Chapter 4 – Transmission & Distribution

BED recognizes there is an ongoing shift in the fundamental aspects of power supply and delivery. The one-way energy flow from large scale generation via high voltage transmission lines to local distribution systems that has dominated grid structure for decades is becoming increasingly bi-directional and dynamic. With the growth of distributed generation ("DG") and net metering, the traditional customer role as an energy user is expanding to include being an energy generator and potentially a supplier of other ancillary grid services. Just as the customer role is evolving, so too must utilities and their transmission and distribution ("T&D") systems.

The sections below describe BED's ongoing efforts to provide reliable T&D services as well as future projects that will ensure BED is prepared for the challenges and opportunities of grid modernization.

Transmission and Distribution Description

BED is connected to Green Mountain Power ("GMP") through the 34.5 kV bus tie breaker at the McNeil Plant Substation and to the rest of Vermont through Vermont Electric Power Company ("VELCO") at the East Avenue and Queen City Substations. The East Avenue 13.8 kV switchgear is supplied by VELCO's 115/13.8 kV T1 transformers rated 30/40/50 MVA and T2 transformer rated 30/40/56 MVA. The Queen City 13.8 kV switchgear is supplied by a VELCO 115/13.8 kV, 33.6/44.8/56 MVA transformer. The McNeil 13.8 kV switchgear is supplied by a BED 34.5/13.8 kV, 20/26.7/33.3 MVA transformer. The VELCO transmission system connects all of the utilities in Vermont to each other and also has interconnections with New York, Quebec, Massachusetts and New Hampshire.

BED's sub-transmission system includes approximately 1.5 miles of 34.5 kV line from the East Avenue Substation to the McNeil Plant Substation. This line is jointly owned by BED (40 MVA) and GMP (20 MVA). The line is connected to the VELCO transmission grid at the East Avenue Substation by VELCO's 115/34.5 kV, 33.6/44.8/56 MVA transformer and to GMP's 34.5 kV system by the 34.5 kV tie bus breaker at the McNeil Plant Substation.

BED's distribution system throughout the City is comprised of sixteen 13.8 kV circuits with approximately 135 miles of 13.8 kV lines and 0.8 mile of 4.16 kV distribution taps. BED also owns the 0.9 miles 12.47 kV distribution circuit that serves the Burlington International Airport ("the Airport"). The distribution system is approximately 47% underground and 53% aerial.

BED has 25 MW of on-system generation at the Burlington Gas Turbine and 7.4 MW at the Winooski One Hydro Plant that are connected to the 13.8 kV system. BED also operates, and is 50% owner of, the McNeil Generating Station. McNeil is on the GMP system, but it is connected to the BED system through the GMP 34.5 kV bus at the McNeil Plant Substation.

BED's distribution system annual peak load for year 2019 was 60.40 MW. The substation transformer and generator ratings and coincident peak demands are provided in the table below:

	Rating	**Peak Load**
East Avenue Bus #3 T1 Transformer	50 MW	15.35 MW
East Avenue Bus #4 T2 Transformer	56 MW	8.79 MW
Queen City Transformer	56 MW	21.53 MW
McNeil Transformer	33.3 MW	12.79 MW
Burlington International Airport	-	0.66 MW
	Rating	**Peak Generation**
Lake Street Gas Turbine	24.8 MW	0.00 MW
Winooski 1 Hydro	7.2 MW	1.28 MW

Transmission & Distribution System Planning & Standards

BED's distribution system is operated as an open primary network. This is a system of interconnected primary circuits with normally open switches at the interconnection points. When problems arise on the circuit, back-up is provided to as many customers as possible by other circuits by changing the normally open and closed points on the system. Switching is performed by BED's Supervisory Control and Data Acquisition (SCADA) system or by manual switching when necessary.

The East Avenue, Queen City and McNeil Substation transformer load tap changers ("LTCs") are set to hold voltage at the peak hour between 122.1 V and 124.6 V (set point of 123.4 V and bandwidth of 2.5 V on a 120 V basis) at the substation 13.8 kV bus. The voltage delivered to BED's customers meets ANSI C84.1-2011 Range A during normal operation and ANSI Standard C84.1-2011 Range B during contingencies. The substation transformer LTC voltage settings allow for ISO New England Operating Procedure No. 13 ("ISO OP-13") Standards for 5% Voltage Reduction, primary voltage drop, and 6 volts of secondary voltage drop (distribution transformer, secondary cable and service wire).

Most of BED's trunk lines are rated 600 amps. This is to allow for the switching of loads between circuits, even at the system peak. The loading on the 600 amps main trunk lines is typically kept below 9 MVA during normal operation. This is to allow for the isolation of a fault to a small section of a circuit and switching the remaining sections to adjacent circuits.

The power factor is measured and monitored by SCADA at the substation breakers for the substation transformer and each circuit, and at reclosers and switches along the circuits. BED maintains a 0.98 power factor or higher on its distribution circuits to comply with VELCO power factor requirements and to keep the circuit voltage from dropping below an acceptable level during normal conditions and contingencies. This is implemented by switched and fixed capacitor banks and close monitoring of the VAR load on each circuit.

BED standard wire sizes are as follow:

- Aerial Primary Circuits: #2 Aluminum, 1/0 Aluminum, 4/0 Aluminum, 336 kcmil AAC and 556 kcmil AAC;
- Aerial Secondary Circuits: #2 Aluminum, 1/0 Aluminum, 4/0 Aluminum and 336 kcmil AAC.
- Underground Primary Circuits: #2 Aluminum, 1/0 Aluminum, 350 kcmil Copper, and 1,000 kcmil Copper;
- Underground Secondary Circuits: #2 Aluminum, 1/0 Aluminum, 2/0 Aluminum, 4/0 Aluminum, 350 kcmil Aluminum, and 500 kcmil Aluminum.

BED standard transformer sizes are as follow:

- Pole mounted transformers: 15 kVA, 25 kVA, 37.5 kVA, 50 kVA, 75 kVA, 100 kVA, and 167 kVA;
- Pad mounted single phase transformers: 15 kVA, 25 kVA, 37.5 kVA, 50 kVA, 75 kVA, 100 kVA, and 167 kVA
- Pad mounted three phase transformers: 75 kVA, 112.5 kVA, 150 kVA, 225 kVA, 300 kVA, 500 kVA, 750 kVA, 1,000 kVA, and 1,500 kVA;
- Submersible transformers: 15 kVA, 25 kVA, 37.5 kVA, 50 kVA, 75 kVA, 100 kVA, 167 kVA, 250 kVA and 333 kVA;

Distribution system planning studies are performed to improve system efficiencies and identify the least-cost options to meet future load requirements in a safe and reliable manner. Distribution system planning is performed consistent with the distributed utility planning principles, and planning process under Vermont PUC Docket 7081. In addition to energy efficiency and DG, BED will also be looking at the potential use of battery storage to avoid future T&D upgrades. Distribution system studies are performed when the city peak load forecast, actual city peak, or an individual circuit experiences significant load change. In 2018, BED performed a planning study to evaluate the ability of BED's distribution system to serve future University of Vermont ("UVM") load additions.

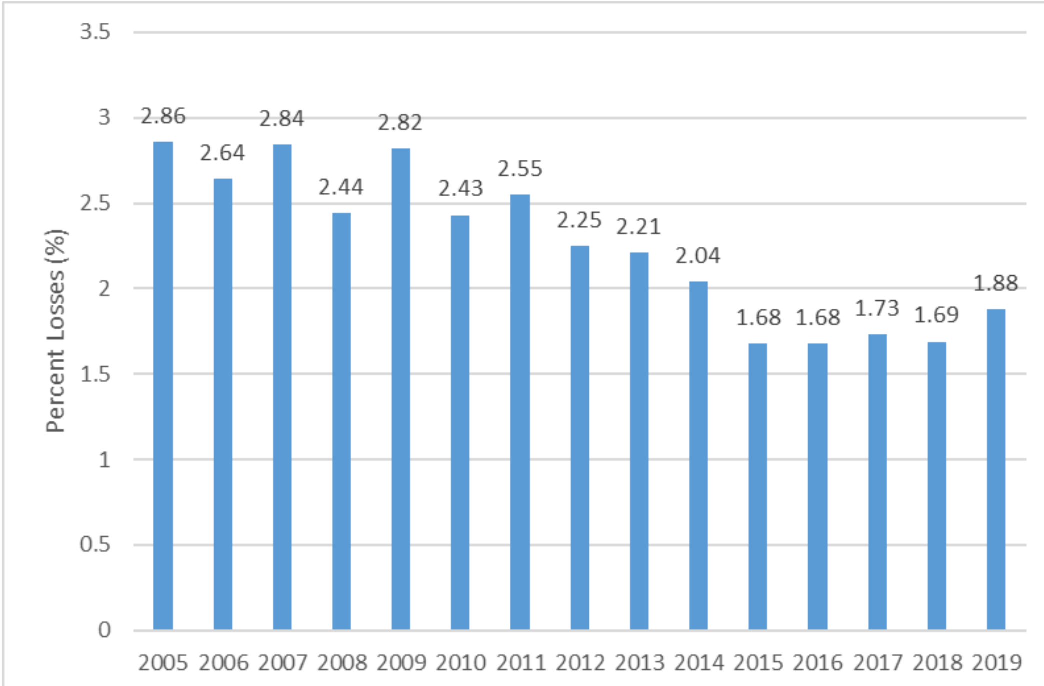
BED performs feasibility and system impact studies to identify the impact of proposed DG on the distribution circuits. The impact studies evaluate the impact of DG on the distribution system at the city peak load hour and also during light load condition and maximum generations under normal system configuration and contingencies.

BED uses CYMDIST software for distribution system analysis, efficiency studies, impact studies and planning studies. The distribution system simulation model is presently updated manually with efficiency gains from CYME Gateway software to convert data from a geographical information system ("GIS") to CYMDIST model. In FY2019, BED completed the integration of CYMDIST with the GIS system to automatically extract distribution circuits and system information from the GIS to the CYMDIST simulation model. This has increased the accuracy of the simulation model and improved staff efficiency by eliminating manual entry of data from one system to another.

Distribution System Efficiency Measures

The movement of power through the distribution system incurs electrical losses due to the resistance of the equipment to the flow of electricity. System losses increase the amount of electricity required to supply the customers' needs. BED has several programs in place and routinely performs analysis to improve system efficiency using methods that are both cost-effective and technically feasible. As a result of BED's system efficiency efforts, BED's total distribution system losses dropped from 2.86 % in 2005 to approximately 1.88% in 2019. Figure 1-0 shows BED's historical distribution system losses.

Figure 1-0: System Losses



Distribution system efficiency measures are evaluated on each circuit and cost-effective measures are implemented. The following efficiency measures are evaluated by BED:

- Optimal locations of capacitor banks;
- Distribution system configuration;
- Phase balancing;
- Single phase to three-phase conversion;
- Increasing distribution voltage level;
- Creating new 13.8 kV distribution circuits;
- Re-conductoring of lines with lower loss conductors;
- Equipment acquisition procedure;
- Transformer/load matching;

Optimal Locations of Capacitor Banks

Capacitor Banks are installed on BED's distribution circuits to reduce the VAR flows, reduce losses and improve voltage. BED maintains a 0.98 power factor or higher on its distribution circuits to comply with the VELCO power factor requirements, reduce losses, improve voltage and be able to serve load with acceptable voltage during contingencies.

Fixed or switched capacitor banks are installed on the distribution circuits. The switched capacitor banks are controlled through the SCADA system, and a few in the field are controlled via stand-alone voltage or VAR controllers. BED's operator remotely opens and closes capacitor banks based on the voltage requirements or circuit breaker preset VAR alarm values to maintain a circuit power factor close to unity.

The optimal locations of existing and new capacitor banks on each circuit are determined using CYMDIST software to minimize losses or improve voltage.

In 2018, BED performed a capacitor bank study to determine the optimal locations for the existing capacitor banks on its distribution circuit. The results of this study showed that the relocation of the existing capacitor banks to new optimal locations is not cost-effective in a 25-year societal-cost analysis.1 (BED depreciates its distribution capacitor banks on a straight-line basis over a 25-year service life).

<u>Distribution Circuit Configuration</u>

Distribution system configurations are evaluated when the City peaks or an individual circuit experiences significant load change. In 2018, BED evaluated balancing the load between 1L1 and 1L4, 2L4 and 3L1, 3L4 and 3L5, 1L2 and 2L5 circuits to optimize losses and improve reliability. The results of this study show that balancing load between the circuit groupings above reduces system peak losses by 31.43 kW and is cost-effective in a 33-year societal-cost analysis(BED depreciates its distribution cables on a straight-line basis over a 33-year service life). One system re-configuration case was implemented in FY2020. Two cases have been re-evaluated due to un-anticipated costs identified after this analysis and are no longer cost effective. The remaining two cases are scheduled for completion in FY2021.

<u>Phase Balancing</u>

Balancing the phase loading on the distribution circuits will decrease line losses and improve line voltages and backup capability. On an annual basis, BED evaluates the loads among the phases at summer peak on each circuit and corrective actions are taken and implemented based on the results of this evaluation. BED evaluates the phase balancing at the substation switchgear breakers for each distribution circuit and going forward at the reclosers and switches located on the distribution circuits.

With BED's distribution system losses of approximately 1.88%, balancing the phases on the distribution circuits is typically done to improve the voltage for normal system operation and during contingencies.

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1 BED depreciates its distribution capacitor banks on a straight-line basis over a 25-year service life.

In 2018, BED evaluated balancing of phases on its distribution system to optimize losses, improve line voltages, and backup capability. The results of this study show that transferring load on Henry Street and Wilson Street from phase C to phase A reduces system peak losses by 2.5 kW and is cost effective in a 33-year societal-cost analysis.[2] This phase balancing was implemented in FY2021.

Single-Phase to Three-Phase Conversion

Single-phase to three-phase conversions are evaluated when the City peak or an individual circuit experience significant load change. Upgrading a line from single-phase to three-phase construction results in line loss reduction. However, the conversion of BED's circuits from single-phase to three-phase construction has not been cost-effective because the potential loss savings from this conversion is low[3] in comparison with high cost of rebuilding BED's aerial and underground circuits.

Such costs may include traffic control during the construction of aerial projects and a $25 per square foot City administrative and excavation fee for placing BED's lines underground within a paved portion of a City street

In 2018, BED evaluated upgrading the highest loaded distribution circuit sections from single to three-phase construction. The results of this study showed that upgrading a section of BED's lines on Canfield Street, part of the 1L2 circuit, from single-phase to three-phase construction reduces system peak losses by 2.3 kW and is cost-effective in a 33-year societal-cost analysis.[4] This upgrade was implemented in FY2020.

Increasing Distribution Voltage Level

As of 2018, approximately 0.9 miles of 4.16 kV taps remained in the City and were fed from stepdown distribution transformers. The 4.16 kV taps are located at Appletree Point, Sunset Cliff and Pearl Street. BED has been working closely with its customers to complete the conversion of these taps to 13.8 kV in the next five years. This conversion plan is contingent on BED obtaining easements from private property owners.

Creating New 13.8 kV Distribution Circuits

Constructing additional 13.8 kV circuits would reduce line losses by reducing the load on an existing feeder. However, creating new circuits on BED's system solely to lower line losses would not cost-effective because BED's distribution losses are extremely low, at approximately 1.88%, while the costs of large main trunk line wires and installing aerial and

2 BED depreciates its distribution cables on a straight line basis over a 33-year service life.

3 Losses on BED's distribution system are approximately 1.88%.

4 BED depreciates its distribution cables on a straight line basis over a 33-year service life.

underground circuits are high.

Re-Conductoring of Lines with Lower Loss Conductors

Upgrading the conductor size of a circuit will result in a lower line resistance and lowering the line resistance will reduce line losses. BED's trunk lines are oversized because BED's distribution system is designed to allow for the isolation of a fault to a small section of a circuit and switching the remaining sections of the circuit to alternate feeds.

In 2018, BED evaluated increasing the conductor size on sections of its distribution circuits. The results of this study showed that reconductoring existing lines was not cost effective in a 33-year societal-cost analysis.

Equipment Selection & Utilization

BED utilizes least-cost principles to select transformers and cables. The specific processes used for transformer and cable acquisitions are outlined below. Other major equipment such as aerial wires, breakers, reclosers, switches, and capacitors are purchased per BED standards, specifications and purchasing process.

a) Transformer Acquisition Procedure

   BED requests quotations for steel metal core and amorphous metal core distribution transformers from multiple suppliers. BED makes purchase decisions according to the standards set out in the Memorandum of Understanding between the Public Service Department and BED dated December 27, 2004 using a distribution transform acquisition program. The Memorandum requires consideration of the initial cost of the transformer, the economic value of the increase in capacity costs, energy costs, VELCO transmission costs, distribution costs and environmental externalities over 25 years[5].Based on these factors, BED then purchases transformers with the least societal costs.

b) Cable Acquisition Procedure

   BED uses a cable acquisition program to make purchase decisions based on 33-year societal-cost analysis. The analysis considers the initial cost of the cable and the economic value of the increase in capacity costs, energy costs, VELCO transmission costs and environmental externalities over 33 years (BED depreciates its cables on a straight-line basis over a 33-year service life).

Transformer/Load Matching

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5 BED depreciates its distribution transformers on a straight-line basis over a 25-year service life.

New or replacement transformers installed on BED's system are purchased using BED’s transformer acquisition procedure and sized to match customer load. When BED replaces an existing transformer, a load study is first done to determine the correct size for the replacement transformer. For new transformers, BED sizes the transformers based on coincident peak load estimates from the customer, customer’s engineer or electrician, similar facilities’ loads in the City, and the expertise of BED’s engineers. The residential transformers are not sized to allow every customer connected to the transformer to add electric vehicle, heat pump, or other strategic electrification loads in the future. Depending on the total magnitude of the additional load from strategic electrification, the transformer may need to be replaced. By correctly matching the size of the transformer to the load being served and existing DG while also allowing for a margin of growth, transformer losses are reduced which improves the overall system efficiency.

Advanced Metering Infrastructure (“AMI”) provides BED with information about the energy consumed and demanded, , reactive power or power factor for each customer, along with voltage monitoring and power quality information. This information is stored in BED’s meter data management system (“MDMS”).

BED has implemented a transformer and service point auto updater feature in ArcGIS to integrate customer information with the transformer connecting that customer. This information is stored in the GIS. This information improves staff efficiency by reducing manual processes. Additionally, BED staff are able to easily create load reports on existing transformers and size future transformers using this AMI data. As part of BED’s current strategic information technology project, BED will implement grid analytics software to automatically create transformer load reports using the newly integrated GIS data. BED anticipates this phase of the project will be complete within three years.

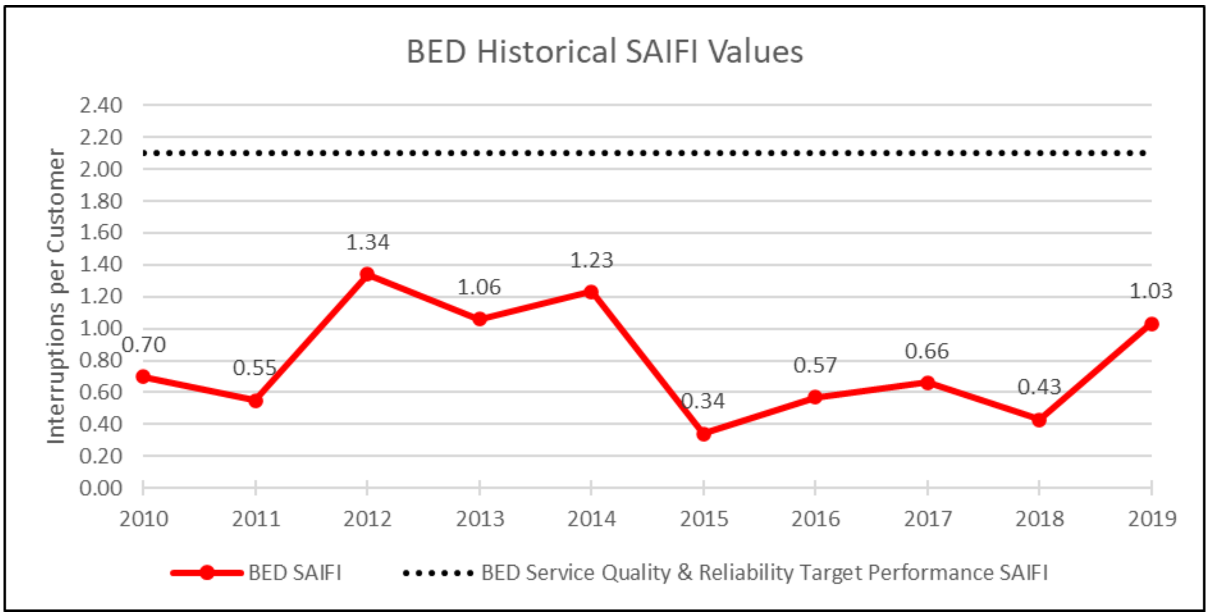
Reliability

BED is committed to supplying the highest system reliability and power quality to its customers that is economically feasible. Like other utilities, BED tracks power interruptions or outages. An interruption of power is considered an "outage" if it is a zero-voltage event exceeding five minutes. There are two types of outages, planned outages and unplanned outages. Planned outages are outages that are initiated and scheduled in advance by BED for purposes of construction, preventative maintenance or repair. Unplanned outages are outages due to unexpected and unscheduled events. BED’s distribution system reliability is measured by the System Average Interruption Frequency Index (“SAIFI”) and Customer Average Interruption Duration Index (“CAIDI”) pursuant to PUC Rule 4.900. These indices

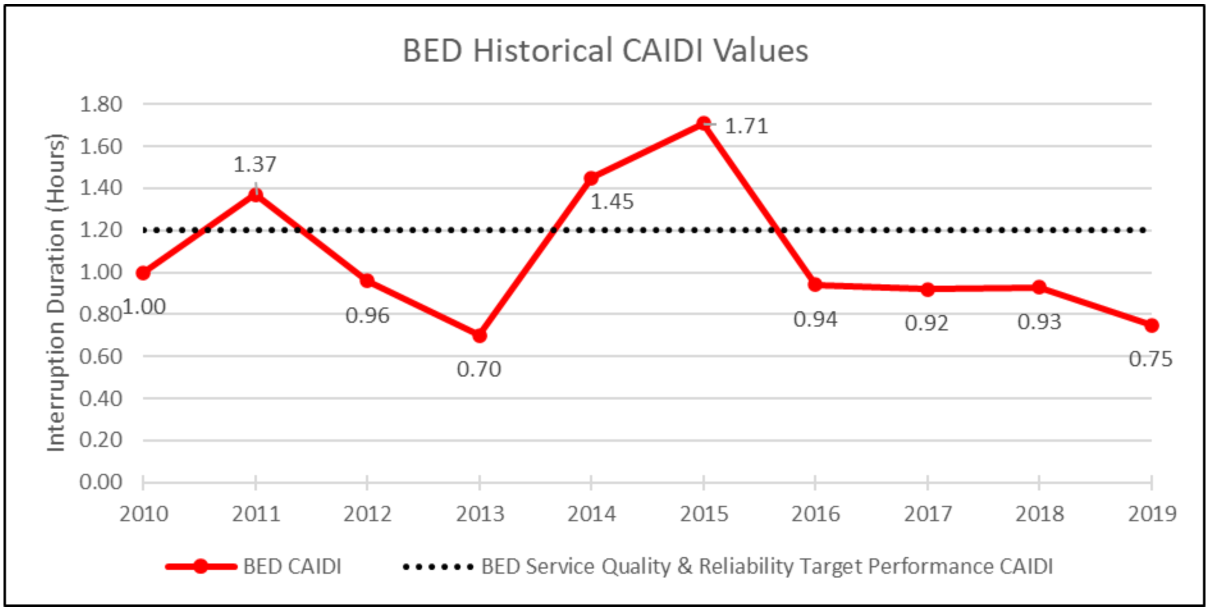
are also impacted by BED's planned outages and include major storms.
Every year, BED analyzes the outage information on its distribution circuits, identifies the worst performing distribution circuits, and updates its distribution action plan to improve the performance on these circuits.

BED's SAIFI for 2019 was 1.03 interruptions per customer, significantly better than the SAIFI service quality and reliability target performance of 2.1 interruptions per customer. BED's CAIDI for 2019 was 0.75 hours, well below the CAIDI target performance of 1.2 hours.

The following Figure 4-0.1 shows BED's historical SAIFI.



The following Figure 4-0.2 shows BED's historical CAIDI.



RELIABILITY IMPROVEMENT PROGRAMS

BED's distribution system is designed to allow for the isolation of a fault to a small section of a circuit and switching the remaining sections of the circuit to alternate feeds prior to making repairs. In addition, BED has several programs in place to ensure that system reliability and power quality remain as high as possible. The following are a few of these programs:

- Distribution System Operating Procedures
- Distribution System Protection
- Wildlife protectors
- Pole Inspection and Maintenance Plan
- Overhead Distribution Inspection and Maintenance Plan
- Underground Distribution Inspection and Maintenance Plan
- Tree wire
- Fault indicators
- Reclosers/SCADA-controlled switches
- Replacement of underground system
- 100- and 500-year flood plains
- Underground Damage Prevention Plan

Distribution System Operating Procedures

BED has created contingency plans for the loss of each 13.8 kV distribution circuit and 13.8 kV substation switchgear. These contingency plans are updated annually and used by BED's dispatch center during planned and unplanned outages to expedite restoring service to impacted customers.

Distribution System Protection

Adequate distribution system protection is required to avoid and/or minimize hazards to the public and BED's line workers, to prevent damage to electric utility infrastructure, to reduce the number of customers impacted by outages and to allow for prompt power restoration. Any time a protective device is installed on a circuit, BED performs a protection study to ensure coordination between the new and existing devices on the circuit.

BED has the following protective equipment installed on the distribution and sub-transmission System:

- Circuit breakers are installed at each end of the 34.5 kV sub-transmission line.
- Distribution circuit breakers are installed in each of BED's three substations. These are the primary distribution circuit protection and quickly de-energize an entire circuit to protect the substation transformer from damage.
- Reclosers are similar to circuit breakers but are used as secondary protection mainly on aerial distribution circuits and to tie circuits together.
- Underground distribution switches with protective breakers are similar to circuit breakers but are used as secondary protection on underground distribution circuits and also to tie circuits together.
- Distribution line fuses isolate permanent faults to minimize the size and number of customer outages
- Transformer fuses protect distribution transformers and secondary lines serving individuals or groups of customers.
- Current-limiting fuses are installed on distribution taps and aerial transformers. These fuses limit the energy released during a short circuit event and protect the associated equipment from failing.
- Over-voltage arresters are used for protection of all aerial transformers, capacitors, normally open switches, normal open points, and at each end of primary underground circuits.

BED's specific sub-transmission protection strategies include:

- The primary forms of protection for the 34.5 kV line are relays with a high-speed line differential scheme on both ends of the line. Relays communicate with each other via fiber, quickly determine if a fault is within its zone of protection and open the breakers.
- Overcurrent and step-distance relay functions are utilized for backup protection in

case the fiber link between the relays is lost.

BED's specific distribution protection strategies include:

- The loading on each circuit is typically kept below 65% of the circuit's steady state summer current carrying capability during normal operation and below 80% of relay pickup setting at all operating conditions. This strategy establishes adequate cold load pickup capability and allows for the switching of loads between circuits.
- Overcurrent protection includes coordination of circuit breakers, reclosers and fuses. Overcurrent protection is designed to maximize load current, allow for cold load pickup and feeder backup configurations and maintain sensitivity required to keep the system protected from bolted faults.
- BED utilizes the so called "fuse saving" protection method on all of its overhead circuits. This method allows for breakers or reclosers to operate faster than a fuse attempting to clear the fault without causing a long duration permanent outage. The same breaker or recloser recloses after approximately eight seconds, attempting to restore the power to the circuit. In the case of a transient fault (e.g. a squirrel, bird, tree branch, etc.), the fault is cleared at this point and power is restored to all customers. In the case of a permanent fault, the fault is still present and is cleared by the nearest upstream fuse. This method is not used on predominantly underground circuits.
- Most of BED overhead circuits utilize multiple recloser schemes which improve the capability of minimizing outages and back-feeding circuits. Similarly, all BED underground circuits utilize multiple underground switches for the same purpose.
- All BED distribution breakers utilize synchronism check function, eliminating the potential of connecting non-compatible sources and causing a significant outage.
- All new designs for underground systems use protective and/or switching devices at taps from the main line circuit.
- Short circuit analysis is completed using CYMDIST modeling software. This analysis is done to simulate BED protection schemes as discussed above. The results of this study help to confirm fuse sizing and protective device settings.
- Short circuit data is also utilized when analyzing arc flash hazards on the primary distribution system. CYMDIST uses the detailed distribution model to calculate the available arc flash energy at every primary voltage point on the distribution system. This enables BED to coordinate the ratings of safety equipment and personal protective equipment ("PPE") used by line crews.

In year 2018, BED and VELCO completed the installation of phase reactors at the East Avenue and Queen City transformers to reduce the line to ground and three-phase fault current levels on BED's distribution system. BED then completed a comprehensive protection coordination study of its entire distribution system. As a result of this study, BED is in the process of implementing new protection settings for its breakers and reclosers. This project is expected to be completed by the end of FY2021.

Wildlife Protectors

BED construction standards include the installation of wildlife protectors on all new exposed transformer, capacitor and circuit breaker bushings and arresters. In addition, BED has started the installation of static guard protectors on reclosers, switches and disconnects. Most of the unplanned outages on BED's distribution system in year 2015 were caused by animal contact. As a result of the new construction standards indicated above, BED's animal-caused outages decreased from 33 in 2015 to 18 in 2018. .. As of 2019, BED has completed a survey and wildlife protection installations of all distribution circuits.

Pole Inspection and Maintenance Plan

The purpose of BED's Pole Inspection and Maintenance Plan is to identify poles that are damaged or showing signs of decay in order to take corrective action before the poles fail. BED's pole inspection plan requires inspection of all wooden distribution and streetlight poles every seven years and tests the poles that are over ten years old. Poles are evaluated and inspected for cracks, split and rot and then tested using industry standard testing practices. All poles that fail the inspection and testing will be labeled as condemned poles and will be replaced.

Overhead Distribution Inspection and Maintenance Plan

The purpose of BED's overhead distribution inspection and maintenance plan is to routinely inspect and maintain the overhead distribution system. BED's overhead inspection plan requires inspection of all overhead utility structures every five years. Structures and all BED attached equipment are visually inspected for signs of wear, damage, missing components and any non-equipment issues such as close proximity to trees. BED maintains records of all inspection cycles. Any repairs associated with these inspections are prioritized and scheduled.

Underground Distribution Inspection and Maintenance Plan

The purpose of the Underground Distribution Inspection and Maintenance Plan is to routinely inspect and maintain the underground distribution system. BED's underground inspection plan requires inspection of all underground utility installations every ten years. This plan proactively identifies and corrects any problems related to underground utility holes or the equipment within them.

Tree Wire

BED uses covered (tree) aerial wire where appropriate to limit the number of faults caused by tree contact.

Fault Indicators

BED installs fault indicators on the aerial and underground distribution circuits to assist the field crews in locating fault locations. The fault indicators are installed at major junctions to allow the crews to identify the direction of the fault.

Reclosers/SCADA Controlled Switches

Reclosers improve the reliability of electrical service for customers who are located upstream of faults by protecting them from downstream faults. The reclosers do so by automatically detecting faults and opening to isolate faulted sections of circuits, thus reducing the number of customers that experience an outage. Reclosers can also be remotely opened and closed by dispatchers to reconfigure the distribution system to quickly restore customers and isolate faulted sections of circuits. Similarly, SCADA-controlled switches allow dispatchers to remotely open and close switches to reconfigure the distribution system. . BED has installed aerial reclosers and SCADA-controlled switches on its main distribution circuits, normal open tie points and on long lateral taps.

To further improve reliability and expedite service restoration, BED plans to replace the following equipment with reclosers and smart switches:

- Replace disconnect 346D with a smart switch;
- Replace manual switches, 227S, 407S, and 917S with smart switches;
- Replace reclosers 112R, 234R, and 252R with SCADA-controlled reclosers.

Replacement of Underground System

Approximately 47% of BED’s distribution system is underground. Although underground circuits experience fewer outages than aerial circuits, underground circuits are more difficult to repair which results in outages of longer durations. Aerial circuits are inherently easier to troubleshoot and repair due to their visibility and relative ease of access, whereas underground circuits are not readily visible and often require work in confined spaces such as vaults and utility holes. In addition, some of BED’s underground circuits are direct buried. The loss of a direct buried underground circuit will result in long customer outages due to the need for excavation to locate and repair faulted cables (cables in conduit can usually be replaced without the need for excavation). BED’s capital construction plan calls for the replacement of underground circuits based on first-hand knowledge of specific problems, age of cable, existing installation (direct buried, availability of spare conduits), type of load, engineering judgment, coordination with Department of Public Works ("DPW") pavement plan or City or State road rebuild projects, and budget constraints. BED's underground circuit replacement work throughout the City will reduce the length of unplanned outages, improve operating efficiencies and coordinate with the City of Burlington's Street Pavement Plan. on

Over the next five years, BED plans to rebuild the old underground system at Farrell Apartments, UVM Living and Learning, UVM Aiken Center, Juniper Terrace, Harbor Watch, and the Airport.

<u>100- and 500-Year Flood Plains</u>
BED's McNeil, East Avenue and Queen City Substations are not within FEMA designated flood hazard areas. This conclusion is based on BED's review of the Vermont Agency of Natural Resources ("ANR") Atlas program using the FEMA flood layers for reference.

<u>Underground Damage Prevention Plan</u>
BED has an underground damage prevention plan that complies with PUC Rule 3.800 and 30 V.S.A. Chapter 86. The plan outlines the State requirements for BED to locate its underground facilities using its underground cable locators upon receiving notification from Dig Safe Systems, Inc. The plan also requires BED to closely monitor its own excavation efforts and manage our damaged infrastructure repairs with an emphasis on employee/public safety and service restoration.

Volt/VAR Optimization

The voltage and VAR flow on BED's distribution system are controlled by the substation transformer LTC controllers, and fixed and switched capacitor banks on the distribution circuits.

The East Avenue and Queen City Substation transformer LTC controllers are owned and maintained by VELCO while the McNeil Substation transformer LTC controller is owned and maintained by BED. The East Avenue, Queen City and McNeil Substation LTCs are set to hold voltage at the peak hour between 122.1V and 124.6V (set point of 123.4V and bandwidth of 2.5V on a 120V basis) at the substation 13.8 kV bus. The voltage at the substation transformer LTC is set as low as possible for the summer peak hour while still providing all the customers on each circuit with ANSI C84.1-2011 Range A voltage during normal operation and ANSI Standard C84.1-2011 Range B during contingencies and meeting ISO OP-13 Standards for 5% Voltage Reduction.

The substation transformer LTCs regulate the 13.8 kV bus voltage for all circuits connected to the substation at the 13.8 kV bus. As a result, all the distribution circuits fed from the substation transformer have the same voltage set point. BED does not use the Line Drop Compensation ("LDC") for voltage regulation because the transformer LTC regulates the 13.8 kV bus voltage of two large generators (Winooski 1 Hydro and Lake Street Gas Turbine) which are connected directly to BED's distribution circuits. The distribution system is operated in a network configuration when the gas turbine is running.

As discussed in the Optimal Locations of Capacitor Banks section, BED remotely controls the capacitor banks. The SCADA system monitors each circuit's VAR flow and will send an alarm to the system operator when the VAR flow is outside of the set points. One or more capacitors are then either turned on or off to return the VAR flow to within the limits. Two of the three large pad-mounted capacitor banks on the distribution system are controlled by SCADA and also by stand-alone voltage controllers. BED has installed stand-alone capacitor bank control units on all aerial SCADA controlled capacitor banks and has connected them to the fiber system. These controllers operate independently on each circuit to control the VAR and voltage.

In 2019, BED and VELCO completed the replacement of the existing transformer LTC controllers at Queen City and East Avenue Substations to allow for multiple voltage set points and a 5% voltage reduction. The new LTC controllers allow BED to operate the distribution system at a lower voltage setting during certain months of the year taking into consideration ISO OP-13 Standards for 5% voltage reduction. Monitoring of the AMI system voltage information will allow for the LTC parameters to be optimally set and provide feedback to BED to assure the voltage stays within required parameters.

With expanded control of the LTCs and monitoring and control of the distribution capacitors, BED can improve the optimization of the system voltage and VAR flow on each circuit.

Grid Modernization/Distributed Generation/Strategic Electrification

BED's 2019 business-as-usual base case 90/10 peak load forecast assumed low increase in installation of electric vehicle chargers and heat pumps which resulted in minimal distribution system load increases. While this minimal load addition may not impact BED's distribution system main trunk lines, it may create line overloads if the load additions are concentrated on a small radial tap. In addition, depending on the number of electric vehicles/chargers and heat pumps being connected to an existing transformer, the total load added may result in an overload on the distribution transformer, secondary wire, and/or service wire and require the replacement of the overloaded equipment. BED's AMI system, in conjunction with the planned grid analytics software, plays a major role in identifying transformers and secondary/service wires that may be impacted by load increases from installation of new electric vehicle chargers and heat pumps.

The distributed renewable generation on BED's system has not yet created reverse power flow issues for BED's distribution system. However, as additional electrification measures are installed and net-metering facilities constructed, depending on the type of connection, the size of the equipment being installed and the total generation on BED's circuits, one or more studies (feasibility, impact, stability, facility) may be required to identify and remedy potential problems with reverse power flow. BED has developed Distributed Generation Interconnection Guidelines that are posted on BED's website, and a solar map to show the DG on each circuit and provide a preliminary screening tool to assess BED's circuit capacity for accepting new distributed renewable generation projects.

NET-ZERO ENERGY PLANS

See the separate chapter on Net Zero for information on distribution impacts when Net Zero activities increase BED's system peak above its current limits (essentially modelling what will be required to serve a load in excess of 80 MW, but not to exceed 102.8 MW). Work expanding this analysis to encompass the load impacts above the 102.8 MW level (i.e. to the potential loads resulting from "full" electrification) is underway.

ADDITIONAL GRID MODERNIZATION

To support a potential future increase in the rate of installations of electric vehicle chargers, battery storage and distributed renewable generation, BED will continue to further modernize its distribution system and internal software platforms. The following are BED's current initiatives to modernize the distribution system:

- GIS integration;

- Asset management system;
- Distributed generation resources;
- Outage management system;
- AMI integration; and
- Distribution automation

Geographic Information System

BED maintains a comprehensive, state-of-the-art GIS and that includes data on the primary distribution circuits, secondary system, service wires, transformers and DG facilities. In addition, customer service points are linked to distribution transformers, significantly simplifying the transformer loading evaluations. The GIS data is also used to track BED's assets, including the quantity and condition of all poles and equipment attached to the poles.

Distributed Generation Resources

BED has developed an online map of existing and proposed DG facilities on each circuit. , The map includes information on the size and type of each facility. Additionally, the map shows each circuit's capacity for interconnection of future DG facilities.

https://www.burlingtonelectric.com/distributed-generation

Through the CYME Gateway software mentioned above, BED is able to extract from the GIS and model every DG resource on its distribution system in the CYMDIST modeling software. This allows for more accurate system modeling and system impact analysis of future DG projects.

Outage Management System

BED maintains an automatic feed to the VTOutages website based on the outage notification capabilities of its Itron AMI meters. That feed went live in November of 2016.

It should be noted that this system is limited compared with a fully featured outage management or distribution management system; meaning, that BED's system is not able to include meters in the outage count where outages are not reported by the AMI system. This situation results from either a mesh network meter being out of communication during the outage ("islanded" without a communication path and thus unable to report), or from the customer having opted out of AMI metering. As a result, the reported information would likely represent a lower number of customers without power, with the relationship being dependent on the size of the outage. For example, if a single meter reports an outage, it is likely that is very close to the extent of the outage. However, if the full system were out, the reported count would be low by the number of non-AMI and "islanded" meters.

<u>AMI Integration</u>

BED has completed the deployment of its AMI meters across its entire service territory by replacing nearly all of the electric meters with AMI meters. The remaining meters on BED's system are 475 Automated Meter Reading (AMR) meters and 267 non-AMI/AMR meters. BED has established a link between meter accounts and the transformer supplying these accounts in the GIS. With this data link and access to the meter data management system MDMS BED engineering staff are able to create load reports for existing transformers and size future transformers as well as develop other reporting tools. This process will be automated with the implementation of the grid analytics software mentioned above.

<u>Distribution Automation</u>

BED's SCADA system allows BED to collect operational and planning data, and remotely control and operate key field devices such as breakers, reclosers, switches, capacitor banks, and transformer LTCs .The SCADA system increases customer satisfaction through reduced service interruptions, less customer down time and improved quality of supply.

BED has replaced all of its substation electromechanical relays with microprocessor-based relays. The protective devices associated with substation breakers, reclosers, and underground switches allow temporary faults to be removed from the system before automatically restoring normal service. In conjunction with fuses, the protective devices give BED the capability to limit permanent faults to the smallest possible number of customers. These devices have greatly increased BED's ability to isolate faults, clear temporary faults, reduce the number of customers impacted by outages and restore service more quickly to customers when outages do occur.
BED has installed reclosers on its aerial distribution circuits to isolate the faulted part of a circuit and improve reliability. These reclosers are also controlled by the SCADA operators.

BED has installed pad-mounted switches with means to automatically transfer critical customer load from a faulted circuit to a different circuit within seconds. In addition, BED has installed pad-mounted switches with protective relays on its underground distribution circuits to isolate the faulted part of a circuit and improve reliability. These switches are also controlled by the SCADA operators.

BED plans to install new and replace/upgrade existing aerial switches and disconnects with reclosers and SCADA-controlled switches as discussed in section 4.1.7. These devices will be able to provide real time information such as amps, kV, kW and kVAR.

BED has installed stand-alone capacitor bank voltage and VAR control units on all aerial SCADA-controlled capacitor banks. These controllers operate independently on each circuit to control the VAR and voltage. The controllers are also controlled by the SCADA operators.

BED also replaced the substation transformer LTCs controllers at Queen City and East Avenue Substations with new ones that allow for multiple voltage set points.

Additional steps toward distribution automation include investigating the deployment of a distribution management system (DMS) and integration with the AMI system as part of the strategic information technology project.

Emergency Preparedness and Response

BED participates in the statewide emergency preparation conference calls. Based on the available information from these calls, BED assesses the appropriate response to an anticipated event and responds appropriately. If additional crews are needed, there are sources available to BED. BED is a member of the Northeast Public Power Association's Mutual Aid program (NEPPA) and as a result has access to numerous municipal utility crews in the northeast. In addition, BED would reach out to GMP and/or Vermont Electric Cooperative ("VEC") to provide aid. In the event that BED's needs are not met through either the NEPPA Mutual Aid program, GMP or VEC, BED would utilize contract crews.

Currently VTOutages is updated automatically when outages occur and during system restorations as described in the Outage Management System section above.

BED currently contacts customers for planned outages using several forms of communication. Customers are contacted directly by using phone calls, emails, letters or the use of door hangers. Customers are contacted well in advance and reminders are sent before the date of the planned outage. In the event of unplanned outages, customers can contact BED during normal business hours for information. After hours calls will be answered either by BED dispatch office or an off-site answering service. Voice messages are used to let customers know that an outage is occurring and that crews are responding. BED also posts unplanned outage information to the BED website and various social media platforms.

Utilities Coordination

BED coordinates pole installations and construction of underground distribution projects with Comcast Corporation, Consolidated Communications Holdings, Inc. (formerly FairPoint Communication, Inc.), and Burlington Telecom. This coordination between utilities cuts costs through sharing of trenching costs, repaving, permit fees, etc. and also expedites the transfer from old installations to new ones.

In addition, BED coordinates its underground construction projects with DPW street paving plans to minimize the City excavation fees when trenching in the road.

Track Transfer of Utilities

BED uses the National Joint Utilities Notification System ("NJUNS") database to track transfer of utilities and dual pole removal.

Relocating Lines to Roadside

In the process of re-building BED's old aerial lines located behind private properties, BED evaluates the feasibility and cost of relocating these lines into the City right-of-way along the roadway and sidewalk areas. Typically, these relocations take many years to complete due to the scope of work, need for securing easements and cost for potentially placing the lines underground.[6]

Vegetation Management Program

The purpose of BED's Vegetation Management Program is to maximize employee and public safety and minimize power outages caused by tree contacts with BED distribution circuits.

BED has adopted a tree trimming program based on outage history, right-of-way requirements and constraints, as well as the associated rates of growth for the particular tree species indigenous to the City of Burlington.

BED has approximately 133 miles of aerial and underground distribution circuits that are divided into three maintenance sectors. Every three years a sector is given priority and our trimming efforts are concentrated in that area. In addition, BED augments its trimming cycle program by identifying specific areas of need through inspection patrols, outage reports, feedback from customers and BED employees, as well as other agencies such as the

6 Placing BED's lines underground within a paved portion of a City street requires a City administrative and excavation fee of approximately $25 per square foot).

Burlington Parks and Recreation Department.

During our trimming cycles, BED's inspector and tree trimming contractors will document any danger trees outside the right-of-way. BED then works with the City's resident arborist and private property owners to remove these trees.

The City's resident arborist contributed the following information about the various species of trees and their associated growth rates. According to the City's arborist these same growth rates apply to pruned branches of healthy trees. The growth rates, however, do slow whenever the health of a tree is compromised.

Species	Growth Rate	Growth Rate After Pruning (assuming healthy tree)
Ash Species	Fast	Fast
Birch Species	Medium	Medium
Box Elder	Fast	Fast
Cedar, White	Medium	Medium
Cherry, Black	Medium	Medium
Cherry, Ornamental	Fast	Fast
Crabapple Species	Medium	Medium
Elm, Species	Fast	Fast
Hackberry	Medium/Fast	Medium/Fast
Honey locust	Fast	Fast
Hawthorn Species	Medium	Medium
Ginkgo	Slow	Slow
Linden, Species	Medium/Fast	Medium/Fast
Locust, Black	Medium/Fast	Medium/Fast
Maackia, Amur	Slow	Slow
Maple, Amur	Medium	Medium
Maple, Hedge	Slow	Slow
Maple, Norway	Fast	Fast
Maple, Red	Fast	Fast
Maple, Sugar	Medium	Medium
Maple, Tatarian	Slow/Medium	Slow/Medium
Oak, Red	Medium	Medium
Oak, White	Slow	Slow
Pine, White	Fast	Fast
Pear, Ornamental	Fast	Fast
Spruce, Species	Slow	Slow
Willow, Species	Fast	Fast

BED utilizes standard pruning, flat cutting and brush mowing techniques in its vegetative management program. BED has selected these types of vegetative management controls in an effort to minimize our environmental impact as well as comply with the City's ordinance which prohibits the use of chemical herbicides.

BED mainly employs the services of the Burlington Parks Department, qualified independent tree trimming contractors, and its own line workers to carry out its vegetation management program.

The "tree" outages in 2018 were approximately 5% of BED's total outages, the five-year average was 3.4% and the 10-year average was5.4%. BED's vegetation management plan has been successful in reducing the number of outages caused by "tree" contact. BED feels that we have achieved the appropriate ratio of spending to outcome and will continue to budget approximately one hundred thousand dollars per year for vegetation management.

BED maintains a vegetation management tracking database that identifies the employee overseeing the project, the circuit number, the date and location as well as the entity that performed the work.

The following table provides the total miles of BED's distribution system, miles needing trimming and trimming cycle:

	Total Miles		Miles Needing Trimming		Trimming Cycle	
Transmission						
Distribution	135		70.84		3-years	
	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022
Amount Budgeted	$100,000	$105,000	$105,000	$110,000	$110,000	$110,000
Amount Spent	$95,640	$72,381	$105,000			
Miles Trimmed	23.8	22.26	26.4	20.33	24.11	26.4

Studies & Planning

LONG-RANGE PLANNING STUDY

In year 2018, BED performed a long-range planning study to evaluate the impact of UVM's proposed 3,700 kW peak load addition on the distribution system.[7]

7 UVM Future Load Spreadsheet document dated April 5, 2018.

The results of this study showed the need for an 1,800 kVAR capacitor bank at the proposed multipurpose recreational facility and the upgrade of two sections of primary underground 350 kcmil copper conductor. The cost estimate for these upgrades ($231,399) was provided to UVM as part of BED's review of distribution system impacts from the proposed facility.

List of Capital Distribution System Projects

a) The following is a list of BED's capital distribution system projects that were constructed between FY17 and FY20:
   - Capacitor bank control units
   - Convert GMP's line to BED's circuit
   - Great Streets – St. Paul Street rebuild
   - Install animal guards & replace cutouts on distribution circuits
   - Install animal guards at BED's McNeil Substation
   - Install conduits on St. Paul from Main Street to King Street
   - Install SCADA-controlled motor operator on switch 144S
   - Install SCADA-controlled motor operator on switch 316S
   - Install SCADA-controlled motor operator on switch 426S
   - Install SCADA-controlled motor operator on switch 343S
   - Install SCADA-controlled motor operator on switch 844S
   - Install new SCADA-controlled switch 905S
   - Rebuild 3L4 circuit from Austin Drive to Lakeside Avenue
   - Rebuild Ferguson/Richardson/Wells Street (Scheduled for FY20)
   - Rebuild Harrington Terrace
   - Rebuild Jackson Court
   - Rebuild Manhattan Drive (Pole 1845 to 1979)
   - Rebuild South Street
   - Rebuild system at Curtis Avenue
   - Rebuild system at Redrock Condos
   - Relocate SCADA server room
   - Replace 806S/807S padmount switch
   - Replace 810S/811S/812S padmount switch
   - Replace cables at Franklin Square
   - Replace cables at Redstone - P787 to 806S
   - Replace #2 unshielded copper cables on Church Street (Cherry Street to Main Street)
   - Replace #2 unshielded copper cables on Cherry Street (Church Street to S. Winooski Avenue)
   - Replace distribution system at Edgemoor Drive and relocate overhead from back yards
   - Replace recloser 109R
   - Replace recloser 412R

- Replace recloser 413R
- Replace recloser 805R
- Replace recloser 112R (Scheduled for FY20)
- Install recloser 405R at Pole 58 - Austin Drive
- Replace underground system at Laurel Court
- Switch replacement (721S/722S/743S/702S)
- UVM Lafayette switch replacement (952S, 953S, 954S, 955S, 956S)
- Various street lighting upgrades
- Replace condemned poles
- Utility hole upgrades
- RTU upgrades and replacement

b) The following is a list of BED's capital distribution system projects planned for the next three years:

- Replace switch 731S/736S/760S/761S (Church Street & Cherry Street)
- Replace switch 910S/911S (UVM Votey Hall)
- Relocate aerial circuit on Bank Street (Great Streets Project)
- Replace the underground system at Farrell Apartments (Off S. Williams Street)
- Replace the electrical system on Scarff Avenue
- Replace the underground system at UVM Living & Learning
- Replace switch 821S/401S/727S/349S/233S (Pearl Street & S. Prospect Street)
- Reconfigure 3L4 circuit long span construction
- Rebuild Airport circuit SA02
- Rebuild the aerial circuit at Appletree Point (Pole P3412 to Pole P3434) from 4.16 kV to 13.8 kV
- Install (9) conduit duct bank from UH#173 to UH#175 on Cherry Street
- Install new duct bank and cables on St. Paul Street from Bank Street to Cherry Street
- Replace the electrical system on Lyman Avenue
- Replace switch 322S/323S/324S (Main Street & University Heights)
- Replace switch 303S/307S/308S/309S (Main Street & S. Prospect Street)
- Replace the underground system at UVM Aiken Center
- Replace the underground system on Juniper Terrace (Off Summit Street)
- Rebuild the aerial circuit at Sunset Cliff (Pole P3706 to P3723) from 4.16 kV to 13.8 kV
- Upgrade the manual switch 407S at pole P2001 (Park Street & Pearl Street) to a SCADA operated switch
- Upgrade the manual switch 917S at P1765 to a SCADA operated switch
- Replace recloser 234R
- Rebuild 1L4 along North Avenue between pole P3131(Starr Farm Road) and P3169 (North Avenue Ext)
- Replace switch 305S/325S/326S (Main Street Reservoir)
- Replace switch 817S/912S/913S (Main Street Reservoir)
- Replace switch 724S/725S (College Street)

- Replace recloser 252R
- Replace disconnects 346D with SCADA operated switch
- Replace the underground system at Harbor Watch
- Upgrade manual switch 227S at pole P1980 (Park Street & Manhattan Drive) to a SCADA operated switch

Maintenance & Implementation of System Efficiency

Through the strategies and procedures described above, BED proactively maintains the efficiency of its distribution system. BED's commitment to linking software and equipment together will further enhance the automation of efficiency efforts and will improve our ability to operate the system as efficiently as possible in the future.

<u>Implementation of Distribution Efficiency Improvements</u>

The following summarizes BED's cost-effective efficiency projects and implementation timeline:

- Balance the load between 1L1 and 1L4, 2L4 and 3L1, 3L4 and 3L5, & 1L2 and 2L5 circuits. One system re-configuration case was implemented in FY2020. Two cases have been re-evaluated due to un-anticipated costs identified after this analysis and are no longer cost effective. The remaining two cases are scheduled for completion in FY2021.
- Transferring load on Henry Street and Wilson Street from phase C to phase A to balance the mainline three phase loading. This project was completed in FY2020.
- Upgrading a section of BED's lines on Canfield Street, part of the 1L2 circuit, from single-phase to three-phase construction. This project was completed in FY2020.