components and where applicable, component installation. With the technical assistance of the overall project team the microgrid will be commissioned and tested. Costs incurred, including those associated with ongoing operation and maintenance shall be recovered through a modification of JBPU electric rates. When an actual microgrid islanding event occurs, JBPU technical personnel shall operate the necessary equipment and maximize the benefit it provides to the widest array of customers possible under the emergency circumstances that exist throughout the event. As all JBPU customers shall benefit from the microgrid's existence and operational capabilities, all customers shall pay a share of the associated costs through PSC approved rate structures.

### 3.5 FINANCIAL VIABILITY

As a central hub for the western NY region beyond Buffalo, the City of Jamestown and surrounding area served by the JBPU encompass resources whose functions are essential to modern life. Considering its geographical location, extreme weather events including heavy lake effect snows that regularly occur, and the fact that the NGrid 115kV electrical transmission system in the region has had a history of causing outages that have significantly impacted all JBPU customers, the creation of an "island ready microgrid" within the JBPU service area is of societal value . Considering the unique characteristics of the JBPU infrastructure and the modest capital and operational costs needed to create such a system, the proposed microgrid represents a viable, practical, economic and scalable solution to improve the resiliency of the energy infrastructure in the area.

Because the existing structure of the NYISO wholesale market does not currently enable cost recovery for the proposed microgrid, it is possible that the JBPU will be unable to justify project advancement. To overcome this barrier the modest costs of implementing a system could be distributed on a societal basis. This could occur through a combination of outside funding for capital investment, as well as operational and variable cost recovery through PSC approved electric rates applied to all JBPU customers. With these provisions in place the overall project is deemed financially viable on both short and long-term basis. To provide further benefits beyond a basic "island ready system," much more extensive costs will be incurred to support the addition of another CHP generation source at Carlson Station or to advance REV related objectives. Significant subsidies are likely to be needed to cost justify such advancements.

### 3.6 LEGAL VIABILITY

In this project, the JBPU is the only owner and operator of the microgrid. The JBPU already possess the generation facilities, the district heat facilities, the energy distribution resources, all necessary permits and the majority of regulatory approvals needed to make the microgrid viable. These unique characteristics of Jamestown make the installation process easier than cases where multiple stockholders and layers of regulatory approval are involved. All customers purchase power from JBPU and all will benefit from the creation of an island ready microgrid. The overall project is therefore deemed viable from a legal perspective. However, regulatory oversight from the PSC will require prior approval and potentially, legal expense to justify project advancement and cost recovery mechanisms including rate adjustments.

# Task 4

# TASK 4: BENEFIT-COST ANALYSIS SUMMARY

The following Benefit-Cost Analysis Summary was provided to the project team by Industrial Economics (IEc), a NYSERDA consultant for NY Prize. The analysis was performed based on assumptions and inputs shown in the attached Microgrid Questionnaire (Appendix) and through subsequent discussions with IEc.

## 4.1 PROJECT OVERVIEW

As part of NYSERDA's NY Prize community microgrid competition, the City of Jamestown has proposed a microgrid that will utilize existing power generation equipment located at Carlson Station. To assist with completion of the project's NY Prize Stage 1 feasibility study, IEc conducted a screening-level analysis of the project's potential costs and benefits. This report describes the results of that analysis.

As proposed, the microgrid would serve a large number of residential, commercial, industrial, and critical service facilities within the City of Jamestown, comprising approximately 45 percent of the load of the Jamestown Board of Public Utilities service area. Currently, this area is served by Carlson Station, a 43 MW natural gas electric generator, and by two natural gas thermal generators (5 MW and 22 MW). Carlson Station is capable of supporting the entire electrical load of the surrounding facilities; as a result, the microgrid design does not call for the addition of new generation assets. The design instead focuses on upgrading system controls and its interconnection to National Grid's network to improve service reliability in the event of a National Grid outage. The project's design also calls for the addition of a black start generator to allow Carlson Station to start up independently in the event of an outage.

Based on information provided by the project team, the benefit-cost analysis (BCA) assumes that, following development of the microgrid, Carlson Station would continue to operate as it does currently. In the event of an outage, development of the microgrid would allow Carlson Station to seamlessly switch from operating in grid-connected mode to islanded mode, thus avoiding a short-term break in power while re-energizing the generator. The only change in operations expected following development of the microgrid is the ability to provide power without interruption during an outage caused by a break outside the microgrid's service area.

## 4.2 METHODOLOGY AND ASSUMPTIONS

In discussing the economic viability of microgrids, a common understanding of the basic concepts of benefit-cost analysis is essential. Chief among these are the following:

- *Costs* represent the value of resources consumed (or benefits forgone) in the production of a good or service.
- *Benefits* are impacts that have value to a firm, a household, or society in general.
- *Net benefits* are the difference between a project's benefits and costs.
- Both costs and benefits must be measured relative to a common baseline - for a microgrid, the "without project" scenario - that describes the conditions that would prevail absent a project's development. The BCA considers only those costs and benefits that are incremental to the baseline.

This analysis relies on an Excel-based spreadsheet model developed for NYSERDA to analyze the costs and benefits of developing microgrids in New York State. The model evaluates the economic viability of a microgrid based on the user's specification of project costs, the project's design and operating characteristics, and the facilities and services the project is designed to support. Of note, the model analyzes a discrete operating scenario specified by the user; it does not identify an optimal project design or operating strategy.

The BCA model is structured to analyze a project's costs and benefits over a 20-year operating period. The model applies conventional discounting techniques to calculate the present value of costs and benefits, employing an annual discount rate that the user specifies – in this case, seven percent.[1] It also

[1] This rate is consistent with the U.S. Office of Management and Budget's current estimate of the opportunity cost of capital for private investments.

calculates an annualized estimate of costs and benefits based on the anticipated engineering lifespan of the system's equipment. Once a project's cumulative benefits and costs have been adjusted to present values, the model calculates both the project's net benefits and the ratio of project benefits to project costs. The model also calculates the project's internal rate of return, which indicates the discount rate at which the project's costs and benefits would be equal. All monetized results are adjusted for inflation and expressed in 2014 dollars.

With respect to public expenditures, the model's purpose is to ensure that decisions to invest resources in a particular project are cost-effective; i.e., that the benefits of the investment to society will exceed its costs. Accordingly, the model examines impacts from the perspective of society as a whole and does not identify the distribution of costs and benefits among individual stakeholders (e.g., customers, utilities). When facing a choice among investments in multiple projects, the "societal cost test" guides the decision toward the investment that produces the greatest net benefit.

The BCA considers costs and benefits under two scenarios:

- **Scenario 1**: No major power outages over the assumed 20-year operating period (i.e., normal operating conditions only).
- **Scenario 2:** The expected frequency and duration of major power outages required for project benefits to equal costs, if benefits do not exceed costs under Scenario 1.[2]

## 4.3 RESULTS

TABLE 4.1 summarizes the estimated net benefits, benefit-cost ratios, and internal rates of return for these scenarios. The results suggest that even if there are no major power outages over the microgrid's assumed 20-year operating life, project benefits would outweigh project costs by a factor of approximately 18; as a result, the analysis does not evaluate Scenario 2. Consideration of Scenario 2 would further increase the project's already positive benefit-cost ratio.

**Table 4.1: BCA Results (Assuming 7 Percent Discount Rate)**

| Economic Measure | Expected Duration of Major Power Outages | |
|---|---|---|
| | **Scenario 1: 0 Days/Year** | **Scenario 2** |
| **Net Benefits - Present Value** | $29.3 million | Not Evaluated |
| **Net Benefits - Annualized** | $2.59 million | Not Evaluated |
| **Benefit-Cost Ratio** | 18.0 | Not Evaluated |
| **Internal Rate of Return** | N/A | Not Evaluated |

FIGURE 4.1 and TABLE 4.2 present the detailed results of the Scenario 1 analysis. As described in the discussion that follows, the analysis notes the possibility that the microgrid could provide ancillary services, such as black start support, voltage support, or frequency regulation, to the New York Independent System Operator (NYISO), but does not attempt to estimate the value of these services. Quantification of the project's potential ancillary service benefits could further improve the results of the BCA. Based on discussions with NYISO, however, we anticipate that the value of these benefits would be small.

[2] The New York State Department of Public Service (DPS) requires utilities delivering electricity in New York State to collect and regularly submit information regarding electric service interruptions. The reporting system specifies 10 cause categories: major storms; tree contacts; overloads; operating errors; equipment failures; accidents; prearranged interruptions; customers equipment; lightning; and unknown (there are an additional seven cause codes used exclusively for Consolidated Edison's underground network system). Reliability metrics can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's control. In estimating the reliability benefits of a microgrid, the BCA employs metrics that exclude outages caused by major storms. The BCA classifies outages caused by major storms or other events beyond a utility's control as "major power outages," and evaluates the benefits of avoiding such outages separately.

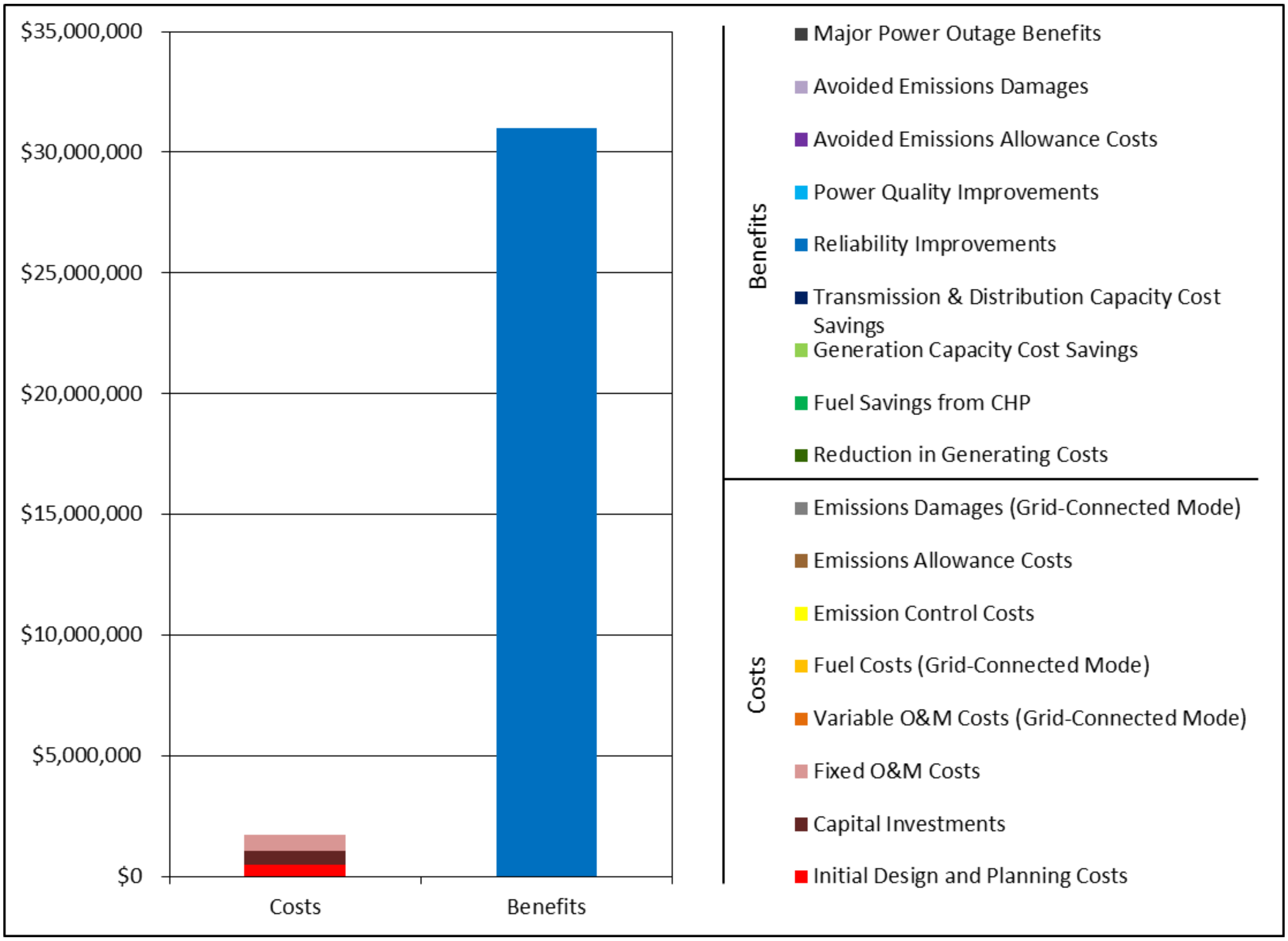



**Figure 4.1: Present Value Results (No Major Power Outages; 7 Percent Discount Rate)**

**Table 4.2: Detailed BCA Results (No Major Power Outages; 7 Percent Discount Rate)**

| Cost or Benefit Category | Present Value Over 20 Years (2014$) | Annualized Value (2014$) |
|---|---|---|
| **Costs** | | |
| Initial Design and Planning | $506,000 | $44,600 |
| Capital Investments | $540,000 | $41,900 |
| Fixed O&M | $680,000 | $60,000 |
| Variable O&M (Grid-Connected Mode) | $0 | $0 |
| Fuel (Grid-Connected Mode) | $0 | $0 |
| Emission Control | $0 | $0 |
| Emissions Allowances | $0 | $0 |
| Emissions Damages (Grid-Connected Mode) | $0 | $0 |
| **Total Costs** | **$1,730,000** | **$147,000** |
| **Benefits** | | |
| Reduction in Generating Costs | $0 | $0 |
| Fuel Savings from CHP | $0 | $0 |
| Generation Capacity Cost Savings | $0 | $0 |
| Transmission & Distribution Capacity Cost Savings | $0 | $0 |
| Reliability Improvements | $31,000,000 | $2,730,000 |
| Power Quality Improvements | $0 | $0 |
| Avoided Emissions Allowance Costs | $0 | $0 |
| Avoided Emissions Damages | $0 | $0 |
| Major Power Outage Benefits | $0 | $0 |
| **Total Benefits** | **$31,000,000** | **$2,730,000** |
| **Net Benefits** | **$29,300,000** | **$2,590,000** |
| **Benefit/Cost Ratio** | **18.0** | |
| **Internal Rate of Return** | **n/a** | |

### Fixed Costs

The BCA relies on information provided by the project team to estimate the fixed costs of developing the microgrid. The project team's best estimate of initial design and planning costs is approximately $506,000. The present value of the project's capital costs is estimated at approximately $540,000, including costs associated with installing an energy management system, black start generator, and other microgrid controls and infrastructure (e.g., phasor measurement units, transformers, relays, etc.). The present value of the microgrid's fixed operations and maintenance (O&M) costs (i.e., O&M costs that do not vary with the amount of energy produced) is estimated at $680,000.

### Variable Costs

To estimate the variable costs of operating the microgrid, the BCA relies on information provided by the project team and projections of fuel costs from New York's State Energy Plan (SEP). In this case, the project team estimates the variable O&M costs associated with new microgrid controls and other new infrastructure to be zero. Because operations under normal conditions are not expected to change following development of the proposed microgrid, incremental fuel costs are also zero.

The analysis of variable costs also considers the environmental damages associated with any changes in emissions from the distributed energy resources that serve the microgrid, based on emissions rates provided by the project team and the understanding that Carlson Station would not be subject to emissions allowance requirements. In this case, operations under normal conditions are not expected to change following development of the microgrid; thus, the estimate of incremental environmental damages is zero.

### Avoided Costs

The development and operation of a microgrid may avoid or reduce a number of costs that otherwise would be incurred, including electricity generating costs, fuel costs, emissions allowance costs, and emissions damages. In this case, however, operations under normal conditions are not expected to change following development of the proposed microgrid; thus, avoided costs are zero.

The project team has indicated that the proposed microgrid will be designed to provide ancillary services, including black start support, voltage support, and frequency regulation, to NYISO. If the Jamestown microgrid is selected to provide these services (e.g., because it can do so at a lower cost than other available resources), the microgrid may offer societal cost savings associated with the provision of these services. The quantity of ancillary services the microgrid would provide is dependent on NYISO's demand for such services and the operating costs of other available resources. In light of these considerations, the analysis does not attempt to quantify the expected social benefit, but notes the potential for such cost savings to occur.

### Reliability Benefits

As described previously, the primary benefit of the proposed Jamestown microgrid is to reduce customers' susceptibility to power outages by enabling a seamless transition from grid-connected mode to islanded mode. The analysis estimates that development of a microgrid would yield reliability benefits of approximately $2.73 million per year, with a present value of $31.0 million over a 20-year operating period. This estimate is calculated using the U.S. Department of Energy's Interruption Cost Estimate (ICE) Calculator,[3] and is based on the following indicators of the likelihood and average duration of outages in the service area:

- System Average Interruption Frequency Index (SAIFI) – 0.92 events per year.
- Customer Average Interruption Duration Index (CAIDI) – 118.2 minutes.[4]
- The estimate is further based on:
- U.S. Census Bureau data on the number of households and businesses within the City of Jamestown;
- U.S. Census Bureau data on the median household income within the City of Jamestown;
- Information provided by the project team on the average hourly electricity load for the area to be served by the microgrid, adjusted by IEc to average annual load; and
- New York State-specific default values from the ICE Calculator on the ratio of small to large commercial and industrial customers; the distribution of commercial and industrial customers among industries; average annual electricity usage per customer, scaled by IEc to align with the average annual aggregate load provided by the project team; and the prevalence of backup generation among customers.

The estimate of reliability benefits takes into account the capabilities of existing backup power systems. It also takes into account the variable costs of operating existing backup generators, both in the baseline and as an integrated component of a microgrid. Under baseline conditions, the analysis assumes a 15 percent failure rate for backup generators.[5] It assumes that establishment of a microgrid would reduce the rate of failure to near zero.

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[3] www.icecalculator.com.

[4] The SAIFI and CAIDI values employed in this analysis were provided by the project team.

[5] http://www.businessweek.com/articles/2012-12-04/how-to-keep-a-generator-running-when-you-lose-power#p1.

Of note, the analysis of reliability benefits also assumes that all outages captured in SAIFI and CAIDI result from grid-level problems that could be avoided by development of a microgrid. To the extent that outages are caused by problems in the local distribution network, development of a microgrid may not be able to avoid these outages entirely, and the BCA may overstate the value of reliability benefits.

### Benefits in the Event of a Major Power Outage

The estimate of reliability benefits presented above does not include the benefits of maintaining service during outages caused by major storm events or other factors generally considered beyond the control of the local utility. These types of outages can affect a broad area and may require an extended period of time to rectify. To estimate the benefits of a microgrid in the event of such outages, the BCA methodology is designed to assess the impact of a total loss of power – including plausible assumptions about the failure of backup generation – on the facilities the microgrid would serve. It calculates the economic damages that development of a microgrid would avoid based on (1) the incremental cost of potential emergency measures that would be required in the event of a prolonged outage, and (2) the value of the services that would be lost.[6,7]

As noted above, the Jamestown microgrid would serve a large number of residential, commercial, industrial, and critical service facilities, including fire, emergency medical, hospital, police, wastewater, and water services. In the event of a prolonged power outage, development of the microgrid would allow Carlson Station to seamlessly switch from operating in grid-connected mode to islanded mode, thus avoiding a short-term break in power while re-energizing the generator.

During a break in power, many of the services ordinarily provided by facilities served by Carlson Station would have to be provided by alternate facilities; for example, patients who would otherwise have sought emergency care at WCA Hospital in Jamestown would need to travel to an alternate facility, which the project team estimates to be approximately 36 miles away. Similarly, fire services and emergency medical services would need to be provided by alternate facilities approximately five miles away. The increased time that would be required for the next-closest provider to respond to an emergency is assumed to result in an increase in property damage and health impacts; development of a microgrid is assumed to avoid these impacts. Other critical services, such as police services, would experience a reduction in effectiveness in the event of a prolonged outage, thus resulting in an increase in property and violent crime. For wastewater, water, and electric power services, the BCA methodology assumes that the population served by each provider would be left without the service and estimates the impact of the lost service on economic activity (for commercial users) and on social welfare (for residential users).[8]

In the case of the Jamestown microgrid, the results of the BCA suggest that even if there are no major power outages over the microgrid's assumed 20-year operating life, project benefits would substantially outweigh project costs. Consequently, the analysis did not evaluate major power outage benefits. Consideration of such benefits would further increase the net benefits of the project's development.

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[6] The methodology used to estimate the value of lost services was developed by the Federal Emergency Management Agency (FEMA) for use in administering its Hazard Mitigation Grant Program. See: FEMA Benefit-Cost Analysis Re-Engineering (BCAR): Development of Standard Economic Values, Version 4.0. May 2011.

[7] As with the analysis of reliability benefits, the analysis of major power outage benefits assumes that all outages result from grid-level problems that could be avoided by development of a microgrid. To the extent that major power outages are caused by problems in the local distribution network, development of a microgrid may not be able to avoid these outages entirely, and the BCA may overstate the value of major power outage benefits.

[8] In some instances, application of the FEMA methodology may result in double-counting the impact of a prolonged outage on economic activity. For example, some businesses may depend on both electric and water service to operate and would shut down when either service is lost. By including the loss of this economic activity in its analyses of impacts to both electric and water services, the BCA may double-count impacts.

# Appendix

# NY Prize Benefit-Cost Analysis: Microgrid Questionnaire

This questionnaire solicits information on the community microgrid you are proposing for the NY Prize competition. The information in this questionnaire will be used to develop a preliminary benefit-cost analysis of the proposed microgrid. Please provide as much detail as possible. The questionnaire is organized into the following sections:



If you have any questions regarding the information requested, please contact Industrial Economics, Incorporated, either by email (NYPrize@indecon.com) or phone (929-445-7641).

Microgrid site: 83. City of Jamestown

Point of contact for this questionnaire:

Name: Neil Webb

Address:

Telephone: 315-569-1599

Email: Neil.Webb@obg.com

## *A. Project Overview, Energy Production, and Fuel Use*

1. The table below is designed to gather background information on the facilities your microgrid would serve. It includes two examples: one for Main Street Apartments, a residential facility with multiple utility customers; and another for Main Street Grocery, a commercial facility. Please follow these examples in providing the information specified for each facility. Additional guidance is provided below.

   - **Facility name:** Please enter the name of each facility the microgrid would serve. Note that a single **facility** may include multiple **customers** (e.g., individually-metered apartments within a multi-family apartment building). When this is the case, you do not need to list each customer individually; simply identify the facility as a whole (see Table 1, “Main Street Apartments,” for an example).

- **Rate class:** Select the appropriate rate class for the facility from the dropdown list. Rate class options are residential, small commercial/industrial (defined as a facility using less than 50 MWh of electricity per year), or large commercial/industrial (defined as a facility using 50 or more MWh of electricity per year).
- **Facility/customer description:** Provide a brief description of the facility, including the number of individual customers at the facility if it includes more than one (e.g., individually-metered apartments within a multi-family apartment building). For commercial and industrial facilities, please describe the type of commercial/industrial activity conducted at the facility.
- **Economic sector:** Select the appropriate economic sector for the facility from the dropdown list.
- **Average annual usage:** Specify the average annual electricity usage (in MWh) **per customer**. Note that in the case of facilities with multiple, similar customers, such as multi-family apartment buildings, this value will be different from average annual usage for the facility as a whole.
- **Peak demand:** Specify the peak electricity demand (in MW) **per customer**. Note that in the case of facilities with multiple, similar customers, such as multi-family apartment buildings, this value will be different from peak demand for the facility as a whole.
- **Percent of average usage the microgrid could support in the event of a major power outage:** Specify the percent of each facility’s typical usage that the microgrid would be designed to support in the event of a major power outage (i.e., an outage lasting at least 24 hours that necessitates that the microgrid operate in islanded mode). In many cases, this will be 100%. In some cases, however, the microgrid may be designed to provide only enough energy to support critical services (e.g., elevators but not lighting). In these cases, the value you report should be less than 100%.
- **Hours of electricity supply required per day in the event of a major power outage:** Please indicate the number of hours per day that service to each facility would be maintained by the microgrid in the event of a major outage. Note that this value may be less than 24 hours for some facilities; for example, some commercial facilities may only require electricity during business hours.

| Facility Name | Rate Class | Facility/Customer Description (Specify Number of Customers if More Than One) | Economic Sector Code | Average Annual Electricity Usage Per Customer (MWh) | Peak Electricity Demand Per Customer (MW) | Percent of Average Usage Microgrid Could Support During Major Power Outage | Hours of Electricity Supply Required Per Day During Major Power Outage |
|---|---|---|---|---|---|---|---|
| *DPW Garage* | *Large Commercial/Industrial (>50 annual MWh)* | *Garage* | *All other industries* | 120 | 0.36 | *100%* | *24* |
| *JBPU Fueling Station* | *Small Commercial/Industrial (<50 annual MWh)* | *Fueling Station* | *All other industries* | 11 | 0.00 | *100%* | *24* |
| JBPU Operation Center | Large Commercial/Industrial (>50 annual MWh) | Utility Operation Center | *All other industries* | 438 | 0.12 | *100%* | *24* |
| WCA Hospital | Large Commercial/Industrial (>50 annual MWh) | Hospital | *All other industries* | 8,756 | 1.58 | *100%* | *24* |
| ST Susan's Kichen/WNY Food Bank | Large Commercial/Industrial (>50 annual MWh) | Food Service | *All other industries* | 493 | 0.13 | *100%* | *24* |
| Jamestown Area Medical Associatea Star Urgent Care | Large Commercial/Industrial (>50 annual MWh) | Health Care | *All other industries* | 1,312 | 0.40 | *100%* | *24* |
| JSB Ice Arena | Large Commercial/Industrial (>50 annual MWh) | Entertainment | *All other industries* | 3,288 | 0.78 | *100%* | *24* |
| Jamestown Housing Authorithy | Residential | Senior Housing | *Residential* | 638 | 0.13 | *100%* | *24* |
| Best Western | Large Commercial/Industrial (>50 annual MWh) | Hotel | *All other industries* | 377 | 0.13 | *100%* | *24* |
| Chadakoin Building | Residential | Residential | *Residential* | 345 | 0.02 | *100%* | *24* |
| Hotel Jamestown | Residential | Senior Housing | *Residential* | 1,407 | 0.29 | *100%* | *24* |
| Wellman Building | Residential | Residential | *Residential* | 708 | 0.04 | *100%* | *24* |
| YWCA | Large Commercial/Industrial (>50 annual MWh) | Recreational Facility | *All other industries* | 204 | 0.06 | *100%* | *24* |
| Covenant Manor | Residential | Senior Housing | *Residential* | 544 | 0.03 | *100%* | *24* |
| The Post Journal | Large Commercial/Industrial (>50 annual MWh) | Publication | *All other industries* | 1,608 | 0.40 | *100%* | *24* |

| Facility Name | Rate Class | Facility / Customer Description (Specify Number of Customers if More Than One) | Economic Sector Code | Average Annual Electricity Usage Per Customer (MWh) | Peak Electricity Demand Per Customer (MW) | Percent of Average Usage Microgrid Could Support During Major Power Outage | Hours of Electricity Supply Required Per Day During Major Power Outage |
|---|---|---|---|---|---|---|---|
| Jamestown High School | Large Commercial/Industrial (>50 annual MWh) | School | *All other industries* | 2,700 | 0.93 | *100%* | *24* |
| Windstream | Large Commercial/Industrial (>50 annual MWh) | Communication | *All other industries* | 1,787 | 0.29 | *100%* | *24* |
| City Hall with verixon Cell Tower | Large Commercial/Industrial (>50 annual MWh) | Communication | *All other industries* | 929 | 0.18 | *100%* | *24* |
| Time Warner Cable | Large Commercial/Industrial (>50 annual MWh) | Communication | *All other industries* | 611 | 0.10 | *100%* | *24* |
| Resource Centers | Large Commercial/Industrial (>50 annual MWh) | | *All other industries* | 1,750 | 0.45 | *100%* | *24* |
| Lakewood Water Pumpstation | Large Commercial/Industrial (>50 annual MWh) | Water Treatment | *All other industries* | 74 | 0.02 | *100%* | *24* |
| Smith Ave. Water Pumpstation | Large Commercial/Industrial (>50 annual MWh) | Water Treatment | *All other industries* | 93 | 0.03 | *100%* | *24* |
| Orr st. Water pumpstation | Small Commercial/Industrial (<50 annual MWh) | Water Treatment | *All other industries* | 46 | 0.02 | *100%* | *24* |
| Chautauqua County South and Center Sewer Treatment Plant | Large Commercial/Industrial (>50 annual MWh) | Water Treatment | *All other industries* | 1,381 | 0.03 | *100%* | *24* |
| Southwestern Central School | Large Commercial/Industrial (>50 annual MWh) | School | *All other industries* | 3,337 | 0.92 | *100%* | *24* |
| Sma's Club | Large Commercial/Industrial (>50 annual MWh) | Shopping | *All other industries* | 2,690 | 0.46 | *100%* | *24* |
| Wegman's | Large Commercial/Industrial (>50 annual MWh) | Shopping | *All other industries* | 4,349 | 0.82 | *100%* | *24* |
| Home Depot | Large Commercial/Industrial (>50 annual MWh) | Shopping | *All other industries* | 1,622 | 0.48 | *100%* | *24* |

| Facility Name | Rate Class | Facility / Customer Description (Specify Number of Customers if More Than One) | Economic Sector Code | Average Annual Electricity Usage Per Customer (MWh) | Peak Electricity Demand Per Customer (MW) | Percent of Average Usage Microgrid Could Support During Major Power Outage | Hours of Electricity Supply Required Per Day During Major Power Outage |
|---|---|---|---|---|---|---|---|
| Kmart | Large Commercial/Industrial (>50 annual MWh) | Shopping | *All other industries* | 1,054 | 0.28 | *100%* | *24* |
| Tanglewood Manor | Residential | Housing | *Residential* | 1,127 | 0.23 | *100%* | *24* |

2. In the table below, please provide information on the distributed energy resources the microgrid will incorporate. Use the two examples included in the table as a guide.

- **Distributed energy resource name:** Please identify each distributed energy resource with a brief description. In the event that a single facility has multiple distributed energy resources of the same type (e.g., two diesel generators), please use numbers to uniquely identify each (e.g., “Diesel generator 1” and “Diesel generator 2”).
- **Facility name:** Please specify the facility at which each distributed energy resource is or would be based.
- **Energy source:** Select the fuel/energy source used by each distributed energy resource from the dropdown list. If you select “other,” please type in the energy source used.
- **Nameplate capacity:** Specify the total nameplate capacity (in MW) of each distributed energy resource included in the microgrid.
- **Average annual production:** Please estimate the amount of electricity (in MWh) that each distributed energy resource is likely to produce each year, on average, **under normal operating conditions.** The benefit-cost analysis will separately estimate production in islanded mode in the event of an extended power outage. **If the distributed energy resource will operate only in the event of an outage, please enter zero.**
- **Average daily production in the event of a major power outage:** Please estimate the amount of electricity (in MWh per day) that each distributed energy resource is likely to produce, on average, **in the event of a major power outage.** In developing your estimate for each distributed energy resource, you should consider the electricity requirements of the facilities the microgrid would serve, as specified in your response to Question 1.
- **Fuel consumption per MWh:** For each distributed energy resource, please estimate the amount of fuel required to generate one MWh of energy. This question does not apply to renewable energy resources, such as wind and solar.

| Distributed Energy Resource Name | Facility Name | Energy Source | Nameplate Capacity (MW) | Average Annual Production Under Normal Conditions (MWh) | Average Daily Production During Major Power Outage (MWh) | Fuel Consumption per MWh | |
|---|---|---|---|---|---|---|---|
| | | | | | | Quantity | Unit |
| Carlson Station | LM6000 | Natural Gas | 43 | 62,728.00 | 1,032 | 9.5 | MMBtu/MWh |
| DH Aux 1 | DH Aux1 | Natural Gas | 5 | 4,808.00 | 120 | 4 | MMBtu/MWh |
| DH Aux 2 | *DH AUx2* | Natural Gas | 22 | 15,718 | 528 | 3.5 | MMBtu/MWh |
| | | Choose an item. | | | | | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |
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| | | Choose an item. | | | | | Choose an item. |
| | | Choose an item. | | | | | Choose an item. |

***B. Capacity Impacts***

3. Is development of the microgrid expected to reduce the need for bulk energy suppliers to expand generating capacity, either by directly providing peak load support or by enabling the microgrid's customers to participate in a demand response program?

☐ No – proceed to Question 6

☐ Yes, both by providing peak load support and by enabling participation in a demand response program – proceed to Question 4

☒ Yes, by providing peak load support only – proceed to Question 4

☐ Yes, by enabling participation in a demand response program only – proceed to Question 5

**Provision of Peak Load Support**

4. Please provide the following information for all distributed energy resources that would be available to provide peak load support:

- **Available capacity:** Please indicate the capacity of each distributed energy resource that would be available to provide peak load support (in MW/year).
- **Current provision of peak load support, if any:** Please indicate whether the distributed energy resource currently provides peak load support.

Please use the same distributed energy resource and facility names from Question 2.

| Distributed Energy Resource Name | Facility Name | Available Capacity (MW/year) | Does distributed energy resource currently provide peak load support? |
|---|---|---|---|
| Carlson Station | LM6000 | 43 | ☒ Yes |
| DH Aux 1 | DH Aux1 | 5 | ☒ Yes |
| DH Aux 2 | DH Aux2 | 22 | ☒ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |
| | | | ☐ Yes |

If development of the microgrid is also expected to enable the microgrid's customers to participate in a demand response program, please proceed to Question 5. Otherwise, please proceed to Question 6.

**Participation in a Demand Response Program**

5. Please provide the following information for each facility that is likely to participate in a demand response program following development of the microgrid:

- **Available capacity:** Please estimate the capacity that would be available to participate in a demand response program (in MW/year) following development of the microgrid.
- **Capacity currently participating in a demand response program, if any:** Please indicate the capacity (in MW/year), if any, that currently participates in a demand response program.

| Facility Name | Capacity Participating in Demand Response Program (MW/year) | |
|---|---|---|
| | Following Development of Microgrid | Currently |
| | | |
| | | |
| | | |
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| | | |
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6. Is development of the microgrid expected to enable utilities to avoid or defer expansion of their transmission or distribution networks?

☐ Yes – proceed to Question 7

☒ No – proceed to Section C

7. Please estimate the impact of the microgrid on utilities' **transmission** capacity requirements. The following question will ask about the impact on distribution capacity.

| Impact of Microgrid on Utility Transmission Capacity | Unit |
|---|---|
| | MW/year |

8. Please estimate the impact of the microgrid on utilities' **distribution** capacity requirements.

| Impact of Microgrid on Utility Distribution Capacity | Unit |
|---|---|
| | MW/year |

***C.*** *Project Costs*

We are interested in developing a year-by-year profile of project costs over a 20-year operating period. The following questions ask for information on specific categories of costs.

**Capital Costs**

9. In the table below, please estimate the fully installed cost and lifespan of all equipment associated with the microgrid, including equipment or infrastructure associated with power generation (including combined heat and power systems), energy storage, energy distribution, and interconnection with the local utility.

| Capital Component | Installed Cost ($) | Component Lifespan (round to nearest year) | Description of Component |
|---|---|---|---|
| Voltage Transformers | 80,000 | 30 | Three 34.5 kV/120 V transformers for each breaker (S505 & S507) |
| Current Transformers | 78,000 | 30 | Three 34.5 kV 1200:5 transformers for e each breaker (S505 & S507) |
| Energy Management System | 65,000 | 10 | SEL PowerMax – microprocessor based computing platform, communication processor, HMI, load shedding processor, generator control system processor, rugged computer |
| Relays | 10,000 | 30 | SEL-751A for S505 & S507 |
| Black Start Generator | 195,000 | 30 | 750 kW natural gas |
| Hard-Wired Circuit Breaker Control Circuit | 28,000 | 30 | |
| Phasor Measurement Units | 19,100 | 30 | SEL 451-4 & SEL 2407 |
| Synchrophasor Vector Processor | 22,000 | 30 | SEL 3378 |
| Synchrophasor Data Concentrator | 9,500 | 30 | SEL 3373 |
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| Capital Component | Installed Cost ($) | Component Lifespan (round to nearest year) | Description of Component |
|---|---|---|---|
| | | | |
| | | | |
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## Initial Planning and Design Costs

10. Please estimate initial planning and design costs. These costs should include costs associated with project design, building and development permits, efforts to secure financing, marketing the project, and negotiating contracts. Include only upfront costs. Do not include costs associated with operation of the microgrid.

| Initial Planning and Design Costs ($) | What cost components are included in this figure? |
|---|---|
| 506,000 | All of the Q9 items except the energy storage |

## Fixed O&M Costs

11. Fixed O&M costs are costs associated with operating and maintaining the microgrid that are unlikely to vary with the amount of energy the system produces each year (e.g., software licenses, technical support). Will there be any year-to-year variation in these costs for other reasons (e.g., due to maintenance cycles)?

☒ No – proceed to Question 12

☐ Yes – proceed to Question 13

12. Please estimate any costs associated with operating and maintaining the microgrid that are unlikely to vary with the amount of energy the system produces each year.

| Fixed O&M Costs ($/year) | What cost components are included in this figure? |
|---|---|
| 60,000 | All the items in Q9 except energy storage and PV |

Please proceed to Question 14.

13. For each year over an assumed 20-year operating life, please estimate any costs associated with operating and maintaining the microgrid that are unlikely to vary with the amount of energy the system produces.

| Year | Fixed O&M Cost ($) | What cost components are included in this figure? |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
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| 13 | | |
| 14 | | |
| 15 | | |
| 16 | | |
| 17 | | |
| 18 | | |
| 19 | | |
| 20 | | |

## Variable O&M Costs (Excluding Fuel Costs)

14. Please estimate any costs associated with operating and maintaining the microgrid (excluding fuel costs) that are likely to vary with the amount of energy the system produces each year. Please estimate these costs per unit of energy produced (e.g., $/MWh).

| Variable O&M Costs ($/Unit of Energy Produced) | Unit | What cost components are included in this figure? |
|---|---|---|
| 0 | Choose an item. | |
| | Choose an item. | |
| | Choose an item. | |
| | Choose an item. | |
| | Choose an item. | |

## Fuel Costs

15. In the table below, please provide information on the fuel use for each distributed energy resource the microgrid will incorporate. Please use the same distributed energy resource and facility names from Question 2.

- **Duration of design event:** For each distributed energy resource, please indicate the maximum period of time in days that the distributed energy resource would be able to operate in islanded mode without replenishing its fuel supply (i.e., the duration of the maximum power outage event for which the system is designed). **For renewable energy resources, your answer may be "indefinitely."**
- **Fuel consumption:** For each distributed energy resource that requires fuel, please specify the quantity of fuel the resource would consume if operated in islanded mode for the assumed duration of the design event.

| Distributed Energy Resource Name | Facility Name | Duration of Design Event (Days) | Quantity of Fuel Needed to Operate in Islanded Mode for Duration of Design Event | Unit |
|---|---|---|---|---|
| | | | | Choose an item. |
| | | | | Choose an item. |
| | | | | Choose an item. |
| | | | | Choose an item. |
| | | | | Choose an item. |

16. Will the project include development of a combined heat and power (CHP) system?

☐ Yes – proceed to Question 17

☒ No – proceed to Question 18

17. If the microgrid will include development of a CHP system, please indicate the type of fuel that will be offset by use of the new CHP system and the annual energy savings (relative to the current heating system) that the new system is expected to provide.

| Type of Fuel Offset by New CHP System | Annual Energy Savings Relative to Current Heating System | Unit |
|---|---|---|
| Choose an item. | | Choose an item. |
| Choose an item. | | Choose an item. |
| Choose an item. | | Choose an item. |
| Choose an item. | | Choose an item. |
| Choose an item. | | Choose an item. |

**Emissions Control Costs**

18. We anticipate that the costs of installing and operating emissions control equipment will be incorporated into the capital and O&M cost estimates you provided in response to the questions above. If this is not the case, please estimate these costs, noting what cost components are included in these estimates. For capital costs, please also estimate the engineering lifespan of each component.

| Cost Category | Costs ($) | Description of Component(s) | Component Lifespan(s) (round to nearest year) |
|---|---|---|---|
| Capital Costs ($) | 0 | | |
| Annual O&M Costs ($/MWh) | 0 | Environmental Compliance Exp - The incremental emission control costs are zero | |
| Other Annual Costs ($/Year) | 0 | Emission Allowance - These are cost of RGGI CO2 allowances for running in combined cycle | |

19. Will environmental regulations mandate the purchase of emissions allowances for the microgrid (for example, due to system size thresholds)?

☐ Yes

☒ No

***D. Environmental Impacts***

20. For each pollutant listed below, what is the estimated emissions rate (e.g., tons/MWh) for the microgrid?

| Emissions Type | Emissions per MWh | Unit |
|---|---|---|
| $CO_2$ | 0 | Lb/MWh |
| $SO_2$ | 0 | Lb/MWh |
| $NO_x$ | 0 | Lb/MWh |
| PM | 0 | Lb/MWh |

***E. Ancillary Services***

21. Will the microgrid be designed to provide any of the following ancillary services? If so, we may contact you for additional information.

| Ancillary Service | Yes | No |
|---|---|---|
| Frequency or Real Power Support | ☒ | ☐ |

| | | |
|---|---|---|
| Voltage or Reactive Power Support | ☒ | ☐ |
| Black Start or System Restoration Support | ☒ | ☐ |

## *F. Power Quality and Reliability*

22. Will the microgrid improve power quality for the facilities it serves?

☐ Yes – proceed to Question 23

☒ No – proceed to Question 24

23. If the microgrid will result in power quality improvements, how many power quality events (e.g., voltage sags, swells, momentary outages) will the microgrid avoid each year, on average? Please also indicate which facilities will experience these improvements.

| Number of Power Quality Events Avoided Each Year | Which facilities will experience these improvements? |
|---|---|
| | |

24. The benefit-cost analysis model will characterize the potential reliability benefits of a microgrid based, in part, on standard estimates of the frequency and duration of power outages for the local utility. In the table below, please estimate your local utility's average **outage frequency per customer** (system average interruption frequency index, or SAIFI, in events per customer per year) and average **outage duration per customer** (customer average interruption duration index, or CAIDI, in hours per event per customer).

For reference, the values cited in the Department of Public Service's 2014 Electric Reliability Performance Report are provided on the following page. If your project would be located in an area served by one of the utilities listed, please use the values given for that utility. If your project would be located in an area served by a utility that is not listed, please provide your best estimate of SAIFI and CAIDI values for the utility that serves your area. In developing your estimate, please *exclude* outages caused by major storms (a major storm is defined as any storm which causes service interruptions of at least 10 percent of customers in an operating area, and/or interruptions with duration of 24 hours or more). This will ensure that your estimates are consistent with those provided for the utilities listed on the following page.[1]

[1] The DPS service interruption reporting system specifies 10 cause categories: major storms; tree contacts; overloads; operating errors; equipment failures; accidents; prearranged interruptions; customers equipment; lightning; and unknown (there are an additional seven cause codes used exclusively for Con Edison's underground network

| Estimated SAIFI | Estimated CAIDI |
|---|---|
| .92 | 1.97 |

SAIFI and CAIDI Values for 2014, as reported by DPS

| Utility | SAIFI (events per year per customer) | CAIDI (hours per event per customer) |
|---|---|---|
| Central Hudson Gas & Electric | 1.62 | 3.74 |
| ConEdison | 0.11 | 3.09 |
| PSEG Long Island | 0.76 | 1.42 |
| National Grid | 1.17 | 2.87 |
| New York State Electric & Gas | 1.34 | 2.97 |
| Orange & Rockland | 1.19 | 2.4 |
| Rochester Gas & Electric | 0.85 | 2.32 |
| *Statewide* | *0.68* | *2.7* |
| Source: New York State Department of Public Service, Electric Distribution Systems Office of Electric, Gas, and Water. June 2015. 2014 Electric Reliability Performance Report, accessed at: http://www3.dps.ny.gov/W/PSCWeb.nsf/All/D82A200687D96D3985257687006F39CA?OpenDocument. | | |

## ***G. Other Information***

25. If you would like to include any other information on the proposed microgrid, please provide it here.

Click here to enter text.

system). SAIFI and CAIDI can be calculated in two ways: including all outages, which indicates the actual experience of a utility's customers; and excluding outages caused by major storms, which is more indicative of the frequency and duration of outages within the utility's contro. The BCA model treats the benefits of averting lengthy outages caused by major storms as a separate category; therefore, the analysis of reliability benefits focuses on the effect of a microgrid on SAIFI and CAIDI values that exclude outages caused by major storms.

**OBG**

THERE'S A WAY