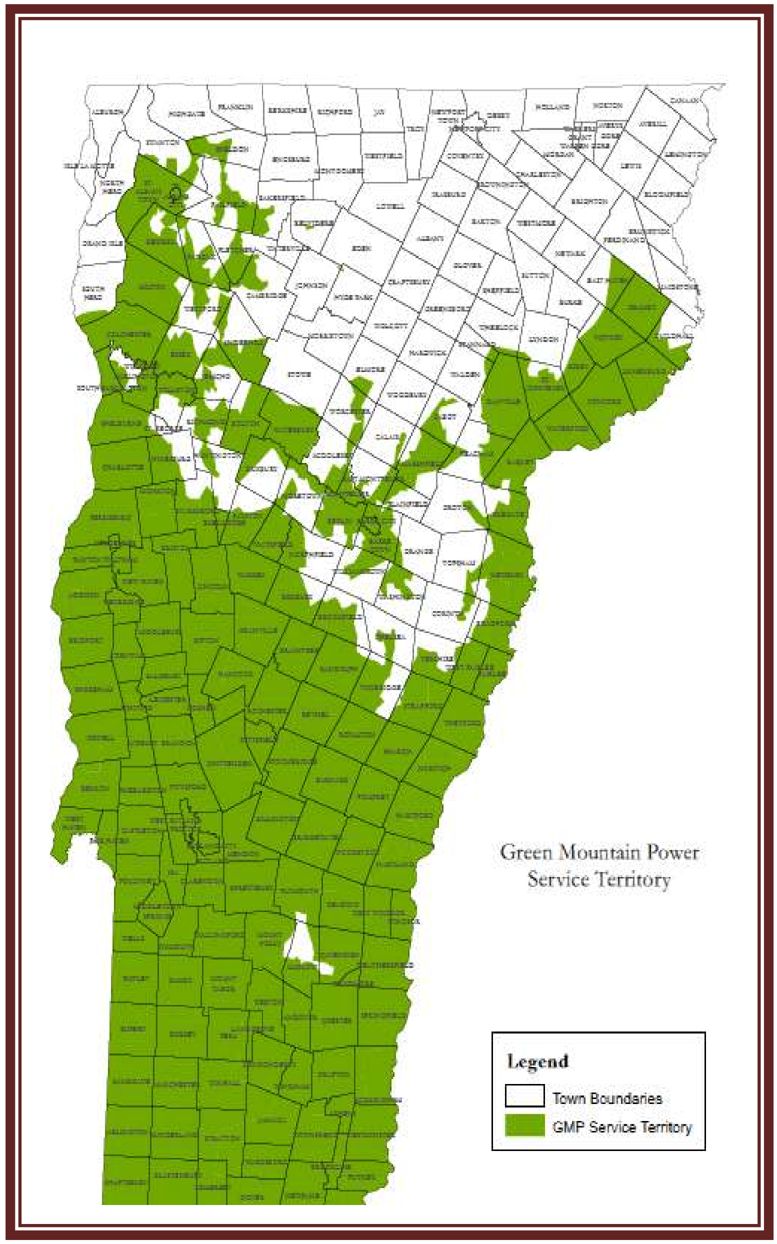
4. The Transmission & Distribution of Electricity

4.1 System Overview

Green Mountain Power provides electric service to approximately 260,000 customers in 202 towns in Vermont. In 2013, the GMP transmission and distribution system delivered over 4.3 million MWh of electricity; the peak load on the system was 762 MW. The backbone of the GMP delivery system is 976 miles of sub-transmission lines. The predominant voltages for the subtransmission system are 34.5 kV, 46 kV, and 69 kV.

The primary supply to GMP's subtransmission system is provided by Vermont Electric Power Company's (VELCO's) 115 kV transmission system. The VELCO system, in turn, is interconnected to the bulk transmission systems administered by ISO New England, New York ISO, and Hydro-Québec at voltages of 115 kV, 230 kV, and 345 kV. GMP is also interconnected to National Grid in several locations at subtransmission voltages.



The interface between the subtransmission system and the distribution system is comprised of 147 distribution substations. These substations supply approximately 300 circuits and 11,300 miles of distribution lines. GMP's predominant distribution voltage is 12.47 kV. GMP also has a limited amount of distribution at voltages of 2.4 kV, 4.16 kV, 8.3 kV, and 34.5 kV.

4.2 System Planning and Efficiency Initiatives

Transmission and Distribution Planning Criteria

Subtransmission

GMP's standard subtransmission voltages are 34.5 kV, 46 kV and 69 kV. Using the subtransmission system, GMP transmits power from VELCO and National Grid delivery points to GMP's distribution substations, wholesale customers, and large industrial customers. The subtransmission system is planned according to the Equal Slope Criteria. The Equal Slope Criteria, discussed in detail in Appendix A, can be described as a modified N-1 criterion in which a reasonable balance is sought between the total costs of a given solution and the total benefits achieved. The goal is to achieve most of the benefit of adhering to a strict N-1 criterion but at substantially less cost. GMP's operating criteria require system voltage to be between 95% and 105% of nominal on the subtransmission system during all-lines-in operation and between 90% and 110% of nominal following a first contingency. Each element in the power delivery system has a thermal design load limit reflecting the load at which an element begins to overheat and fail. GMP applies a 100% maximum load limit on all elements during normal operation. For specific cases for limited periods of time during first contingency operation, we allow overloading, but only with the understanding that operators will take quick action to remedy the overload by any means necessary, including the use of load shedding. This criterion for overloading is explained further in Appendix A.

Distribution

GMP's standard distribution system voltage is 12.47 kV/7.2 kV grounded wye[1]. We also employ a limited amount of 34.5 kV/19.9 kV distribution system facilities, but because of operating challenges with 34.5 kV equipment we restrict the expansion of this voltage to areas where 34.5 kV distribution has already been established. A limited amount of 2.4 kV, 4.16 kV, and 8.3 kV distribution remains on the system; however we are steadily converting these voltages to the standard 12.47 kV to improve voltage performance, reduce losses, accommodate load growth, and permit feeder backup between substations. The voltage delivered to customers adheres to the standards prescribed by the American National Standards Institute (ANSI) Standard C84.1.

[1] A wye is a three phase, four-wire electrical configuration where each of the individual phases is connected to a common point, the "center" of the Y. This common point normally is connected to an electrical ground.

System Monitoring

There are a number of data sources that are used by GMP to effectively monitor the subtransmission and distribution system. This information is used to make decisions regarding transferring load between circuits, removing substation banks for maintenance, correcting out-of-standard voltages, interconnection of distributed generation, and addressing load growth in potentially constrained areas. This information can dictate where area studies will be needed and provides insight into areas where non-transmission alternatives may be effective in deferring capital upgrades. The information used to monitor the system includes:

- Observations by line workers and substation technicians in the course of their daily duties.

- The VELCO Long-Range Transmission Plan, which is updated every three years and identifies portions of the GMP subtransmission system that could violate subtransmission planning criteria considering forecasted load growth over the next 20 years.

- Line and equipment loading obtained from GMP's supervisory control and data acquisition (SCADA) database. This database contains real power, reactive power, the status of capacitor banks, and phase unbalance data for the majority of our subtransmission lines and a number of our distribution feeders. SCADA data is essential in calibrating transmission and subtransmission load flow models that are used in planning studies.

- Substation and circuit MV90 data, which includes real and reactive load and voltage data for substations and individual circuits. Selected substations have per phase metering to further enhance the understanding of critical circuit loading.

- Additional monitoring equipment, including thermal demand ammeters and revenue meters, for those distribution feeders that are not monitored by SCADA or MV90.

- Customer interval load data is presently available for a number of customers. Through the use of AMI, GMP's goal is to have interval load data available for all customers. Customer interval load data can be combined with load data from other sources to help determine spatial loading of a circuit at a given point in time.

- New relays, such as the Schweitzer SEL-351, collect and store data including per phase current, voltage, real power, reactive power, and neutral currents. These relays have been installed at a number of substations and their data can be retrieved as needed.

- Load loggers are portable devices that attach to an individual phase wire and record current flow in 1, 5, or 15 minute intervals. These devices are useful for analyzing phase balancing and determining spatial load distribution across a given circuit.

- Tong tests are instantaneous current readings taken with a recording ammeter. Tong testing is useful for balancing loads and verifying load estimates. This information is often used when doing planned outage analyses.

- Per Act 250, developers planning new load additions greater than 100 kW must submit an Ability-to-Serve request to GMP. These requests are reviewed to ensure that the T&D system can accommodate the proposed new load. All requests are stored in a database, and review of these proposed load additions and their respective analyses can provide an indication of system adequacy and the potential for future constraints.

- Outage history and outage analyses, including identification of distribution feeders with the poorest reliability performance, are helpful in identifying system problems. Similarly, customer complaints, such as those involving reliability concerns, low voltage, and voltage flicker are valuable in identifying system weaknesses.

- GMP's geographic information system is used to locate aging infrastructure and equipment that may be in need of replacement.

- GMP is continuing to develop its advanced metering infrastructure (AMI) in which meters that collect large amounts of data are deployed at most customers' service entrances. In the future, GMP will be able to collect, sort and utilize increasingly detailed data, including energy use, real power, reactive power, and voltage levels for each participating customer. This data will be stored in the meter data management system (MDMS). The MDMS integrates the capabilities of the advanced meters, and the large amount of collected data, with GMP's existing systems including the Customer Care and Billing (CC&B) system and the outage management (Responder) system. Efficient access by the engineering team to the MDMS, via new reporting and analytic tools, will greatly improve the capability and response time required to analyze electric system issues. Whereas traditional distribution analysis required little more than summer peak load simulations, the growing complexity and variance of the distribution system makes the ability to efficiently calibrate load flow models even more important than in the past. These complexities are driven by customer loads, the marked increased in distributed generation interconnections, load management schemes, and automated protection strategies. The access to MDMS data will allow for the efficient and accurate development of an expanded "family" of distribution load models, including models for light loads, post-sundown peak loads, winter peak loads, and intermediate shoulder loads. The current timeline for AMI development is to have all voltage and VAR information reading into the MDMS by first quarter 2015. The remainder of 2015 will be used to retrieve, evaluate and correct the data. ORACLE's® DataRaker analytics platform will be leveraged for analysis and reporting purposes in 2015 and 2016. A more detailed description of AMI and MDMS is included in Chapter 5 on GMP SmartPower.

The Planning Process

GMP conducts T&D system planning to assure that the electric system can deliver power to its customers safely and reliably while achieving a reasonable balance between costs and benefits. A number of efforts are required in the overall planning process. The three main steps in planning include:

- Orientation: A system problem (or potential problem) is identified; information is gathered; coordination with likely stakeholders is organized and a study scope and time-line are identified.

- Study Development and Analysis: Necessary methods, tools and data requirements are identified to solve the problem. Analysis such as loadflow simulation is used to better understand system deficiencies. Alternative solutions are devised and studied using loadflow analysis, engineering calculations, and economic analysis as appropriate.

- Decision Making and Action: Results are reviewed; conclusions are drawn; and recommendations are made and supported. These recommendations, typically in the form of a proposed project, may require various regulatory approvals. After all approvals are secured, the project is implemented.

Generally speaking, there are three main drivers behind system planning: efficiency, reliability and growth. As illustrated by the individual projects discussed later in this chapter, many planning exercises encompass all three. Planning also includes consideration of non-transmission alternatives (NTAs). As discussed below, GMP's planning considers NTAs through a public process directed by the Vermont System Planning Committee (VSPC).

The T&D Planning process also recognizes that the performance of the transmission, subtransmission, and distribution systems are highly interdependent and cannot be viewed in isolation. In order to develop effective, least-cost plans, close coordination among these successive electric system levels is required. Planning coordination is discussed further below.

GMP has 147 distribution substations supplying over 300 distribution circuits. Ideally, an integrated and comprehensive efficiency study would be performed periodically on every circuit. Unfortunately, it would not be a cost effective use of GMP's limited resources to perform this level of detailed analysis for every location on the GMP system. In order to provide the maximum benefit for its customers, GMP uses available system data and screening methodologies to identify those areas that would most benefit from an in-depth examination of adequacy and efficiency improvements. These screenings identify circuits that have potential thermal or voltage constraints, inadequate power factors, phase imbalances, relay pickup overloads, or that otherwise do not meet GMP's planning criteria. Many of these overall analyses require manual review of system data and the creation of numerous reports that are generated from multiple databases. Comprehensive system screenings are done on different timelines. For example, peak load reviews for all substations and circuits are typically done on an annual basis, whereas an overall review of all circuits' power factor performance or phase imbalance would be done less often. If an individual circuit experiences a significant change, such as additional load, substantial distributed generation, or reconfiguration, then it would be flagged for review for efficiency opportunities.

By focusing on the identified circuits, GMP is able to find those areas that would most benefit from efficiency improvements. All subsequent analyses for the purpose of addressing capacity, reliability, and asset management inadequacies also incorporate a review of loss-avoidance opportunities, including capacitor placement, reconductoring, voltage conversion, feeder balancing, and circuit reconfiguration. This strategy helps GMP direct its limited resources towards those circuits most in need of upgrades and most likely to provide cost effective opportunities for efficiency upgrades.

GMP uses a number of strategies to screen circuits, including peak load reviews for substations and circuits. GMP is presently integrating a number of data resources into a single, company-wide ORACLE® database known as the business intelligence (BI) tool. The BI tool combines these data sources and allows for the development of custom reports to streamline the screening process. The BI tool will also permit GMP to decommission numerous small databases and disparate reports while providing for a standardized and unified system of record. The development of BI reporting for transmission and distribution planning is budgeted for 2015. GMP is also implementing ORACLE's® DataRaker. DataRaker is a cloud-based analytics platform that will allow GMP to leverage vast amounts of its AMI data to optimize operational performance and to transform GMP's voluminous AMI data into meaningful and useful information for business analysis. It is GMP's goal to utilize BI reporting and DataRaker analytics to provide automated screening for all of its substations and circuits. The current timeline has the development of automated screening beginning in 2016.

Planning Coordination

VELCO and the Vermont System Planning Committee

GMP participates with the Vermont Electric Power Company (VELCO) and the other Vermont distribution utilities in planning the Vermont transmission system. In 2005, the Vermont legislature amended the laws governing electric utility planning. Specifically, 30 V.S.A. § 218c(d) requires that every three years VELCO, in coordination with Vermont's distribution utilities, develop a transmission plan (the Vermont Long-Range Transmission Plan) that:

- Identifies existing and potential transmission system reliability deficiencies by location within Vermont;
- Estimates the date, and identifies the local or regional load levels and other likely system conditions at which these reliability deficiencies, in the absence of further action, would likely occur;
- Describes the likely manner of resolving the identified deficiencies through transmission system improvements;
- Estimates the likely cost of these improvements;
- Identifies potential obstacles to the realization of these improvements; and
- Identifies the demand or supply parameters that generation, demand response, energy efficiency or other non-transmission strategies would need to resolve the reliability deficiencies identified.

30 V.S.A. § 218c(d) also establishes requirements for notice and public input regarding the development of the Long-Range Transmission Plan, requires that distribution utilities incorporate the most recently filed transmission plan in their individual least-cost integrated planning processes, and mandates that VELCO and the distribution utilities cooperate as necessary to develop and implement joint least-cost solutions to reliability deficiencies identified in the Long-Range Transmission Plan.

In 2007, in the context of Docket No. 7081, the Public Service Board developed a process for satisfying these planning requirements and established the Vermont System Planning Committee (VSPC). The VSPC is the body responsible for implementing the planning process and is comprised of VELCO, Vermont's electric distribution utilities, public members, and members representing supply and demand resources. The goal of the planning process is to ensure the full, fair and timely consideration of all options to solve grid reliability in a manner that is transparent and public. Ultimately, the VSPC allows Vermont's electric utilities to fulfill the public policy goal behind 30 V.S.A. § 218c(d), namely that the most cost effective solution gets chosen, whether it is a traditional transmission upgrade, energy efficiency, demand response, generation, or a hybrid solution. As part of this process, the VSPC coordinates with stakeholders at the local, state and regional levels. These stakeholders include ISO New England, which has the primary responsibility for transmission planning in the region; regional planning commissions; local energy committees; Vermont's energy efficiency utility (EEU); and Vermont's Sustainably Priced Energy Development (SPEED) facilitator.

The transmission planning process, as approved by the Public Service Board and implemented by the VSPC, is comprised of the following steps:

- Step 1: VELCO performs a transmission analysis and creates a draft plan. This transmission analysis is closely coordinated with ISO New England and considers a twenty-year horizon. The analysis also identifies deficiencies with subtransmission systems owned and operated by the distribution utilities.

- Step 2A: The VSPC reviews the draft plan and makes a preliminary determination of the utilities impacted by reliability deficiencies.

- Step 2B: Distribution utilities and VELCO determine the applicable reliability criteria for each reliability deficiency, identify transmission solutions, and determine the non-transmission alternative equivalence.

- Step 3A: VELCO conducts a preliminary NTA analysis for bulk transmission system reliability deficiencies where appropriate.

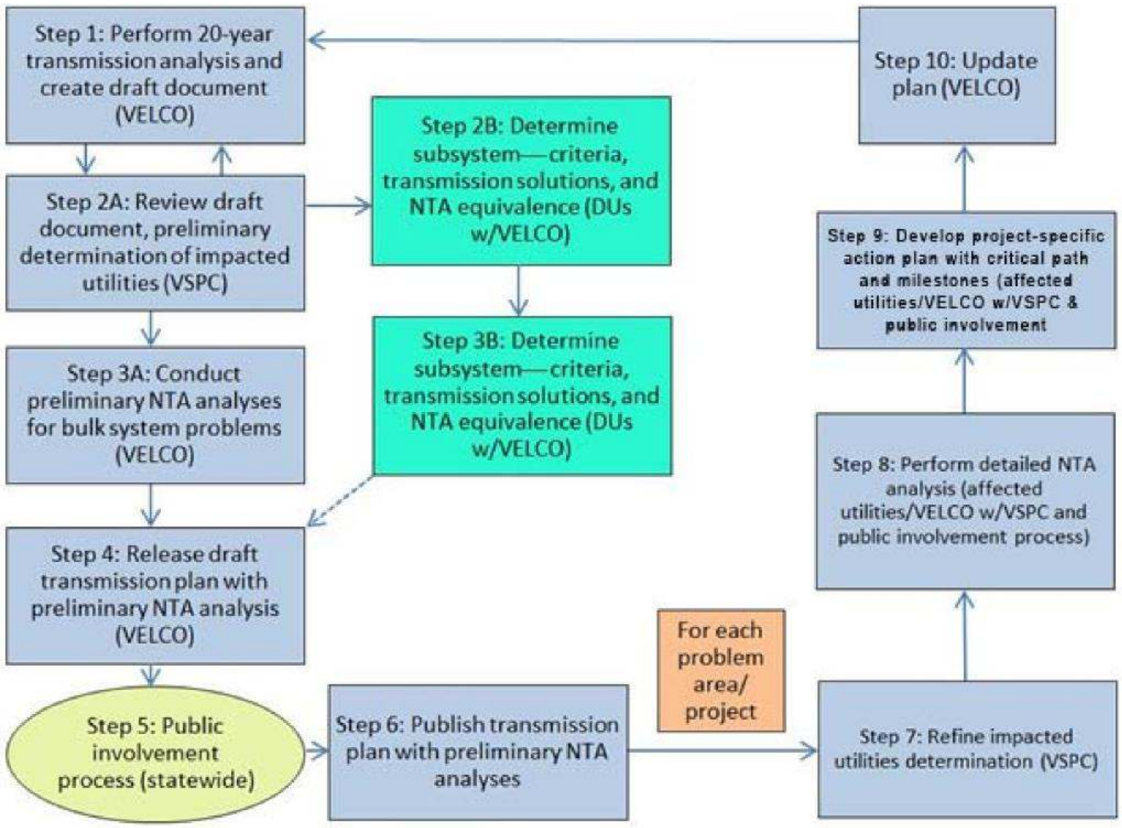
- Step 3B: Distribution utilities together with VELCO conduct preliminary NTA analyses for subtransmission system deficiencies where appropriate.

- Step 4: VELCO releases a draft Long-Range Transmission Plan.

- Step 5: The draft Long-Range Transmission Plan is subject to a statewide public involvement process.
- Step 6: VELCO with the VSPC publish the Long-Range Transmission Plan.
- Step 7: For each reliability deficiency or group of deficiencies, the VSPC refines the impacted utilities determinations.
- Step 8: For each reliability deficiency or group of deficiencies, the affected utilities, VELCO, and the VSPC engage in a public involvement process and perform the required detailed NTA Analysis.
- Step 9: For each reliability deficiency or deficiencies, the affected utilities, VELCO, and the VSPC, based on the results of the public involvement process, select a solution and determine cost allocation among the parties.
- Step 10: VELCO updates the Long-Range Transmission Plan.

These steps are summarized in the following flow chart:

Figure 4.2.1: Flow Chart of Planning Coordination



The status of GMP's projects subject to the VSPC process is contained in the VSPC 2014 Annual Report to the Public Service Board and Public Service Department, February 14, 2014 and is attached as Appendix B.

The Consideration of Standard Offer Projects to Address Reliability Constraints

In 2012, the Vermont General Assembly passed Act 170 mandating certain changes to the Sustainably Priced Energy Enterprise Development (SPEED) standard offer program, pursuant to 30 V.S.A. §§ 8005a and 8006a. Among these changes is the exclusion from cumulative plant capacity of new standard offer plants that provide sufficient benefits to the operation and management of the electric grid. By orders in Docket Nos. 7873 & 7874, the Board adopted screening framework and guidelines that provide potential standard offer project developers with information on transmission and distribution constrained areas in which renewable generation may resolve the constraints. The Board-approved screening framework and guidelines uses VSPC processes, reporting mechanisms, and subcommittees to identify and resolve T&D constraints via NTAs, including standard offer projects. These processes analyze the electric grid for reliability gaps, make recommendations to the Board regarding the potential for NTAs to mitigate those reliability gaps, provide stakeholders with the opportunity to comment on the VSPC recommendations, and result in Board decisions on whether an RFP will be issued for new standard-offer plants.

GMP has been an active participant in the VSPC processes outlined above. Since the adoption of the screening framework and guidelines, GMP has brought forward no fewer than 17 transmission and distribution constraints to the VSPC Geotargeting Subcommittee, and the full VSPC, for consideration and review. Among these constraints, two have been determined by the VSPC to be potentially resolvable through the use of NTAs, namely the St. Albans area and the Rutland area. Consistent with the above outlined processes, a reliability plan was developed for the St. Albans area and was provided to the Board and interested parties in April 2014. GMP analysis shows that the need date, even under a very aggressive growth scenario, is not until 2021. Even under this scenario, it is unlikely that major upgrades would be required to address the deficiency. As such, GMP is continuing to monitor the area. A preliminary reliability plan for the Rutland area was also filed in April 2014 and further analysis is currently underway that may reveal the potential for cost-effectively addressing the reliability gap with some combination of targeted energy efficiency, demand response, battery storage, or distributed generation. GMP expects to file its updated reliability plan in April 2015.

Other Electric Utilities

GMP regularly communicates and coordinates with other electric utilities to share information and develop system upgrades that can benefit one or the other utility. Examples of this coordination include the following:

- GMP is collaborating with the Vermont Electric Cooperative (VEC) in the Hinesburg area to relieve high loads on the GMP system. Specifically, a new 12.47 kV distribution feeder is under construction that will originate at the VEC Rhode Island Corners substation and extends into Hinesburg to supply GMP load and relieve loading on a long feeder that originates at the GMP Charlotte substation and extends over eight miles into Hinesburg.

- Similarly, GMP has an agreement with VEC in which VEC supplies the GMP load in the Sheldon area in the short term to relieve a reliability exposure on GMP’s area 34.5 kV subtransmission system. GMP will resume supply to its Sheldon load following completion of the Georgia Interconnection Project, described in detail below under the heading Projects Completed or Under Construction.

- GMP is working the Burlington Electric Department (BED) to transfer ownership of a recently disconnected GMP subtransmission line to BED. This transfer of assets would provide BED with the opportunity to develop a low-cost express feeder from its Queen City substation into the downtown Burlington area. This arrangement would also benefit GMP by allowing GMP to avoid the expense of retiring and removing this line.

- GMP provides bulk power, operational services, and engineering services to the Village of Jacksonville Electric Department (Jacksonville) and to the Northfield Electric Department. GMP recently collaborated with Jacksonville to study the feasibility of a proposed 150 kW solar installation in the Jacksonville service territory.

- GMP is supplied by the National Grid subtransmission system at several interconnection points throughout the system. On an annual basis, GMP provides National Grid with load forecasts and power factor data to assist National Grid in fulfilling certain ISO New England planning and reporting requirements.

- GMP is working with the Village of Ludlow Electric Department (Ludlow) to develop a primary-metered delivery point that would be connected to the Ludlow system for the purpose of supplying a proposed ski lift located within GMP's service territory. This strategy avoids the need for GMP to upgrade several miles of single phase line to three phase line in its territory, lowers the cost to the customer, and helps the customer meet its project timelines. GMP is also collaborating with Ludlow on future configurations to supply expanding loads on the Ludlow system. These collaborations lower the overall cost of service for both utilities and optimize the use of existing distribution facilities.

Conservation Voltage Regulation

Conservation Voltage Regulation (CVR) is an energy efficiency program applied to an electric utility's distribution system, involving measures and operating strategies designed to provide service at the lowest practicable voltage level in a cost-effective manner, while meeting all applicable voltage standards. Field studies have shown that, in general, a one percent reduction in the voltage delivered to customers results in a one percent reduction in energy consumption. To date, the primary strategy for implementing CVR has been the use of line drop compensation (LDC). LDC is a control device connected to tap-changing transformers and voltage regulators that measures feeder load current and computes the resultant voltage drop. The value of the voltage drop is then used by the tap changer or regulator to raise or lower the feeder voltage.

GMP supplies service voltage to its residential customers at 120 volts nominal with a range of +5% to -5% as required by ANSI Standard C84.1-2011. CVR has been implemented on a number of circuits for both the legacy GMP and legacy CVPS portions of the distribution system. On the legacy GMP system, the CVR strategy has been to use LDC to keep the end-of-feeder voltage as low as possible while maintaining this voltage at or above 114 Volts (i.e., 120 Volts -5%). On the legacy CVPS system, the CVR strategy has been to reduce the maximum service voltage by 2% resulting in a compressed service voltage range of +3% to -5% with 120 Volts nominal. This is accomplished by changing the central mean voltage (CMV) settings on distribution substation and line regulators from 122 volts to 120 volts.

Not all circuits are appropriate for the implementation of CVR. These can include long circuits, circuits in which voltage regulation occurs at the substation bus, and circuits with large commercial and industrial loads in which customers provide their own voltage regulation. Some circuits that were previously on CVR have been removed from CVR to allow for circuit transfers during planned or contingency situations or because of complaints from sensitive customers.

An emerging issue with CVR pertains to the installation of distributed generation on the distribution system. Large quantities of generation on a distribution feeder reduces the amount of current that LDC controls can detect, thereby reducing the apparent voltage drop across the length of the feeder and resulting in low voltages delivered to customers at the ends of feeders.

GMP believes that, moving forward, further development of CVR should take advantage of the maturing advanced metering infrastructure (AMI) program. Among the strategies available with AMI is the integrated Volt/VAR control (IVVC) of distribution circuits. IVVC is a control strategy in which distribution circuit voltages along a given circuit are measured in real time. These voltage measurements are then used to optimize voltage regulator settings and capacitor bank switching. An IVVC pilot program will be conducted in 2015 and 2016 as part of GMP's Rutland Grid Innovation project. This pilot program, together with the potential for the expansion of IVVC to other parts of the GMP system, is discussed further below under the heading Distribution Automation and System Management / The Rutland Grid Innovation Project.

Power Factor Correction

Appropriate reactive power (VAR) compensation through the placement of capacitors allows for a more efficient and less costly power delivery system and can reduce or postpone investments in system facilities. The majority of capacitor placements on the GMP system take place at the distribution level. To maximize benefits, it is generally best to correct reactive power flow closest to the load. When this is accomplished, efficiency opportunities are maximized through the use of lower voltage distribution capacitors that are generally less expensive than higher voltage subtransmission capacitor banks. The close placement of VAR sources to loads also reduces losses. In addition, ISO New England strictly limits reactive power flow between reliability regions. ISO New England requires that VELCO hold its transmission system power factor to no less than 0.98. In turn, VELCO limits the power factor at GMP's delivery points to no less than 0.95. GMP calculates power factor using real and reactive power obtained from GMP's supervisory control and data acquisition (SCADA) database and from substation and circuit MV90 data.

To help meet these limitations, enhance circuit performance, and decrease losses, GMP has performed capacitor optimization studies for the majority of its circuits. Several factors are involved with optimal capacitor placement including voltage drop, regulator placement, loss reduction, and capacitor costs. In 2011, GMP Legacy North completed a capacitor placement program that installed 93 capacitor banks totaling 57 MVAR on its distribution system. Moving forward, these analyses will be conducted when engineering judgment or monitoring suggests that loading, DSM efforts, growth, and circuit configuration require re-evaluation of capacitor placements. As AMI is further developed, AMI VAR and voltage data will be used to assist in power factor correction analysis. GMP expects to develop reporting and analytics in 2016 to support these efforts.

To incentivize customers to correct their power factors directly adjacent to loads, GMP Legacy North has set the minimum power factor required for customers to avoid a demand determination adjustment under its commercial and industrial tariffs to 95%. For the same reasons, GMP Legacy South increased its tariff power factor demand determination adjustment levels from 85% to 90% power factor. Among GMP's long-term goals for integrating the Legacy North and Legacy South systems is consistency among its tariffs, including the power factor level used for demand determination adjustment.

Circuit Balancing and Reconfiguration

GMP analyzes the load balance among phases on a circuit whenever large single-phase loads are added to the system, feeder back-up studies are performed, or protection issues call into question the balance among phases. Swapping loads from one phase to another to balance circuits has the added benefits of reducing losses and improving voltage performance. In the past, phase imbalance was screened by reviewing available per-phase MV90 or relay data at the substation. The availability of AMI information will streamline this effort by identifying the distribution of circuit loads by phase. This could assist in identifying not only imbalance concerns at the substation, but also along the circuit at key locations including protective devices, tie points and distributed generation sites.

Similarly, GMP evaluates the relative loading of adjacent circuits and optimizes the normally-open points between these circuits to lower losses, improve voltage performance, enhance circuit protection, and extend the load capabilities of substation transformers. Opportunities for circuit reconfiguration are most likely to occur in relatively densely loaded urban areas. Circuits that serve rural areas generally do not lend themselves to backup with other distribution feeders.

The need to reconfigure circuits can be driven by many factors including capacity problems, reliability issues, interconnecting distributed generation, voltage complaints, low fault currents, and loss savings opportunities. In recent years, GMP has reconfigured circuits in the following areas:

- Montpelier: Circuits between the Montpelier, Berlin and Mountain View substations have been reconfigured to manage area load growth and enhance feeder backup.

- Essex-Colchester: Circuits between the Essex, Gorge, Ethan Allen, and Mallets Bay substations were reconfigured to address load growth in Essex that was driven in large part by a new, large industrial load.

- Essex: Two circuits supplied by the Essex substations were reconfigured to help address growing commercial load in the Route 289 area.

- Essex-South Burlington: An existing 4.16 kV circuit from the Airport substation in South Burlington was converted and joined to a 12.47 kV circuit from the Essex substation to accommodate a 2 MW solar generation project at the Vermont Air National Guard.

GMP also sees a number of opportunities for circuit reconfiguration arising over the next several years. These include:

- Barre: GMP plans to convert the remaining 2.4 kV and 4.16 kV circuits in the Barre area to 12.47 kV. As part of this effort, GMP will reconfigure these circuits to maximize feeder backup capabilities.

- Waterbury: GMP plans to relocate its existing Waterbury substation and convert the associated feeders to 12.47 kV. As part of this project, GMP will reconfigure the area's circuits to address load growth and to allow for feeder backup with the Waterbury Center substation 12.47 kV circuits.

- White River Junction-Wilder: GMP plans to rebuild its White River Junction substation and expand the number of circuits from this substation from one to three. As part of this project, GMP will reconfigure these circuits with the adjoining three circuits from the Wilder substation to optimize losses and enhance feeder back-up capability.

- Winooski: GMP plans to construct a new 34.5 kV distribution feeder into Winooski from the Gorge substation. In conjunction with this project, 34.5 kV feeders from the Winooski and Ethan Allen substations will be reconfigured to better balance the loads among these three feeders and enhance reliability.

- Dover-Wilmington: GMP plans to construct a new substation in Dover to supply expanding ski area loads. GMP will also reconfigure the circuits between this new substation and the Dover and Wilmington substations to better balance loads, improve reliability, and enhance feeder backup.

Voltage Conversion

GMP's standard distribution system voltage is 12.47 kV/7.2 kV grounded wye. While a limited amount of 2.4 kV, 4.16 kV, and 8.3 kV distribution remains on the system, GMP has been steadily converting these voltages to the standard 12.47 kV to accommodate load growth, permit feeder back up between substations, improve voltage performance, and reduce losses. Voltage conversions over the previous three years include the following:

- The distribution circuits supplied by the Westminster substation were converted from 8.32 kV to 12.47 kV. This conversion permits back-up with feeders from the Bellows Falls Bridge Street substation.

- The 4.16 kV circuit that supplies the Central Vermont Hospital in Berlin was converted to 12.47 kV distribution. This conversion enhances reliability to the hospital by providing feeder backup to this circuit.

- The 4.16 kV circuit supplied by the Marshfield substation was converted to 12.47 kV and is now supplied by the Plainfield substation. The Marshfield substation could not accept a mobile transformer whereas the Plainfield substation can accept a mobile transformer, thereby enhancing reliability to the loads supplied by this circuit.

- GMP converted the Gorge substation 4.16 kV circuits to 12.47 kV. This conversion relieved heavily loaded circuits from the Essex substation, balanced feeder loads, and provided limited feeder back-up between these circuits.

Voltage conversions in the planning stage include the following:

- The Barre area is served by distribution circuits at 2.4 kV, 4.16 kV, and 12.47 kV. As part of the larger Barre area upgrades, presently in planning and discussed further below, all 2.4 kV and 4.16 kV circuits will be converted to 12.47 kV.

- The existing 34.5 kV to 4.16 kV Waterbury substation will be rebuilt and relocated. As part of this rebuild, the substation and all of its circuits will be converted to 12.47 kV to accommodate future load growth and to permit feeder backup with circuits from the Waterbury Center Substation.

- The Fair Haven and Hydeville substations supply 4.16 kV circuits. Conversion of these circuits to 12.47 kV is tentatively scheduled for 2018. These conversions will reduce losses and allow for improved backup between the Fair Haven, Hydeville, and Castleton substations.

GMP does not have an explicit timetable for converting all of its lower voltage circuits to 12.47 kV. Rather, the decision to convert a given circuit or area is considered on an individual basis and can be driven by a number of considerations including capacity constraints, the desire for feeder backup with adjoining substations, opportunities arising from the need to replace deteriorating plant, low voltage complaints, inadequate fault currents, and potential loss savings. Loss analysis for a voltage conversion considers line losses, substation transformer losses and distribution transformer losses. Given that losses vary as the square of the voltage, loss savings can be significant for highly loaded circuits that are converted. In addition, voltage conversions can provide opportunities for feeder reconfiguration and balancing with adjacent area circuits thereby providing further opportunities for loss savings. Voltage conversions can often be economically justified on the basis of loss savings. As with all capital upgrades, GMP evaluates individual projects' costs and potential benefits, and selects those projects that provide the greatest value to its customers.

Roadside Relocation

A portion of GMP's distribution lines traverse cross country and away from roadsides. For the most part, these line sections were originally constructed in rural areas in mid-1900s at a time when customer densities were relatively low and when there was less emphasis on the need for highly reliable electric service. Unlike lines that are constructed roadside, cross country lines cannot be accessed by bucket trucks. The need to access cross country lines by foot or all-terrain vehicles makes tree trimming, line maintenance, and outage restoration significantly more time intensive and costly. In addition, climbing remotely located poles can be a safety issue due to the fact that these poles are often older, smaller, and in poor condition. For these reasons, GMP has a strong preference to move cross country lines roadside whenever these lines require reconstruction. Despite the advantages of roadside relocation, however, there are factors that can inhibit GMP's ability to relocate the lines. Among these can be cost, limited availability of roadside terrain, aesthetic impacts, or the inability to obtain needed easements or Act 250 permits. In these cases, one potential option, although costly, is to underground the line. In circumstances when a cross country line must be rebuilt in place, GMP may attempt to improve the line's reliability through more robust construction, enhanced tree trimming clearances, installation of animal guards, or the use of poly-coated tree wire for primary conductors and transformer taps.

Transformer Acquisition

GMP adds and replaces distribution transformers on its system for a variety of reasons including unit failure, distribution circuit voltage conversion, load growth surpassing a transformer's capacity, and storm damage. GMP adds transformers to its inventory that are the lowest life-cycle cost based on both the first cost of a given unit and the expected cost of demand and energy losses over the unit's life. We determine the cost of life-cycle losses for a given transformer with an Excel®-based analytical tool developed in collaboration with the Public Service Department. The transformer acquisition tool assumes a 30-year total owning cost for transformers and is updated annually with appropriate avoided costs, financial data, and system parameters. Life-cycle loss factors are developed for each of the following size distribution transformers:

- 10 kVA and below
- 15 kVA
- 25 kVA
- 37.5 kVA
- 50 kVA
- 75 kVA and above

The most recent version of GMP's distribution transformer acquisition tool is attached as Appendix C. Substation transformers are evaluated, using the same analytical tool, on an individual basis.

GMP provides the resultant first cost, no-load loss, and full-load loss multipliers to vendors who then bid transformers with a given first cost and loss characteristics. GMP then evaluates these bids and selects for purchase the lowest life-cycle cost transformers available. GMP also requests bids for amorphous steel core transformers when purchasing distribution transformers and purchases these units if they are bid with the lowest life-cycle cost. Amorphous core units, while having a higher first cost, can have core losses one-third that of conventional steels. Amorphous core units are purchased when their extra cost is more than offset by the loss savings over the assumed 30-year life of the unit.

Moving forward, GMP finds that it will be in its customers' interest to diversify its purchases of distribution transformers from among suppliers. Recent experience shows that reliance on a single, low-cost supplier for a given size transformer can leave GMP vulnerable to unexpected production shortages and delays, thereby forcing GMP to purchase immediately-available, refurbished units to keep up with system demands. To mitigate against the risk of exhausting its transformer stock, GMP plans to purchase approximately 90% of its most popular sized distribution transformers from the lowest cost bidder, and to purchase the remaining 10% from the next-to-lowest cost bidder.

Distribution Transformer Load Management

As GMP's advanced metering infrastructure (AMI) program matures, one of the benefits could be the development of a distribution transformer load management (DTLM) program. DTLM programs match individual distribution transformers to their respective loads with the goal of:

- Optimally sizing new transformers, taking into consideration the existing loads, motor starting requirements, and the projected capacity and energy losses over the lifetime of the installation;
- Replacing highly-loaded transformers that are sources of failures and high load losses; and
- Replacing under-loaded transformers that are sources of excessive capital investment and no-load losses.

Through the use of AMI, a link could be established between meter accounts and the individual transformer supplying these meters. This would allow:

- Calculation of the coincident demand imposed on a given transformer;
- Calculation of the energy supplied by the transformer;

- The calculation of load losses and no-load losses on the transformer;
- The identification of overloaded units;
- The identification of potentially under loaded units; and
- The evaluation of the effects of anticipated load growth on the losses and remaining capacity of a given transformer.

The development of DTLM could allow for the efficient management of transformer loading, postpone unnecessary transformer replacements, and identify overloaded and inefficient units that are in service. This program could be especially useful for areas in which the distribution voltage will be converted and a large number of transformers will be replaced. The utilization of ORACLE® BI reporting and DataRaker analytics will be required for the development of a DTLM program. The current timeline calls for the development of automated system efficiency screenings to be initiated in 2016. It is possible that a DTLM could be developed before the next IRP filing.

Conductor Selection

GMP selects conductors for its subtransmission and distribution systems that are least cost based on the conductors' first cost together with the present value cost of the demand and energy losses of the conductor calculated over a twenty-year period. The least-cost conductor is selected for all new construction, line extensions, and line reconstruction. Using this least-cost methodology, GMP has selected a number of standard conductors which have been placed into application charts known as wire nomographs. Wire nomographs are employed by system planners to select the appropriate conductor using the expected (non-contingency) conductor loading. However, before ultimately choosing a conductor for a given application, the planner will consider other factors including expected voltage drops, fault currents, post-contingency current levels, geographic constraints, and expected system changes. For example, reconductoring on the 34.5 kV subtransmission system in Chittenden County in recent years has used 795 ACSR conductor. Besides having very low losses under normal loads, 795 ACSR was chosen because it can carry the post-contingency thermal loadings of this system, be supported with single pole/cross-arm construction without the expense of excessively robust structures or short spans, and is a common conductor used in Vermont and New England thereby making it readily available under emergency conditions.

Past studies have shown that, with few exceptions, reconductoring solely for the purpose of loss savings is not cost effective. The cost of new conductors, together with the new and larger pole plant often required to support these conductors, will generally surpass the value of any expected loss savings. However, GMP does analyze the benefits of reconductoring whenever the reconstruction of subtransmission and distribution plant is required. The need to rebuild plant can arise to support road improvement projects, address age, improve degraded plant condition, relocate lines from cross-country to roadside, or establish feeder backup between substations.

Implementation of T&D Efficiency Improvements

Efficiency screening is a routine part of any GMP T&D system study or capital upgrade. As previously described, efficiency opportunities are captured through wire sizing, power factor correction, transformer purchasing, circuit balancing, voltage conversions, and circuit reconfigurations. The implementation schedules for these measures are project specific. For example, distribution transformer installations quickly capture loss-avoidance opportunities given that transformers generally are installed within one year of being evaluated using the least-cost transformer acquisition tool. The least-cost conductor for a given application would be selected at the time that the project is designed while the timing of project construction will vary depending on the scope of the upgrade and its priority in relation to other projects in the queue. Projects that provide multiple benefits, including combinations of asset management, feeder backup improvement, line relocation from off road to on road, capacity increases, as well as loss avoidance are given priority. These projects often involve a substation upgrade, subtransmission line reconductoring, or larger three phase distribution line upgrade. Such larger projects are typically completed in a three-to-five year period. Smaller projects involving individual distribution circuits, including capacitor placement, phase balancing, or load balancing among feeders typically take less time to implement due to their smaller scope and reduced preconstruction requirements.

Distributed Generation Interconnection

GMP supports the interconnection of distributed generation onto its transmission and distribution system. Over the past decade, federal and state incentives for the development of renewable distributed generation have resulted in a marked increase in applications and installations. Depending on the size of the generation and the method of compensation for power produced, developers of distributed generation would follow one of three paths: net metering, purchase power contracts through the Sustainably Priced Energy Enterprise Development (SPEED) programs, or direct purchase power agreements.

Before interconnecting with the GMP system, each generator must receive a Certificate of Public Good (CPG) from the Public Service Board. As part of the CPG process, GMP ensures that the generator can be interconnected to its system in a safe and reliable manner, consistent with applicable GMP, ISO New England, and Public Service Board procedures and requirements.

GMP is active with the ISO New England Distributed Generation Forecast Working Group (DG Working Group). The DG Working Group considers various issues with distributed generation including national trends, interconnection requirements, under-frequency setting concerns, and interconnection costs. In addition, GMP continues to develop a number of tools to help distributed generation developers navigate the interconnection process. These tools include the following:

- GMP has produced A Guide to Customer-Owned Generation & Distributed Resources (the DR Guide) which is available at: http://www.greenmountainpower.com/customers/distributed-resources/a-guide-to-customer-owned-generation-and-distributed-resourc. The DR Guide provides resources to the developer including applicable tariffs, registration and application forms, enabling statutes, Public Service Board rules, trade association information, and regulatory contacts. The DR Guide also provides technical information in the form of service requirements, meter socket connections, a map of the GMP subtransmission system, and a map showing the location of GMP's three-phase distribution lines.

- GMP has developed detailed technical interconnection requirements which are provided in the Green Mountain Power Distributed Resource Interconnection Guidelines (Interconnection Guidelines). The Interconnection Guidelines are attached as Appendix D and provide developers with information on the interconnection process, equipment requirements, application instructions, screening criteria, and service extensions.

- GMP has created, for internal use, a distributed resources database. This database contains information on distributed resources, both proposed for, and installed on, the GMP system. The database includes: the developer's contact information; type of generator; the primary energy source; generator technical parameters; generator location; interconnection voltage; ancillary equipment; and site information. This database links to GMP's CYME® distribution system planning software thereby automatically updating GMP's planning models and streamlining any needed interconnection studies or future system analyses.

- GMP has enabled on-line interconnection applications. Compared to paper submissions, the on-line applications have proven to be more efficient, secure and error free. The on-line applications automatically link to GMP's distributed resources database. In the future, GMP hopes to automatically link its on-line applications with the Public Service Board's emerging electronic case management system.

- GMP is presently creating a Distribution Systems Information Map (the Solar Map) for use by distributed generation developers. The Solar Map displays, for any given location, the distribution circuit that is closest to a proposed development, the distance to that circuit, the number of phases that are available, circuit voltage, the distance to the substation, the amount of generation presently connected to the circuit, and proposed generation queue information for the circuit. Future enhancements to this tool are planned that would include the amount of generation that can be interconnected at any given location, solar irradiance information, and links to Agency of Natural Resources GIS environmental data layers. GMP is also developing a cost estimation tool to assist developers in estimating the cost of interconnection for a proposed generator at a given location.

- GMP's efforts to implement ORACLE's® BI reporting and DataRaker analytics should provide more accurate and granular input into GMP's CYME® loadflow circuit models. The improved circuit depictions will assist in proactively evaluating the impacts of DG penetration.

LED Streetlight Replacement

GMP has collaborated with Efficiency Vermont to develop the Municipal Streetlight Initiative. This initiative helps municipal customers improve the lighting efficiency on streets and in public spaces by re-examining their lighting needs and replacing less efficient streetlights with new light-emitting diode (LED) technology. As part of this effort, Efficiency Vermont has prepared a step-by-step "Guide to Improving Efficiency in Municipal Street and Public Space Lighting" available at https://www.efficiencyvermont.com/docs/for_my_business/lighting_programs/StreetlightingGuide.pdf.

The benefits of LED streetlights include:

- Significantly reduced energy use;

- Longer lasting lamps. The life of an LED lamp is at least four times longer than mercury vapor fixtures, thus lowering maintenance costs; and

- Improvement in the nighttime environment. LED fixtures are 100% full cut off, meaning that no light escapes from the top which reduces light pollution into the night sky and neighboring properties and decreases glare to motorists and pedestrians.

GMP and Efficiency Vermont offer financial incentives for municipal customers to convert to LED lighting. Customers need only determine where to install LED lighting and what size those LED lights should be. GMP has developed street lighting tariffs that offer financial savings for LED lights when compared to older technology lights.

In 2014, GMP collaborated with the City of Rutland to pilot a street lighting program that improves efficiency, streamlines streetlight repairs, and enhances public safety. This program installed 100 high-efficiency LED streetlights with intelligent controls in Rutland City together with 41 solar panels mounted on utility poles. The panels should produce about 12,800 kWh annually, enough energy to offset the lights' use. These lights are the first on the GMP system with the ability to notify the company when they fail, thereby resulting in less down time, more continuous street lighting, and improved customer service.

Emerging Opportunities and Challenges with T&D System Planning

Electric Vehicles and Heat Pumps & the Effects of Load Growth on the T&D System

Among the load types that have the potential for significant impacts on GMP's T&D system are plug-in electric vehicles (EVs) and cold climate heat pumps. EVs are becoming increasingly popular throughout GMP's service territory. As part of its load forecast for this IRP, GMP considered forecasts of EV penetration rates from the Vermont Department of Transportation and the Vermont Air Pollution Control Division together with goals established by the Vermont Comprehensive Energy Plan. GMP's low, medium, and high outlooks for EV's over the next 10 years each shows a total penetration of 5% or less. In addition, heat pumps are beginning to displace fossil fuels for heating ventilation and air conditioning. Throughout the state, rebates are available promoting the adoption of heat pumps. GMP presently offers customers a lease to defray the up-front cost of installing heat pumps. Over the next 10 years, both the Energy Information Administration and Efficiency Vermont forecast heat pump penetration in Vermont to be approximately 5%.

The overall forecast of load growth for the GMP service territory, including the effects of EVs and heat pumps, indicates essentially flat load growth through 2024 increasing to about 1% annual load growth from 2024 through 2034. The implications for increasing penetration of EVs and heat pumps on the T&D system appear to be twofold. First, given the forecast for modest increases in overall loads for the next twenty years, the effect of these new technologies on the transmission, substation, and primary feeder levels are unlikely to be significant. Few areas of the transmission and primary distribution system are vulnerable to the effects of a few percent load increase. However, at a more local level, specifically at the distribution transformer and service wires level, the installation of these devices could have an effect. Currently, EV chargers have peak loadings in the 1 kW to 4 kW range. More powerful fast chargers can impose demands of up to 15 kW on the system. Residential heat pumps impose demands on the system generally in the 2 kW to 5 kW range. Depending on the types of appliances, the numbers of these appliances in close proximity, and the size of the existing distribution transformer and service conductors, installation of these devices could result in local equipment overloads and low voltages that in turn could require the installation of larger transformers, larger service wires, or dedicated (split) services. One method of anticipating locations where the penetration of EVs and heat pumps could cause problems is with the use of AMI and the Network Management System (NMS), described further below. Use of the NMS will help identify locations where loads are approaching thermal limits, voltages are marginal, and equipment upgrades would be required.

Managed Charging

To ensure the best use of the T&D system, EV charging will be managed to occur primarily at off-peak times. Researchers at the University of Vermont have concluded that, if charging occurs during off-peak hours, the Vermont grid is capable of supporting more than 100,000 EVs without the need to expand generation and transmission capacity.[2] (As noted above, upgrades may still be needed at more local levels, most likely with larger distribution transformers and service wires.) By charging at off-peak hours, EVs could help fill late-night valleys in system demand which would mitigate line losses, lower the cycling stresses on generating units, and more efficiently utilize existing infrastructure. This would result in lower costs to customers and allow the electric system to satisfy EV demands without the need for significant upgrades.

Managed charging of EVs can take several forms. Time-of-use rates are a relatively simple method whereby rates are developed to encourage off-peak charging, which flattens electric loads over the course of a day. While owners may plug in their EVs whenever they return home, charging timers or automated controls can be set to delay charging to correspond with a lower off-peak rate.

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[2] Letendre, Steven, Richard Watts, and Michael Cross. "Plug-in Hybrid Vehicles and the Vermont Grid: A Scoping Analysis." *University of Vermont Transportation Research Center*, February 2008. http://www.uvm.edu/~transctr/pdf/Final_PHEV.pdf.

Another method by which EV charging can be controlled is through direct control by the utility. GMP has many years of experience with the direct control of residential water heaters. As EVs become more ubiquitous, similar direct control strategies can mitigate the negative effects of numerous EV chargers coming on at the same time by randomizing the time at which vehicles start charging. Direct control could also allow utilities to stop charging EVs when the grid is reaching peak demand and resume charging when system loads are lower.

Vehicle to Grid Power Flows

Apart from simply acting as loads, the battery storage capability of electric vehicles may, in the future, permit EVs to serve as a resource to the electric grid. For example, the balance of generation and loads in Vermont, and throughout New England, is managed by ISO New England. Presently, the most common balancing resources are natural gas generators that ramp up or down in response to changing loads. In the future, however, EVs may be capable of providing this resource. While gas turbines require several minutes to respond to changing demands, electric vehicle battery systems have the potential to provide near-instantaneous responses to grid operator signals. Using EVs as a resource in this manner would allow EV owners to participate in ISO ancillary service markets thereby providing value to both the grid and the EV owners.

Another potential use of EV battery storage could be to supply energy to homes or businesses when demand is high. This peak shaving potential would be most advantageous to customers served on demand rates. With the appropriate interface technologies in place, EVs could also serve as backup power sources to customers during power outages. When fully integrated, EVs have the potential to enhance reliability, enable the more efficient use of existing resources, and allow for the greater penetration of renewable resources.

Penetration of Distributed Generation

The increased penetration of distributed generation onto radial distribution circuits presents numerous challenges to the planning and operation of the system. The challenge in interconnecting any given unit is a function of the size and type of the proposed generation, the relative strength of the electric system at the proposed point of interconnection, and the nature of the protection strategies in the area. As described in the Interconnection Guidelines at Appendix D, a series of studies may be necessary to identify potential problems and develop appropriate solutions. These can include a feasibility study, system impact study, stability study, and facilities study. Following these studies, GMP works with the generation developer to address the concerns of interconnecting a proposed unit and arrive at solutions. Among the issues that can arise from the increased penetration of distributed generation are the following:

- Thermal Loading: Equipment along the electrical path to the point of interconnection, including conductors, transformers, and voltage regulators, can potentially exceed their thermal ratings due to current contributions from distributed generators.

- Operational Loading: Protective devices such as fuses and reclosers can exceed their thermal rating (above nameplate but below trip level) and operational rating (above trip level).

- Reverse Power Flow: A relatively large distributed generator can cause reverse power flow through voltage regulators and protective devices. Devices not capable of proper operation during a reverse flow condition would need to be replaced with appropriate devices.

- Voltage Fluctuations: Power injection from distributed generation into the grid can affect voltage levels. The most typical result is a voltage rise at the point of interconnection. Another concern is that induction generators can have a large reactive power inrush when first starting up resulting in voltage sags. Larger generators may need to come online in a gradual manner to allow distribution voltage regulation equipment to keep pace with changing voltage levels.

- Islanding: Islanding is a phenomenon whereby distributed generation supplies loads that have been disconnected from the grid due to the operation of a protective device. Unintentional islanding is undesirable from a safety and reliability perspective. Without the strength provided by the larger grid, voltage and frequency can vary during islanding conditions causing damage to equipment and resulting in unsafe conditions.

- Fault Current Contributions: Protection schemes on radial feeders are designed with the assumption that current flows into a fault through the upstream protective devices. Distributed generators can provide fault current from alternate directions resulting in the failure of existing protection.

- Ground Fault Over-Voltages: High voltages can occur during ground faults in circumstances in which a proposed generator is not effectively grounded and there is a relatively large generation-to-load ratio in the area.

Distribution Grid of the Future

Over the next few years, the GMP distribution system will continue to evolve and change as a result of changing customer needs, technology advancement, and public policy objectives. The distribution system will need to continue to provide cost effective, reliable, and secure services while it is utilized in ways that are different than it was originally designed. In particular, the amount of distributed generation on GMP's system is expected to grow rapidly in this decade, with solar PV capacity (through a combination of net metering, SPEED standard offer projects, direct power purchase agreements, and GMP-owned capacity) likely to surpass 200 MW by the end of the decade.

The specific impacts of this distributed generation on GMP's distribution system are uncertain, and will depend on a range of factors – including the size of the distributed generation plants, where on the system they are located, and how closely together they are located. In general, smaller and more dispersed plants tend to raise fewer operating concerns, while large projects which are located in concentrated areas (or far from load) have the potential to raise more serious operating issues and to face more costly interconnection requirements. GMP has a systematic approach to screen proposed new distributed generation projects, with the goal of maintaining system integrity and reliability after the generation is operational. Specifically, GMP screens significant distributed generation projects to assess their potential impacts on system performance and to identify interconnection upgrades and protection schemes that will be needed to maintain system performance. This approach is designed to ensure that the GMP distribution will continue to operate safely and reliably after distributed generation is installed. It is reasonable to expect, however, that as the penetration of distributed generation on the GMP system increases to unprecedented levels, the scale and cost of required interconnection investments for distributed generation at some locations may be substantial enough to make its cost-competitiveness uncertain. As noted earlier, GMP is seeking to address this concern by developing tools (e.g., the Solar Map, interconnection cost estimation tool) that we expect will help identify sites where distributed generation can be interconnected at relatively low cost, and help limit development at sites where interconnection would be particularly problematic or costly.

GMP also recognizes that in the longer term, the proliferation of distributed generation plants, along with the emergence of energy resource technologies such as energy storage and electric vehicles, along with advances in other grid technologies including sensing and measurement equipment, advanced analytics and controls, power electronics, and telecommunications, will also require GMP to consider different planning and design methods, capital investment strategies, and cyber security requirements.

Planning and Design Considerations

The continued growth of distributed energy resources being deployed on the distribution system and on the customer side of the meter will require GMP to take a more holistic approach to distribution system planning and design. The distribution system of the future will need to accommodate bi-directional power flows from distributed and variable resources that can be redirected to different substations and feeders across the GMP system. To accomplish this, distribution designs may need to evolve from radial designs to other configurations including looped systems, self-healing networks, and micro grids. The operation of the distribution system may need to transition from passive/reactive management to active management with real time processing of large amounts of information and proactive operation of the system. This will need to be done in the context of cost effectively improving grid resiliency and reliability and enhancing system efficiency, while facilitating the integration of more and more distributed and renewable resources.

Investment Strategies

In addition to the traditional investments currently being made on the distribution system aimed at replacing aging plant, accommodating load growth, and improving system operability and reliability, GMP will need to invest a larger share of its expenditures on more sophisticated control and sensing equipment, advanced system protection designs, and SCADA enabled distribution devices. The investment in these technologies and equipment will be essential in facilitating integration of larger amounts of renewable resources and providing the opportunity for broader market participation by customers and third party energy resource providers, as well as improving system utilization and efficiency.

Cyber Security

As the distribution system becomes more sophisticated with increasing amounts of connectivity to more field devices and more interfaces between IT systems and field devices, the overall system becomes more vulnerable to cyber-attack. This is made more complex by the blurring of boundaries between the transmission and distribution systems. It will be important that the overall security of the system is maintained as the grid of the future is built out. To accomplish this, GMP plans to leverage its current experience with cyber security as well as the work that has been done in this area by other organizations including EPRI and other industry working groups.

NRG Partnership

Among the steps GMP is taking to develop the distribution grid of the future is to partner with NRG Energy, a national leader in green energy solutions. Beginning in 2015, this partnership plans to bring innovative products and services to Rutland while furthering the development of an advanced distribution grid. Details of this program are contained in Chapter 5.

4.3 Projects Completed or Under Construction

This section describes GMP's large transmission and distribution capital construction projects that have either been completed since the publication of GMP's last Integrated Resource Plan in 2011 or that are presently under construction.

Gorge Substation Voltage Conversion

This project converts the GMP Gorge substation 4.16 kV distribution circuits to 12.47 kV.

Prior to this project, the GMP Gorge substation in Colchester included 34.5 kV switching facilities; peaking generation; a 7 MVA, 34.5 kV to 4.16 kV transformer; and two 4.16 kV distribution circuits which serve approximately 600 customers in the towns of Colchester, Winooski and South Burlington. In addition, a 12.47 kV circuit originating from the GMP Essex substation was overloaded due to rapid growth in the area which resulted in low voltages to customers. The area had limited flexibility to serve existing and new loads or to provide feeder backup.

This project removed the Gorge substation 7 MVA, 34.5 kV to 4.16 kV transformer as the supply to the distribution circuits, but kept the transformer as a generator step-up unit. For purposes of supplying distribution, the 4.16 kV transformer was replaced with a 14 MVA, 34.5 kV to 12.47 kV transformer together with associated voltage regulators, station service transformer, and surge arresters. A transformer oil containment system was already in place following a substation upgrade that took place in 2011. The 4.16 kV distribution circuits were converted to 12.47 kV.

Installation of a larger transformer and conversion of the Gorge substation circuits to 12.47 kV increased the capacity of the area to serve existing and new load, allowed GMP to unload the overloaded circuit that originated from the Essex substation, corrected low voltages, provided for operational flexibility, and greatly enhanced feeder backup between the area's Gorge, Essex and Ethan Allen substations. The project also helps defer the need for a new 115 kV to 12.47 kV substation in the Susie Wilson Road area of Essex.

3309 Subtransmission Line Relocation

This project reconstructs and relocates approximately one-half mile of the GMP 3309 subtransmission line in Winooski.

The GMP 3309 line is a two-mile-long 34.5 kV subtransmission line which extends from the McNeil generating plant in Burlington to the Gorge substation in Colchester. In May 2011, spring flooding in the Winooski River severely damaged a one-half-mile-long section of the line that was located adjacent to the river and constructed with 336 ACSR conductor. Further damage to this section of line occurred during Tropical Storm Irene in August 2011.

This project rebuilds this one-half-mile section of the 3309 line and relocates it away from the Winooski River. The majority of the construction is overhead, co-located with an existing distribution line, and uses 795 ACSR conductor. A short section of the line was placed underground using 1250 MCM aluminum cable.

Reconstruction and relocation of this line is required to restore the connectivity of the 3309 line and to ensure system reliability and first contingency coverage. The upgrade of this section of line to the larger 795 ACSR conductor and 1250 MCM aluminum cable provides for future thermal needs under contingency.

Barre South End Transformer Replacement

GMP installed a new transformer and upgraded the oil containment system at its Barre South End substation.

The GMP Barre South End substation is located in Barre and transforms incoming 34.5 kV subtransmission voltage to distribution voltages of 2.4 kV, 4.16 kV, and 12.47 kV via three separate transformers. On June 8, 2012, lightning struck the then existing 3 MVA, 34.5 kV to 2.4 kV transformer resulting in a catastrophic failure of this unit. GMP replaced this transformer with a new, 5.25 MVA, 34.5 kV to 2.4 kV transformer that it had in stock. GMP placed this transformer on the same concrete pad as that of the failed transformer. There was no need to expand the substation fence or make any other significant changes to accommodate the transformer.

In 2014, GMP upgraded the oil containment system surrounding the substation. This project installed one closed berm oil containment system with oil/water separators and associated drainage to prevent oil from migrating outside of the substation in the event of a large release and three closed oil containment systems under each transformer to prevent the oil from migrating into the water table in the event of a slow continuous release.

The transformer replacement allows GMP to continue serving its 2.4 kV distribution load from the Barre South End substation. The upgraded oil containment system lowers the probability that oil would migrate into surrounding waters following a release.

Wilder Subtransmission Switching Station

This project upgrades the GMP Wilder subtransmission switching station.

The Wilder subtransmission switching station is a 46 kV single-circuit breaker switching station that provides a tie from the National Grid Wilder substation to the GMP 46 kV subtransmission system in Hartford. This substation contained equipment that was aged, did not meet modern codes or design standards, was near the end of its useful life, and in which replacement equipment was often no longer available.

The upgrade project included the replacement of equipment, all within the existing switching station fence-line. The equipment that was replaced and upgraded included the relays and protection systems, SCADA and communications, control wiring, lightning arresters, station service transformer, air-break switches, ground grid, and battery system.

This project replaced aging infrastructure, maintains proper system operation, and improves reliability.

Woodford Road / Pickett Hill Substations

GMP's Woodford Road substation contained equipment that was aged and near the end of its useful life. Some of this equipment was upgraded and remains at the Woodford Road substation. The balance of the equipment was retired with replacement equipment located to a new GMP Pickett Hill substation.

Prior to this project, the "old" VELCO Bennington substation, located adjacent to the GMP Woodford Road substation, contained 115 kV switchgear, two 115 kV to 69 kV transformers, and two 115 kV to 46kV transformers. VELCO recently constructed a "new" Bennington substation, located it approximately one mile north of the old Bennington substation, and then retired the old Bennington substation. VELCO reconstructed and relocated its Bennington Substation to address issues of design and reliability. At the same time, the GMP Woodford Road substation contained equipment that was aged and near the end of its useful life. The GMP Woodford Road substation included of 46 kV switching infrastructure and one 12.5 MVA, 46 kV to 12.47 kV transformer supplying two 12.47 kV distribution feeders.

The Woodford Road/Pickett Hill substations project:

- Constructs a new Pickett Hill substation, which contains upgraded 46 kV switchgear, adjacent to the new VELCO Bennington substation to accommodate the newly located 115 kV to 46 kV source for the Bennington area;

- Constructs several sections of new 46 kV transmission line to tie the Pickett Hill substation to the 46 kV subtransmission system;

- Constructs one section of 69 kV transmission line to tie the new VELCO Bennington substation to the 69 kV subtransmission system; and

- Upgrades and reconfigures the GMP Woodford Road substation.

The upgrade and reconfiguration of the Woodford Road substation includes new bus work, switches, control building, breakers, relays, SCADA equipment, larger voltage regulators, batteries, station service transformer, oil containment and a control house. It also includes the addition of a high-side circuit breaker and transformer differential to better protect the existing transformer.

This project maintains system reliability to the Bennington area, addresses aging infrastructure, and replaces aging equipment that has reached the end of its useful life and in which replacements are no longer available. The project also maintains proper system operation, corrects deficiencies that do not meet current NESC standards, and improves safety and reliability.

Georgia Interconnection Project

A new 115 kV to 34.5 kV interconnection is required in northwest Vermont for load serving and reliability.

The GMP subtransmission system in northwest Vermont includes networked 34.5 kV lines bounded by the towns of St. Albans, Milton, Fairfax, Johnson, and Lowell. The summer peak load in this area is approximately 83 MW and is forecasted to be 101 MW in ten years. The supply to this subtransmission system is by VELCO 115 kV to 34.5 kV substation interconnections at Nason Street and East Fairfax, a 34.5 kV line from the Johnson/Lowell/Stowe area, and local hydro generators at Milton, Peterson, Clark Falls, and Fairfax.

This system contains a number of deficiencies. Loss of the Nason Street source results in significant voltage and thermal violations at various points in the system. Loss of the East Fairfax source also results in thermal overloads and widespread undervoltages. The loss of the

34.5 kV subtransmission line between the Nason Street substation and the Ben & Jerry's substation results in undervoltage at the Ben & Jerry's substation.

To address these deficiencies, a new 115 kV to 34.5 kV supply into the subtransmission system is planned with an interconnection at Ballard Road in the Town of Georgia. The full project is comprised of the following components:

- A new 56 MVA, 115 kV to 34.5 kV transformer at the VELCO Georgia substation together with oil containment and associated switchgear and controls.

- A new GMP Ballard Road switching station to interconnect the VELCO source to the GMP subtransmission system. This switching station will be comprised of three-circuit breakers and associated foundations, relaying, disconnect switches, control building and SCADA.

- A new two-mile-long 34.5 kV subtransmission line from the VELCO Georgia substation to the new GMP Ballard Road switching station to be located within an existing VELCO transmission line right-of-way.

- Reconductoring of the five-mile-long GMP Milton to St. Albans 34.5 kV subtransmission line.

- A new 5.4 MVAR, 34.5 kV capacitor bank at the VELCO East Fairfax substation.

Berlin Substation 4.16 kV Retirement

The 4.16 kV transformer and distribution circuit at the GMP Berlin substation was retired, and the associated load transferred to 12.47 kV distribution, to enhance the reliability to the Central Vermont Medical Center.

The Berlin substation in the town of Berlin included a 10.5 MVA, 34.5 kV to 4.16 kV transformer and a 10.5 MVA, 34.5 kV to 12.47 kV transformer. The 4.16 kV transformer was 45 years old, near the end of its useful life, and supplied a single 4.16 kV circuit that was dedicated to the Central Vermont Medical Center. Because this was the only 4.16 kV circuit in the area, feeder backup was not available and a substation transformer failure would necessarily result in an extended outage to the hospital.

GMP retired the 4.16 kV transformer at the Berlin substation and transferred the Central Vermont Medical Center load onto an existing Berlin substation 12.47 kV circuit.

This project enhances reliability to the hospital by removing an aged transformer from service and by providing feeder backup to the circuit that supplies the hospital. This project is consistent with GMP's strategy of retiring older 2.4 kV and 4.16 kV systems and equipment to obtain loss benefits, increase operational flexibility, enhance reliability, reduce the requirements for spare equipment, and lower maintenance expenses.

Marshfield Substation Rehabilitation

The GMP Marshfield substation is being rehabilitated to address aging plant and improve reliability.

The Marshfield substation is located in the town of Marshfield. Before the upgrade, the substation included 34.5 kV switching facilities; a 6 MVA, 34.5 kV to 4.16 kV transformer that was installed in 1926 that served as both a hydro generator step-up transformer and a distribution transformer; one 4.16 kV distribution feeder and associated recloser; and one 34.5 kV distribution feeder with associated recloser and grounding bank.

The substation is aged with clearances that do not meet modern code requirements and contains obsolete equipment. The transformer had reached the end of its useful life and had limited ability to support load growth on the distribution system. The 4.16 kV distribution voltage did not permit backup with the adjacent 12.47 kV feeder originating from the Plainfield substation and the substation could not accept a mobile transformer. The 34.5 kV distribution feeder could not be adequately protected during certain system conditions and maintenance procedures.

This project installs a new 6 MVA, 34.5 kV to 4.16 kV generator step-up transformer, new steel structures, foundations, fence, and oil containment. The 4.16 kV feeder has been retired and its load moved to an adjacent 12.47 kV feeder out of the Plainfield substation. A second 34.5 kV distribution circuit recloser was added to provide for adequate protection under certain system conditions and maintenance procedures.

This project replaces aged and obsolete equipment and structures, improves reliability, enhances safety, and allows for growth on the distribution system.

West Danville Substation Rebuild

This project rebuilds and relocates the GMP West Danville substation.

Prior to this project, the West Danville substation was located adjacent to the GMP West Danville 1.25 MVA hydroelectric site for the purposes of connecting this generation to the GMP subtransmission system and supplying a single distribution circuit. The substation included a 1 MVA, 7.2 kV to 34.5 kV step-up transformer bank comprised of three single-phase 333 kVA transformers built in 1928. The substation also supplied one 7.2 kV single-phase distribution circuit. In 2012, the penstock, which feeds the hydroelectric station, experienced a catastrophic failure causing extensive flooding and damage to the generation building and substation. After the incident, two of the three single-phase transformers tested poorly and were not safe to re-energize.

This project rebuilds and relocates the West Danville substation on land that is adjacent to the old substation and owned by GMP. The rebuilt substation includes a new three-phase 1.4 MVA, 7.2 kV to 34.5 kV step-up transformer with oil containment, station service transformer bank, one 34.5 kV gang-operated air break switch, enhanced protection schemes, and fused disconnect switches. The substation is constructed to modern code requirements, provides increased vertical and horizontal clearances, and is equipped with a security system and video surveillance. The distribution loads are no longer served from this location but rather are supplied by the GMP Barker Avenue substation in St. Johnsbury.

This project returns the substation and generating unit to service, replaces obsolete equipment with modern infrastructure, better matches the transformer size to the generating unit, improves worker safety, enhances system reliability, and improves environmental safety.

Marble Street to Danby Subtransmission Line Reconstruction

This project rebuilds the 46 kV subtransmission line from the Marble Street switching station in West Rutland to the Danby substation in Danby.

The 46 kV subtransmission line from Marble Street to Danby is comprised of structures that were installed between 1938 and 1951 and is conductored with #2 ACSR. Until 2011, this line was owned and operated by the Vermont Marble Power Division of OMYA (VMPD). In 2011, the VMPD assets were acquired by the Central Vermont Public Service (CVPS). These assets were subsequently acquired by GMP in its acquisition of CVPS in 2012. The Danby substation serves a single customer, the Danby Imperial Quarry, with a load of approximately 500 kW. Due to their age, the poles, crossarms and insulators were in poor condition and the line vulnerable to failures during storm events.

As part of the Board-approved acquisition by CVPS of the VMPD assets, CVPS agreed to reconstruct this subtransmission line within the five-year period from 2011 to 2016. GMP is continuing this work, and the on-going rebuild includes the replacement of the line with new poles, crossarms and insulators. The existing conductor is being re-used; however the structures are designed to accept a larger 477 ACSR conductor in the future.

This project addresses the aging infrastructure and poor reliability of the existing subtransmission line and allows for a larger capacity wire in the future if needed.

Taftsville to Wilder Subtransmission Line Reconductoring

The 46 kV subtransmission line between the GMP Taftsville and Wilder substations is being reconductored to address aging infrastructure and reliability concerns.

Prior to this project, the 9.4-mile subtransmission line between the Taftsville and Wilder substations included 3/0 ACSR and 336 ACSR conductor. Some of the conductor was installed in 1929 and near the end of its useful life. Also, load flow analysis indicates that the loss of the VELCO Hartford 115 kV to 46 kV autotransformer could result in thermal overloads of this line and low voltages which could lead to wide-spread outages in the Hartford area.

This project reconductors the 9.4-mile Taftsville to Wilder 46kV transmission line with 556 ACSR.

This reconductoring addresses post-contingency thermal overloads and low voltages and replaces aging infrastructure. The project also allows for future reconfiguration changes to accommodate the planned 46 kV subtransmission tap line to the new White River Junction substation.

North Springfield Tap to South Street Subtransmission Line

This project reconductors four miles of 46 kV subtransmission line from the North Springfield Tap to the South Street substation.

The 46 kV subtransmission line from the North Springfield Tap to the South Street substation includes aged 4/0 ACSR that is near the end of its useful life. In addition, load flow analysis indicates that during peak summer loads significant thermal overloading occurs on this line following a National Grid Bellows Falls substation 115 kV bus fault.

This project retires the existing 4/0 ACSR from the North Springfield Tap to the South Street line and replaces it with 477 ACSR, thereby increasing the thermal capacity of this line from 25.9 MVA to 49.7 MVA. This project addresses aging infrastructure and allows for higher thermal capability following system contingencies.

St. Johnsbury Center Substation

The St. Johnsbury Center substation is being upgraded to improve feeder backup in the area, enhance reliability, and accommodate load growth.

Prior to this project, the St. Johnsbury Center substation was comprised of a 7 MVA, 34.5 kV to 12.47 kV transformer and one 12.47 kV distribution circuit with associated circuit breakers. This transformer is 45 years old and recent testing indicated signs of insulation degradation. The distribution circuit breakers are aged and near the ends of their useful lives. The St. Johnsbury Center substation is limited in its ability to provide feeder backup for the area's Barker Avenue and Bay Street substations.

For this project, the existing 7 MVA transformer at the St. Johnsbury Center substation is being replaced with a new and larger 14 MVA transformer. The existing distribution circuit breakers will be replaced. The project also adds SCADA control to the substation's two 34.5 kV motor-operated air-break switches.

The larger transformer will improve the ability of the St. Johnsbury Center substation to back up the circuits supplied by the Barker Avenue and Bay Street substations during emergency and planned outages and will accommodate future load growth. The second distribution circuit will more efficiently utilize the larger transformer capacity and decrease reliability exposure to a number of customers, including a large industrial load. Addition of SCADA to the substation's two 34.5 kV motor-operated air-break switches will improve the operability and reliability of the subtransmission line supplying this substation.

Woodstock Substation

A second transformer is being added to the Woodstock substation to enhance reliability and to provide backup for the existing transformer.

Prior to this project, the Woodstock substation included a single 10.5 MVA, 46 kV to 12.47 kV transformer and three 12.47 kV distribution circuits. This existing transformer is 43 years old and at peak load experiences 95% of its top thermal rating. There are no feasible backup or alternative methods for supplying these distribution circuits from other area substations. As such, loss of the Woodstock transformer would necessarily result in an extended outage to all customers supplied by these three circuits.

Because the existing transformer has minimal capacity available, and because it is 43 years old, GMP believes that it is prudent to install a second transformer at the Woodstock substation. This project installs one new 14 MVA, 46 kV to 12.47 kV transformer, a new oil containment system, high-side circuit breaker, control cabinet and associated switchgear. The project also installs new distribution circuit breakers and larger distribution voltage regulators.

This project provides transformer redundancy to prevent the simultaneous loss of all three Woodstock substation circuits due to a single failure, allows for maintenance activities without the need to take an outage, and accommodates future load growth. The larger regulators (328 amp to 437 amp) allow for greater flexibility with circuit ties during planned outages and contingencies.

4.4 Planned Projects

This section describes GMP's large transmission and distribution capital construction projects that have construction start dates within the three years following publication of this Integrated Resource Plan.

Stratton Substation Transformer

This project replaces an existing 14 MVA transformer at the Stratton substation with a 28 MVA transformer to increase capacity and enhance reliability.

Presently, the Stratton substation contains two transformers. The #1 unit is a 28 MVA, 46 kV to 12.47 kV unit and the #2 transformer is a 14 MVA, 46 kV to 12.47 kV unit. In addition, a spare 28 MVA, 46 kV to 12.47 kV transformer is currently located at the Stratton substation site. The 14 MVA unit has experienced loads as high as 14.1 MVA.

Replacing the 14 MVA transformer with the larger 28 MVA transformer will adequately serve existing load, allow for additional area load growth, and provide backup capability in the event the #1 transformer failed or required maintenance during the winter season.

White River Junction Substation

The White River Junction substation needs to be replaced.

Two substations operate in the GMP service area in and around White River Junction: the Wilder substation and the White River Junction substation. In recent years, GMP upgraded the White River Junction substation and its associated distribution system from 4.16 kV to 12.47 kV to accommodate load growth and to permit partial back-up with circuits originating from the Wilder substation. Over time, this upgrade has proved inadequate.

A new White River Junction substation is necessary because of:

- Area load growth;
- Limitations on the non-standard 13.8 kV transmission supply to the White River Junction substation off of the National Grid Wilder substation hydro generation bus; and
- Limited ability to perform feeder back-up.

This new substation would be comprised of a 28 MVA, 46 kV to 12.47 kV transformer; oil containment; high-side circuit breaker; 5.4 MVAR capacitor bank; three distribution circuits (with accommodations for a fourth circuit); voltage regulators; and SCADA control.

GMP plans to locate the new substation by expanding the existing site on Lantern Lane in White River Junction. Supply to the new substation would be by way of a new 2.5-mile 46 kV transmission line, overbuilt on distribution, located along Old River Road in Hartford that would tap into the Hartford to Taftsville 46 kV line. This transmission line would replace the existing, non-standard 13.8 kV transmission supply that presently traverses over rugged and hard-to-reach terrain.

Wilder Substation

As discussed immediately above, the Wilder and White River Junction substations are adjacent to each other in the Towns of Norwich and Hartford respectively. The capacity limitations for these two substations together with anticipated load additions could overload the White River Junction substation and leave a very small amount of capacity remaining at the Wilder substation. GMP is concerned that the narrow capacity margins remaining in the area could result in the area exceeding its capacity on very short notice.

In addition to addressing capacity constraints, upgrade of the Wilder substation, in conjunction with the new White River Junction substation, would provide for robust feeder backup between these substations.

Upgrade of the Wilder substation includes replacing the existing 14 MVA, 46 kV to 12.47 kV transformer with a new 28 MVA, 46 kV to 12.47 kV transformer together with installation of a high-side circuit breaker, oil containment, distribution circuit breakers, and feeder voltage regulation.

Haystack Substation

A new substation in Wilmington, Vermont, to be named the Haystack substation, is required. This substation is needed to accommodate load growth, improve area reliability, and reduce system losses.

The Hermitage Club (previously, the Haystack ski area) is undergoing extensive expansion and requires a supply for 10 MW of new load. The Dover substation, which presently supplies this ski area, does not have sufficient capacity for the proposed load. The other area substation, the Wilmington substation, is also unable to support the load. A new Haystack substation will have the additional benefits of accommodating future area growth, improving the limited feeder backup capability between the Wilmington and Dover substations, and significantly lowering system losses by placing the substation close to the load.

The Haystack substation would be located adjacent to the Hermitage Club ski area and be comprised of one 28 MVA, 69 kV to 12.47 kV transformer with oil containment; a high-side circuit breaker; three distribution circuits with circuit breakers and voltage regulation for each feeder; motor operated load break switches; and SCADA. The new substation would be supplied by the existing 69 kV Searsburg to Dover subtransmission line.

Graniteville and Wetmore Morse Substations

The Graniteville substation needs to be rebuilt to address aging infrastructure and improve reliability.

In Barre Town, among the substations supplying granite quarry loads are the Graniteville substation and the Wetmore Morse substation. The transformer at the Graniteville substation is a 3 MVA, 34.5 kV to 2.4 kV bank comprised of three individual 1 MVA units that are 90 years old. The transformer at the Wetmore Morse substation is a 1.5 MVA, 34.5 kV to 2.4 kV bank comprised of three individual 500 kVA units. Both substations are aged and near the end of their useful lives.

GMP will rebuild the Graniteville substation with all new components including a 10.5 MVA, 34.5 kV to 12.47 kV transformer, oil containment system, and associated bus work and foundations. Also included would be distribution feeder circuit breakers, voltage regulators, security system, and a control cabinet. The larger transformer will allow for motor starting at area quarries without voltage flicker concerns and will allow for future backup of the Websterville substation. An existing 2.4 kV distribution line between the Graniteville and

Wetmore Morse substations would be converted to 12.47 kV for the purpose of supplying the Wetmore Morse loads from the rebuilt Graniteville substation.

Waterbury Substation

GMP plans to relocate and rebuild its Waterbury substation.

The existing Waterbury substation includes a 10.5 MVA, 34.5 kV to 4.16 kV transformer; voltage regulators; and three 4.16 kV feeders. This substation is located in Waterbury and is in a flood plain adjacent to the Winooski River. The other substation serving the Waterbury area, the Waterbury Center substation, contains a 14 MVA, 34.5 kV to 12.47 kV transformer, regulators, and two 12.47 kV feeders.

The need to relocate the substation is driven by significant flooding of the existing facility that occurred during Tropical Storm Irene in 2011. The need to redesign and rebuild the facility is driven by load growth, the impact of several large customers, including the State of Vermont and Vermont Coffee Roasters, and the desire to obtain feeder backup for the area. The Waterbury area's 4.16 kV feeders are approaching their capacity and cannot be backed up by the Waterbury Center substation because the feeder voltages are dissimilar. Rebuilding the Waterbury substation to 12.47 kV distribution voltage and converting the area's feeders will allow for mutual feeder backup between the Waterbury and Waterbury Center substations, lower distribution line losses, accommodate new loads, and enhance the ability to accommodate distributed generation installations.

The new Waterbury substation will be comprised of one 28 MVA, 34.5 kV to 12.47 kV transformer, a high-side circuit breaker, motor-operated load break switches for transmission line sectionalizing, oil containment, three distribution circuits with associated circuit breakers, voltage regulation at each feeder, and SCADA. Area feeders will be converted from 4.16 kV to 12.47 kV. The new substation will be located outside of the flood plain, along Vermont Route 100, and adjacent to GMP's Middlesex to Duxbury Switch 34.5 kV subtransmission line.

Third Winooski 34.5 kV Feeder - 16Y3

A third feeder into the City of Winooski is needed.

One 34.5 kV feeder, the 46Y1, currently serves the City of Winooski load. The adjacent 36Y5 feeder, originating at the Ethan Allen substation in Colchester, backs up this feeder, albeit not at all hours of the year. This inability to provide full-time backup creates the need for a third 34.5 kV feeder for the city

This third feeder, the 16Y3, would originate at the Gorge substation. The recently completed, Board-approved, Gorge substation upgrade created a footprint and take-off structure to accommodate the 16Y3 feeder. To create the feeder, GMP must rebuild one-half mile of the existing 3309 transmission line between the Gorge substation and the downtown Winooski redevelopment area. This rebuild would upgrade the 3309 transmission conductor and install the 16Y3 feeder as underbuild on the same structures. Upgrades at the Gorge substation to accommodate the new feeder would include installation of a circuit breaker, reactor, and voltage regulators.

Beyond reliability and feeder backup, other benefits accruing from this project include:

- Upgrading portions of the 3309 transmission conductor to enhance its thermal performance;
- Deferral of the need for future area substations;
- Replacement of aged (over 60 years old) infrastructure that is near the end of its useful life;
- Reduced line losses; and
- Enhanced area voltage performance following certain contingencies.

Danby Substation

This project constructs a new 46 kV to 12.47 kV substation in Danby.

A new Danby substation will feed a portion of the load presently supplied by the Wallingford substation. The Danby substation would also increase available capacity to serve new area load and provide feeder backup to the Wallingford substation. A further benefit would be to provide a 12.47 kV distribution supply to the Danby Imperial Quarry (presently served directly off of the 46 kV system) which would give the quarry improved voltage regulation.

A new Danby substation would likely be comprised of one 28 MVA, 46 kV to 12.47 kV transformer, oil containment, a 46 kV high-side circuit breaker, and associated fence, ground grid, communications and security. In addition, there would be two 12.47 kV distribution circuits and associated circuit breakers and voltage regulators.

A new Danby substation would initially be supplied by the existing 46 kV Marble Street to Danby Quarry line. The next phase of the project would construct a new 46 kV tie line from the existing Dorset substation to the Danby substation to form a network. Sequencing the project in this manner provides the following benefits:

- The new substation, initially supplied by the existing 46 kV Marble Street to Danby Quarry line, would immediately provide capacity relief to Wallingford.
- A new 46 kV line from Dorset would provide additional capability for the Danby substation and allow for additional capacity and backup capability for Wallingford. This line also takes two relatively long and weak radial 46 kV subtransmission lines, the Marble Street to Danby Quarry line and the Blissville to Dorset line, and reconfigures them into a network thereby enhancing reliability to the area.
- With a 46 kV supply from Dorset in place, the Marble Street to Danby line can be reconductored to 477 ACSR without interrupting service to Danby substation customers, including the Quarry.
- If required in the future, an even stronger, more reliable network could be established in the area by constructing a new 46 kV tie line from the existing Bromley substation to either the Danby substation or the Dorset substation.

South Brattleboro Substation

The South Brattleboro substation requires upgrading.

Presently, there are two transformers located at the South Brattleboro substation: a 3.75 MVA, 69 kV to 12.47 kV transformer that feeds two circuits, and a 14 MVA, 69 kV to 12.47 kV transformer that feeds two circuits. The 3.75 MVA unit is 54 years old and has limited capacity for feeder backup. The 14 MVA transformer is 27 years old and is also limited in its ability to provide feeder backup to area substations. Upgrades are needed at the South Brattleboro substation to address aging infrastructure and to provide enhanced feeder backup for the area.

The upgrades to the South Brattleboro substation would be comprised of one new 28 MVA, 69 kV to 12.47 kV transformer, oil containment, a 69 kV high-side circuit breaker and associated fence, ground grid, communications and security. In addition, there would be three distribution circuits with associated circuit breakers and regulators. Larger regulators would be installed to allow for greater flexibility with circuit ties during planned outages and contingencies.

Hinesburg Substation

A new substation or other form of grid support is required to serve the town of Hinesburg and support local area reliability.

Hinesburg is presently served by an eight-mile-long 12.47 kV distribution line that originates at the GMP Charlotte substation. The Hinesburg load is over 4.6 MW at peak (winter) and there is a likelihood of new load in the area from housing developments and the rehabilitation of the former Saputo cheese factory. The load concentration in Hinesburg, together with its distance from the Charlotte substation, results in potential thermal and voltage limitations as well as challenges to adequately protecting the distribution line from contingencies. To provide temporary support to the area, GMP recently connected a portion of this load to the Vermont Electric Cooperative Rhode Island Corners substation.

Among the solutions for this area is the construction of a new 34.5 kV to 12.47 kV substation in Hinesburg. The substation would be comprised of a 28 MVA transformer with oil containment, high-side circuit breaker, associated fence, ground grid, communications and security, and two distribution circuits with circuit breakers and regulators. A new seven-mile-long 34.5 kV subtransmission line originating at the LeClair switch in Williston would be the supply to the substation. A substation solution would increase the available capacity to the area to serve existing and new load, allow for appropriate circuit protection, reduce losses, and provide feeder backup to the Charlotte substation. The new substation could also provide backup for Vermont Electric Cooperative circuits in the area and backup to circuits originating at the GMP North Ferrisburg substation.

Alternatives for supporting this area will also be considered, including the use of distance relaying for protection together with generation and demand-side measures. Emerging technology solutions, including battery storage and the use of renewable generation interconnected to the system with reactive inverters will be evaluated. A more extensive discussion of GMP’s plans to employ emerging technologies is included in Chapter 5, GMP SmartPower.

North Brattleboro Substation

This project will upgrade underground cables at the North Brattleboro substation to improve reliability and increase the transfer capability onto North Brattleboro substation circuits.

The North Brattleboro substation contains a 14 MVA, 46 kV to 12.47 kV transformer, 328 amp voltage regulators, and two 12.47 kV distribution circuits. The distribution circuits each have

350 MCM copper underground cable getaways. The transformer is connected to the 12.47 kV bus by a 750 MCM copper underground cable.

The existing 350 MCM copper underground cable getaways have summer ratings of 384 amps which constrain the ability of the North Brattleboro substation to backup area substation feeders. The 750 MCM copper underground cables have summer ratings of 619 amps which do not allow for full utilization of the capacity of the 14 MVA transformer.

To relieve these constraints, GMP will replace the substation cables with 1000 MCM copper cables. In addition, the existing 328 amp voltage regulators will be upgraded to 437 amp regulators. The larger regulators will allow for greater flexibility with circuit ties during planned outages and contingencies.

Airport Substation

This project relocates, converts and upgrades the GMP Airport substation.

The existing Airport substation is located on the property of the Vermont Air National Guard in South Burlington and includes one 1.5 MVA, 34.5 kV to 4.16 kV transformer which is 59 years old; and two 4.16 kV distribution circuits. The 4.16 kV distribution circuits are the only circuits at this voltage in the area that do not allow for feeder backup from adjacent substations. The wood structures are aged with clearances that do not meet modern code requirements. The existing site is too small to accommodate rebuilding and expanding the substation.

This project consists of installing one new 28 MVA, 34.5 kV to 12.47 kV transformer, oil containment, two or more 12.47 kV distribution circuits, and associated circuit breakers, voltage regulators, bus work, foundations, fence, ground grid, security system, control cabinet, and switchgear. The substation will be relocated to a new site that is on the property of, or close to, the Vermont Air National Guard.

The new substation would be centrally located in Chittenden County and allow for the reconfiguration of existing circuit loads among the GMP Gorge, Ethan Allen, Dorset Street, Essex, and Tafts Corners substations. The project would enhance feeder backup in this area, extend the useful lives of these adjacent substations, address aging infrastructure, and improve safety and reliability.

East Middlebury to Smead Road to Silver Lake Subtransmission Lines Upgrade

This project rebuilds 3.5 miles of 46 kV subtransmission line from the East Middlebury substation tap in Middlebury to the Silver Lake Hydro station in Salisbury to address post-contingency thermal overloads and aged equipment.

The East Middlebury tap to Smead Road 46 kV subtransmission line is approximately one-half miles long, has pole plant that is nearing the end of its useful life, and is conductored with 4/0 ACSR that was installed in 1954. The Smead Road to Silver Lake 46 kV subtransmission line is three miles long, has pole plant that is in good condition, and is conductored with 4/0 ACSR conductor that was installed in 1937. The VELCO Connecticut Valley Study, which focuses on the need to upgrade the VELCO Coolidge to Ascutney 115 kV transmission line, shows that these two subtransmission lines are overloaded following certain contingencies on the VELCO transmission system. These post-contingency overloads expose the Connecticut River Valley to low voltages and possible voltage collapse.

This project rebuilds the East Middlebury to Smead Road and Smead Road to Silver Lake subtransmission lines with new pole plant and installs larger 477 ACSR conductor to address post-contingency thermal constraints and enhance reliability.

Mill Street Substation

This project upgrades the GMP Mill Street substation.

The Mill Street substation is located in Bennington and was constructed in 1974. It includes a 14 MVA, 46 kV to 12.47 kV transformer, enclosed switchgear, and two 12.47 kV distribution feeders. Much of the substation equipment is aging and has reached the end of its useful life such that replacement parts and equipment are no longer available. Deficiencies exist in the control wiring, cabling, distribution panels, and grounding.

This project replaces the existing transformer with a new 28 MVA, 46 kV to 12.47 kV unit and adds oil containment. The project also replaces the enclosed switchgear with new open-air bus work and installs new switches, breakers, relays, SCADA equipment, circuit regulators, batteries, station service and a control building. The project adds a high-side circuit breaker to provide better protection to the transformer. The underground getaways, presently 350 MCM Cu, will be upgraded to 1000 MCM Cu to enhance feeder backup capability and support distributed generation. Larger regulators will be installed to allow for greater flexibility with circuit ties to the adjacent Lyons Street, South Bennington, Woodford Road and Silk Road substations during planned outages and contingencies.

This project addresses aging infrastructure, improves system operation, corrects deficiencies that do not meet current safety codes, and improves safety and reliability.

East Barnard to Bethel Subtransmission Line Rebuild

This project rebuilds the 46 kV subtransmission line from the East Barnard substation in Barnard to the Bethel substation in Bethel.

Most of the structures on the six-mile-long East Barnard to Bethel line were installed in 1967 and in 1986. The conductor on this line is 4/0 ACSR. While most of the structures are in good condition, some structures are nearing the end of their useful lives. Moreover, results from the VELCO Connecticut River Valley Study indicate that the existing 4/0 ACSR conductor will become overloaded following certain contingencies which could result in cascading line overloads and the loss of up to 40 MW of load.

This project rebuilds the East Barnard to Bethel subtransmission line with new structures and larger 477 ACSR conductor to address potential post-contingency thermal overloads and the resulting loss of load.

4.5 Planning Studies

This section describes GMP's large transmission and distribution planning studies that are planned to take place during the three years following publication of this Integrated Resource Plan.

Barre Area Study

The Barre area is presently served by three substations: the Barre North End substation; the Barre South End substation; and the Websterville substation. (A fourth area substation, the Barre substation, was removed from service in 2014.) These substations are generally characterized as aged with equipment that is reaching the end of its useful life. Each of these substations is supplied from the 34.5 kV subtransmission system and in turn supply, in varying amounts, distribution circuits at voltages of 2.4 kV, 4.16 kV, and 12.47 kV.

GMP is engaged in an on-going process of converting all of the area's feeders to 12.47 kV. Having all of these feeders at 12.47 kV will permit maximum flexibility in loading among the circuits, lower line losses, enhance feeder voltage profiles, permit feeder backup throughout the area, allow for load growth, allow for future installations of DG, and lower maintenance and equipment stocking costs.

The Barre area study, scheduled for completion in 2015, assumes that all of area's distribution circuits have been converted to 12.47 kV. Among the goals of the study is to determine a configuration for the substations and circuits that will enable any one substation to be out of service while allowing all of that substation's load to be served through feeder backup. The study will analyze the feasibility, costs and benefits of various area configurations and determine:

- The number and size of the 34.5 kV to 12.47 kV transformers to be installed at each substation;
- Whether the existing area 34.5 kV to 12.47 kV substation transformers should be re-used, relocated, or retired;
- Any environmental or space constraints at the existing substation sites;
- Whether a given substation should be relocated to another site;
- Subtransmission line upgrades or relocations required to accommodate the substations;
- Substation equipment upgrades that would be required;
- The number of circuits supplied by each substation;
- The location of the main-line feeders between substations; and
- The amount of area load to be served by each substation.

At the conclusion of the study, GMP will develop a plan and timeline for upgrading the Barre area substations and distribution feeders.

Rutland Area Study

The GMP system in the greater Rutland area includes the 46 kV subtransmission system and associated distribution system, concentrated customer loads in the Rutland and Cold River areas, and sparser loads to the south and west of Rutland. The primary supply points to this system are the VELCO North Rutland substation 115 kV to 46 kV transformer, VELCO Cold River 115 kV to 46 kV transformer, and the VELCO Blissville 115 kV to 46 kV transformer. Also included in the area are the recently acquired VMPD 46 kV subtransmission system, distribution system and loads. The legacy VMPD system is supplied primarily by the VELCO Florence 115 kV to 46 kV transformer and is effectively islanded from the Rutland area 46 kV system.

Among the most problematic contingencies for this area is the loss of any one of the VELCO transformers. Following the loss of one of these transformers, at high load levels, at least one of the remaining two transformers can overload, accompanied by local 46 kV line overloads and/or system undervoltage. While load growth has been effectively zero in the past several years, further load growth, say from a single large customer, without remediation, will exacerbate these problems. Further, as discussed above, the recently acquired VMPD loads are sourced solely from the VELCO Florence 115 kV to 46 kV transformer. Connecting this system to the greater Rutland area system could enhance the reliability to these loads.

The Rutland Area Study will be completed by April 2015 to inform the Rutland Area Reliability Plan which is required by the Docket Nos. 7873 & 7874 Attachment II Screening Framework and Guidelines. This study will consider the feasibility, costs and benefits of various upgrades to the Rutland area. Among the potential upgrades to be considered will be the installation of a new 115 kV to 46 kV transformer located at the VELCO West Rutland substation, targeted energy efficiency programs, and strategically located generation. The study will also include consideration of the following:

- Updated area load levels, load distribution, and load forecasts.
- Whether an existing circuit breaker position at the VELCO West Rutland substation will be used by a proposed wind generation project. If this position is, in fact, utilized by the generation project, the cost of installing a new 115 kV to 46 kV transformer at the West Rutland substation would increase by approximately $10 million.
- Confirmation that GMP's solar generation initiatives in the Rutland area have effectively shifted the summer peak loads to post-sundown time periods.
- Whether a proposed bio-gasification plant for the Rutland area, other generation, demand response, storage at the Stafford solar facility, or targeted energy efficiency would be effective in addressing the area's thermal and voltage concerns.
- An updated contingency analysis.
- An updated economic analysis.
- Whether closing a normally-open 46 kV tie between the Rutland subtransmission system and the legacy VMPD system provides reliability benefits to the respective systems.

Windsor Area Study

The GMP service territory near Windsor is presently served by a single substation - the GMP Windsor substation. This substation includes a 14 MVA, 46 kV to 12.47 kV transformer that supplies three 12.47 kV distribution circuits. The Windsor substation attained its top nameplate rating in July 2013 highlighting the need to address thermal issues. Also, because there are no other substations in proximity to the Windsor substation, there are no opportunities for feeder backup in the area.

This study, scheduled for completion in 2015, will consider the feasibility, costs and benefits of constructing a new substation to be named the North Windsor substation. This substation could conceivably consist of a 14 MVA, 46 kV to 12.47 kV transformer with oil containment that supplies two 12.47 kV distribution circuits. Supply to the substation could be via a 46 kV subtransmission tap line off of the existing 46 kV VELCO Windsor to GMP Taftsville line. The substation, if constructed, would also likely include distribution circuit breakers, feeder voltage regulators, steel structures, foundations, and a 46 kV high-side circuit breaker. If constructed, this substation would supply a portion of the load presently supplied by the Windsor substation, increase available capacity to the area to serve new load and host distributed generation, and provide feeder backup for Windsor area loads.

Legacy VMPD North Subtransmission Lines

The GMP Huntington Falls and Beldens hydro units are interconnected to the system via a 14-mile-long 46 kV subtransmission line extending from Huntington Falls to the GMP Salisbury switching station. Until 2011, these hydro units and subtransmission line were owned and operated by the Vermont Marble Power Division of OMYA (VMPD). In 2011, the VMPD assets were acquired by Central Vermont Public Service (CVPS). These assets were subsequently acquired by GMP in its acquisition of CVPS in 2012.

The proximity of the Huntington Falls to Salisbury line to other GMP 46 kV subtransmission lines provides potential opportunities for system improvements. These configurations were first studied in 2004 as part of a Middlebury and New Haven area study. This study will be updated in 2016 and will consider the feasibility, costs and benefits of the following potential projects:

- The first potential project connects the Huntington and Beldens hydro units directly to the VELCO Middlebury substation. This could be accomplished by constructing a 0.7-mile-long 46 kV subtransmission line, beginning at the point where the Huntington to Salisbury line crosses the GMP Middlebury Lower to VELCO Middlebury 46 kV line, and extending this new line segment to the VELCO Middlebury substation. This new line segment would allow GMP to decommission a nine-mile-long section of the 46 kV Huntington to Salisbury line.

- The second potential project constructs four miles of new 46 kV subtransmission line to connect Huntington to the VELCO New Haven substation. This would transform the radial line connecting the Huntington and Beldens hydro units to a networked line and allow GMP to return the 46 kV, 5.4 MVAR capacitor at the GMP Hewitt Road substation to inventory.

The potential benefits of pursuing one or both of these projects include reduced reliability exposure, reduced maintenance expenses, enhanced aesthetics, improved system connectivity, and lower losses.

Berlin to Mountain View Subtransmission Line Analysis

The GMP 3325 line is a three-mile-long 34.5 kV subtransmission line that extends from the GMP Berlin #5 substation to the GMP Montpelier substation. At a point on this line one-half mile to the east of the Berlin substation is the Dog River Switch. The Dog River switch marks the starting point of a 0.7-mile-long radial tap line to the GMP Mountain View substation.

The Mountain View substation supplies 12.47 kV loads in and around Montpelier and supplies two dedicated 4.16 kV circuits to the National Life Building in Montpelier. The Mountain View substation also provides feeder backup to Montpelier substation distribution circuits and Berlin #40 substation distribution circuits in the area.

Preliminary analysis indicates that the one-half-mile section of the 3325 line between the Berlin #5 substation and the Dog River switch may be thermally overloaded following the loss of the 115 kV to 34.5 kV source at the VELCO Barre substation. Also, the 0.7-mile-long radial tap line from the Dog River Switch to the Mountain View substation may be thermally overloaded under certain feeder backup configurations.

This study, scheduled for completion in 2015, will examine the thermal and voltage parameters of the 3325 line and the tap to the Mountain View substation. The study will consider normal peak loads, post-contingency scenarios, the impact of possible future distributed generation, and various feeder backup configurations. Following this analysis, options for system improvements will be developed. Possible improvements to the system could include reconductoring the 3325 line between the Berlin #5 substation and the Dog River switch; reconductoring the tap line from the Dog River switch to the Mountain View substation; retiring the Dog River switch and upgrading the radial tap to the Mountain View substation with a two-line, in-and-out configuration; and upgrading the Mountain View substation with a high-side circuit breaker and 34.5 kV switching capability.

4.6 System Reliability

Vegetation Management

In 2013, trees that contacted GMP's overhead subtransmission and distribution lines accounted for 49% of all outages. To reduce tree contact outages and improve operational efficiency, GMP employs an integrated vegetation management program. GMP's objective is to administer a long-term vegetation management program that provides for the safe and efficient operation of the subtransmission and distribution system, reduces service interruptions and power quality disturbances, provides a high level of customer satisfaction, and is executed in a safe and cost-effective manner with minimum impact to the environment.

Distribution

In 2013, GMP trimmed 1,284 miles of its distribution system and removed 4,933 danger trees. Herbicide treatment on the distribution system covered an estimated 614 distribution line-miles. Statistics for the GMP vegetation management program, including dollars budgeted, dollars spent, and miles trimmed for the period 2011 to 2016 are provided in Appendix E. GMP also monitors the number of tree related outages on a monthly basis. Tree-related outages to date for 2013 are also provided in Appendix E.

GMP's distribution system vegetation management plan, provided as Appendix F, was updated in 2014 to reflect the combination of the Legacy GMP and Legacy CVPS systems. This plan details the relative composition of tree species on the system, provides growth rates for the dominant species, and lists low-growing compatible species. GMP's distribution vegetation management program is designed to attain an average seven-year trimming cycle. This cycle was developed based on the species composition within the service territory, species' growth rates, and the desired clearance from trees to energized lines. As of 2013, an average trimming cycle of 7.9 years had been attained. While GMP believes that a seven year cycle is optimum, variables that have prevented GMP from attaining this cycle length include budget considerations and the shifting of resources to areas that experience frequent interruptions. Factors determining the program needs in an area for a given period include the year that the area was last trimmed, frequency of service interruptions, customer density, and whether there are sensitive customers such as schools, hospitals, and customers on life support.

GMP's standard for clearance from energized distribution lines to most species is 20 feet above and 10 feet beside the trees. Clearances are increased where there is a danger of ice and snow loading on conifer trees. Most villages, towns, and cities are maintained with greater frequency to maintain a reasonable canopy of shade trees. Rural circuits are placed on relatively longer cycles due to the greater clearances that can be obtained. The techniques used by GMP for its vegetation program include flat cutting, various pruning methods, mowing with large equipment, and the application of herbicides. Detailed descriptions of these techniques are included in Appendix F.

Subtransmission

In 2013, GMP cut 205 miles of its subtransmission system and removed 873 danger trees. Herbicide treatment on the subtransmission system covered an estimated 1,235 acres. Maintenance of the rights-of-way for hydroelectric penstocks also follows the vegetation management plan established for the subtransmission system.

GMP's subtransmission right-of-way management plan, provided as Appendix G, was updated in 2014 to reflect the combination of the Legacy GMP and Legacy CVPS systems. The GMP subtransmission system is maintained on a five-year cycle. This shorter cycle reflects the fact that the subtransmission system is a main supplier of power to large areas such as cities and villages, and that the loss of a single subtransmission line can negatively impact a relatively large number of customers. The average GMP subtransmission right-of-way width is maintained to 100 feet - 50 feet on each side of the centerline. The techniques used for the subtransmission system are similar to that of the distribution system and include flat cutting, trimming, mowing with large equipment, and the application of herbicides. Detailed descriptions of these techniques are included in Appendix G.

In the application of its plan, GMP strives to be sensitive to the concerns of property owners and contacts property owners before working in the right-of-way. GMP also encourages property owners to use the land in its right-of-way in a manner compatible with the transmission of electricity.

Herbicide Use

Following manual and mechanical cutting, remaining vegetation is selectively treated with herbicides to reduce the density of tall growing species, promote desirable low growing vegetation, retard re-growth, and increase plant bio-diversity. This selective treatment with herbicides reduces overall environmental impacts, lowers costs, and decreases the volume of herbicides required for future maintenance cycles.

GMP applies herbicides in three ways: Stem and foliar application is typically used in areas where sprout growth is dense. Herbicide is applied so that it contacts only the target plants' leaves and stem surfaces. This method eliminates 85% to 95% of the target plants in one year. Basal bark treatment is used to control susceptible woody plants with stems less than six inches in basal diameter. With this technique, herbicide is applied to basal parts of brush and stems including the root collar area. Cut stump treatment is used on recently cut tree stumps to inhibit the growth of stump sprouts. The primary advantage of this method is enhanced aesthetics as there is no brown-out or dead stems left standing. Cut stump treatment eliminates approximately 65% to 75% of the targeted plants.

The optimum schedule for a foliar treatment is one growing season after mechanical cutting. This allows for adequate sprout growth, which is easily identified by the applicator, and which responds well to herbicide application. Stump treatment is performed as soon as possible after mechanical cutting with follow-up applications as needed during the next maintenance cycle.

The application of herbicides on the GMP system is regulated by the Environmental Protection Agency and the Vermont Agency of Agriculture, Food & Markets.

Substations in Floodplains

A number of GMP's substations are located within Federal Emergency Management Agency (FEMA) designated 100-year and 500-year floodplains. Under extreme weather conditions, these substations may be vulnerable to damage from flooding. The location of these substations follows closely with the history of settlement in Vermont. In particular, many of Vermont's cities and towns, which contain concentrations of population, industry, and electrical loads, were settled within Vermont's river valleys. Not surprisingly, power system infrastructure, including substations, is located close to these populations and their associated electric loads. To understand which of GMP's substations may be located in floodplains, GMP cross referenced the locations of its substations with the available FEMA geographic information systems (GIS) floodplain maps. For Vermont, FEMA has developed GIS layer maps showing 100-year and 500-year floodplains for the counties of Chittenden, Washington, Rutland, Windsor, and Windham. These five counties contain 110, or 54% of GMP's 202 distribution, hydro, and switching substations. Of these 110 substations, 15 distribution substations, or approximately 14%, are located in either a 100-year or 500-year floodplain. Appendix H provides a list of these substations and their locations. Assuming that these five counties are representative of Vermont as a whole, this suggests that, in total, perhaps 28 of GMP's distribution substations are located in either a 100-year or 500-year floodplain.

GMP believes that the most effective method to protect a substation against the risk of flooding damage is to relocate the substation out of the floodplain. However, relocating substations solely to mitigate against risks that could arise following infrequent weather events is a costly undertaking. For example, GMP's planned reconstruction and relocation of its Waterbury substation, scheduled for 2015, is projected to cost over $2.4 million.

Moving forward, GMP will avoid locating new substations in floodplains. For existing substations, GMP believes that the most cost-effective strategy for addressing the risks posed by substations in floodplains is to evaluate the costs and benefits of relocation at the time that a given substation is scheduled for a major upgrade. The need for major substation upgrades can be triggered by a number of issues including obsolescence, structure or equipment deterioration, load growth, or the desire for enhanced feeder backup with adjacent substations. The costs associated with relocating a substation to a new location can include transmission line additions to provide a supply to the new substation, distribution line upgrades required to relocate main feeders to the new location, and the environmental impacts of disturbing and developing a new site.

As an example of the application of this strategy, and as stated above, GMP plans to rebuild and relocate its Waterbury substation in 2015. The need to rebuild this substation is driven largely by the desire to convert the Waterbury area from 4.16 kV distribution to 12.47 kV distribution and to provide for mutual feeder backup between the Waterbury and Waterbury Center substations. At the same time, the existing Waterbury substation is located within the 100-year floodplain of the Winooski River. The need to rebuild the Waterbury substation has provided GMP with an opportunity to relocate this substation out of the floodplain, which GMP intends to do, for a relatively small incremental cost.

Pole Inspections

GMP inspects all poles on its subtransmission and distribution system once every 10 years. Subtransmission poles are provided a full excavation inspection that entails a 360 degree removal of the soil to 18 inches below the ground line. The below grade portions of the poles are then wrapped and treated with an antifungal compound.

GMP also checks the integrity of the subtransmission poles by: visually inspecting them to detect splits, holes, and abrasions; performing core boring; and carrying out sound tests for portions of the pole both above and below ground to detect soft spots or other internal imperfections. When decay is detected, the pole will be chemically treated in cases when its life can be reasonably extended. If the life of the pole cannot be extended, it will be replaced.

Distribution poles are excavated to eight inches below grade on two sides of the pole. Visual inspections are performed to detect splits, holes, and abrasions. GMP also performs core boring and sound tests for portions of the pole above the ground. Decayed distribution poles that fail inspection are simply replaced because, by that time, they generally fail to meet the current specifications for height and class.

Underground Utility Damage Prevention

Preventing damage to underground infrastructure is important to GMP from two perspectives. First, GMP owns and operates subtransmission, distribution, and fiber optic underground cables that are vital to system reliability. Damage to these facilities by outside parties can create serious safety hazards, compromise reliability, and result in costly repairs. Alternatively, GMP itself routinely engages in excavation activities, for example when utility poles are set. It is important that GMP perform these activities without damaging either its own facilities or those of water, natural gas, telephone and cable television.

To avoid damage to our own and others' facilities, GMP participates in, and adheres to the procedures of, Dig Safe® for the states of Maine, Massachusetts, New Hampshire, Vermont and Rhode Island. Dig Safe® is a not-for-profit clearinghouse that notifies participating utility companies of plans to excavate in areas where underground facilities may be present. In turn, these utilities respond and mark out the location of their underground facilities. When excavation activities occur within 18 inches of a marked facility, non-mechanical (hand-digging) means are required to prevent damage to the facilities. Dig Safe® is a free service that is funded by its member utility companies, including GMP.

GMP's participation in Dig Safe® is required by Vermont state law, 30 V.S.A. § 7001-7008. This participation is also codified by the Public Service Board in PSB Rule 3.800. Specifically, Vermont law and Rule 3.800 require that GMP:

- Be a member of Dig Safe®;
- Provide notice to Dig Safe® at least 48 hours (but not more than 30 days) in advance of excavation;
- When notified by Dig Safe®, mark its own facilities within 48 hours;
- Upon discovery of damage to underground facilities, forward an Underground Facility Damage Prevention Report to the Public Service Board and Public Service Department;
- Construct its facilities to conform to the National Electric Safety Code; and

- Install subsurface markers above all underground facilities.

GMP is in the process of formalizing its practices by developing the Green Mountain Power Underground Utility Prevention Plan. This Plan will be provided to the Public Service Department and any other interested parties upon completion.

Aerial Patrols and Infrared Inspections

Every spring and fall, GMP flies helicopters to perform aerial patrols of its entire subtransmission system. During these patrols, we fly close to visually detect danger trees, broken cross arms, floating phases, cracked insulators, displaced cotter pins, and other problems that can negatively affect the performance of the transmission lines. Aerial patrols are also conducted following major storms to assess possible damage.

During the peak load period in August, GMP flies an additional aerial patrol to conduct infrared scans of both transmission lines and substations. Infrared scans employ an infrared camera mounted directly to the helicopter to identify hot spots that can indicate a failing conductor, corroded splice, loose connection, or other problem area where a line or substation is stressed and vulnerable to failure. From the ground, GMP also periodically performs substation infrared scans using hand-held infrared cameras.

Power Quality Solutions

Over the last few decades, the electric industry has paid increasing attention to the issue of power quality. Poor power quality adversely affects the reliability of the now ubiquitous computers and microprocessor-based equipment.

Power quality is the relative frequency and severity of deviations in the incoming power supplied to electrical equipment from the customary, steady, 60 Hertz sinusoidal voltage waveform. Examples of poor power quality include voltage impulses, high frequency noise, harmonic distortion, unbalanced phases, voltage swells and sags, and total power loss. Because the sensitivity to such deviations varies from one piece of equipment to another, what might be considered poor power quality to one device might be acceptable power quality to another.

GMP's immediately responds to power quality issues that are identified by its customers. In most cases, GMP operations personnel are able to quickly identify and solve power quality issues. The majority of power quality issues are the result of inadequate wiring, failed connections, or poor grounding. When a power quality issue cannot be immediately resolved, GMP investigates the cause by using power quality recording devices installed at the customer's premises. Once the cause of poor power quality is discovered, GMP informs the customer as to its source. If the problem originates with the customer's equipment, GMP assists the customer in finding appropriate consultants and vendors to help provide power quality solutions. If the problem originates with the transmission or distribution system, GMP immediately develops and implements a solution. In the future, the availability of AMI voltage information, by customer, may allow GMP to proactively address customer low voltage issues.

Distribution System Protection

Appropriate distribution system protection is necessary to prevent hazards to the public, protect utility workers, prevent damage to equipment, maximize reliability, and allow for prompt service restoration. GMP employs overcurrent devices on its distribution circuits with the goal of removing temporary faults and restricting the number of customers impacted by permanent faults. Specific strategies employed by GMP include the following:

- Circuit loads are not permitted to exceed 66% of relay pickup settings. Exception can be made for circuits that feed only one customer (such as a ski areas) or at times of feeder backup. This strategy provides for 150% cold-load pickup capability.

- Overcurrent protection, including circuit breakers, reclosers, and fuses, are sized and set to allow for maximum load current, cold load pickup, feeder backup, and load growth while maintaining the sensitivity required to detect bolted faults at that ends of the devices' zones of protection.

- Under normal circumstances, temporary protection operating sequences are set for "fuse saving." Fuse saving is a strategy in which the initial operations of circuit breakers and reclosers are performed with a "fast" timing characteristic which allows temporary faults to clear before down-stream fuses operate. Fuse saving avoids permanent outages downstream of fuses, but subjects upstream customers to momentary interruptions. Fuse saving may not be appropriate for all circuits including circuits supplying customers that are especially sensitive to momentary interruptions.

- Where justified, three-phase or single-phase electronic reclosers are deployed, in place of fuses, to provide additional capability and flexibility for present and future loads.

Weather Event Planning and Response

Severe weather events pose a significant threat to GMP's system reliability. To exacerbate the situation, these events often occur with only 24 to 72 hours' notice. To react quickly to an anticipated weather event, GMP has established a culture of immediate response in which its employees are trained in preparing for weather events and executing the restoration plan.

From experience, certain types and severity of weather predicate power outages. GMP subscribes to a weather monitoring service that the on-call storm director closely monitors for conditions that may cause outages. When potentially onerous weather is identified, the storm team is convened and a storm plan, commensurate with the threat, is put into effect. These efforts enable the storm team, field assessors, and field crews to mobilize before an outage occurs. GMP is also a member of the North Atlantic Mutual Assistance Group (NAMAG). As a member of NAMAG, GMP can request crews from around New England and beyond in the event that Vermont is faced with a catastrophic weather event. This proactive process has significantly minimized the duration of outages.

In addition to nine on-call storm directors, GMP has adopted the Incident Command System (ICS) as a means of managing its restoration efforts. As part of the ICS process, the following teams have been established, each with an upper management "chief" and executive sponsor:

- Incident Commander: The Incident Commander oversees the overall restoration effort and works directly with the ICS chiefs to ensure a safe, fast and effective restoration.
- Operations: The Operations Chief assembles and supervises each district office dispatching team. The Operations Chief also has overall supervision of the line workers, contract crews, and tree crews.
- Assessment: The Assessment Chief is responsible for assembling assessor crews and providing an inventory of the storm damage.
- Logistics: The Logistics Chief oversees the logistics team and is responsible for securing rooms and meals for all field crews.
- Information Technology: The Information Technology Chief is responsible for ensuring the 24/7 functioning of all computer hardware, software, and communications equipment during storm restoration.
- Communications: The Communications Chief supervises, and ensures coverage for, the call center, public relations, press, and social media.
- Safety: The Safety Chief is responsible for providing safety briefings to all contract crews and performs safety visits to crews during storm restoration.

Technology plays a significant role in managing weather events (see the section "**Error! Reference source not found.**" below for details). GMP uses several interrelated systems to manage its restoration efforts thereby allowing us to efficiently answer the high volumes of customer calls, manage the outages that have been reported, and maximize the use of available resources. GMP has recently completed installation of its advanced metering infrastructure (AMI) meters. AMI is enhancing restoration efforts by allowing storm organizers to contact or "ping" meters to determine which are out and which have had their power restored thus saving valuable crew time.

As part of GMP's restoration efforts, a focus is placed on restoring power to priority areas first. Priority areas include critical roadways that are blocked with downed wires, outages that are affecting the largest number of customers, and outages that are affecting key facilities including hospitals and patient care facilities.

Outage Management

Outage Analysis and Technology

GMP employs a device-driven, highly integrated outage management system (OMS) known as Responder. Responder accepts a variety of customer and system information and outputs information useful for analyzing and responding to outages.

Data input into Responder comes from a variety of sources:

- Customer service representatives take phone calls reporting outages and input this information into our outage portal, which then automatically communicates pertinent outage data to Responder. GMP also employs an overflow call center that can be used to assist with large volumes of calls. Like the GMP customer service representatives, the overflow call center uses the same outage portal to log outages directly into Responder.

- In a similar fashion, GMP's integrated voice response (IVR) system uses pre-recorded voice messages and subsequent customer responses to automatically obtain the customer's outage information, communicate this information to Responder, and if available provide customers with anticipated restoration times.

- GMP customers can sign-up for a text notification service that allows users to report an outage as well as obtain the status of when power will be restored. Customers can also report outages and obtain status updates from GMP's website.

- GMP's geographic information system (GIS), which contains the locations of customer data, line types, and the interrupting devices, is also integrated into Responder.

- Finally, GMP's fleet truck tracking system is integrated with Responder which allows operators to track the locations of line crews and tree crews.

Armed with this information, Responder predicts the discrete interrupting device that most likely operated for a given fault and provides operators with the device's location. Operators can then dispatch line crews or outage assessors to confirm the operation of the device. Once confirmed, the line crew or outage assessor patrols downstream of the device to determine the cause of the outage. Once the cause of an outage is known, an estimated restoration time is established and crews are dispatched to restore power.

Outage History

Below is a compilation of overall system outages for 2013 - the first full year of integration of Legacy GMP and Legacy CVPS - both with and without major storms.

Table 4.6.1 2013 GMP Outages With Major Storms

GMP 2013 Outages With Major Storms		
Outage Cause	**Customers Affected**	**Customer Hours Out**
1 - Trees	347,892	1,235,666
2 - Weather	78,247	353,889
3 - Company Initiated	23,605	42,041
4 - Equipment	70,257	125,260
5 - Operator	585	535
6 - Accident	41,540	66,098
7 - Animal	15,534	34,251
8 - Supplier	2,442	2,482
10 - Other	977	4,200
11 - Unknown	24,054	52,332
Grand Total	**605,133**	**1,916,754**

Table 4.6.2 2013 GMP Outages Without Major Storms

GMP 2013 Outages Without Major Storms		
Outage Cause	**Customers Affected**	**Customer Hours Out**
1 - Trees	269,399	669,267
2 - Weather	50,976	151,540
3 - Company Initiated	21,668	33,791
4 - Equipment	69,022	117,037
5 - Operator	585	535
6 - Accident	41,534	66,090
7 - Animal	15,534	34,251
8 - Supplier	2,442	2,482
10 - Other	976	4,197
11 - Unknown	21,918	42,100
Grand Total	**494,054**	**1,121,291**

GMP annually reviews and analyzes outage data. In addition to analyzing overall trends, each year GMP identifies its worst performing circuits, develops a priority list, and implements plans to improve the reliability of these circuits. GMP creates a priority list by ranking each circuit by the number of customers affected by outage events and by total customer hours out. This priority list allows us to focus our available resources on the least reliable areas of the power system thereby cost-effectively improving overall performance. Coupled with a system-wide focus on preparedness, technology, and a proactive vegetation management plan, this initiative creates a comprehensive approach to advancing the reliability of our power system.

The list of the 20 worst circuits represents the place where GMP first analyzes and targets improvements. Circuits making this list do not automatically result in a plan for capital improvements since other factors must be considered. For example, if the majority of the hours out on a given circuit were the result of a car pole accident, there might be no justification for undertaking additional improvements. Also, changing the operation or maintenance of a given circuit might be the best way to address an issue, as this requires no financial investment. For the 20 worst circuits identified in 2013, GMP has implemented improvements including road-side rebuild projects, SCADA upgrades, and reconstruction projects.

With the help of the BI tool (described above under the heading "The Planning Process") GMP uses business analytics query tools to analyze and generate reports, including monthly reports that identify customers who have experienced a high number of outages over a short period of time. These reports help GMP to decide where improvement dollars may best be invested. Historically, these types of analyses were limited to institutional knowledge of an area and/or rudimentary outage report summaries.

GMP continues to make significant investments in the reliability of its electric system. GMP invests approximately $50 million each year in capital upgrades to its transmission and distribution system. Examples of such projects include rebuilding substations, moving cross-country lines to the roadside, installing new protection devices, upgrading SCADA controls, and replacing end-of-life plant. All distribution rebuilds in which feeder back-up may be possible are performed with conductor large enough to support feeder back-up. These capital investments are in addition to the operation and maintenance expenses associated with vegetative management, pole inspections, aerial patrols, and infrared scanning.

Smart Grid Technologies

GMP will employ Smart Grid technologies to improve the functionality and reliability of the transmission and distribution system. A discussion of the overall development of GMP SmartPower is contained in Chapter 5. A number of recent and near-future developments for the purpose of enhancing power system control and outage management are discussed below.

Enhanced Communications and Data Acquisition

The recently completed VELCO fiber network provides high bandwidth, secure, two-way communication from GMP's substations to our control center. This enhanced, real-time communication improves data acquisition and the ability of GMP operators to remotely control substation equipment. Microprocessor-based substation equipment was installed over the past several years as part of the America Recovery and Reinvestment Act. This equipment is a significant upgrade over the electrometrical equipment that was present in many locations. The enhanced communication permits GMP engineering staff to more readily access substation data and allows overloaded and failing equipment to be more easily identified.

Distribution Automation and System Management / The Rutland Grid Innovation Project

GMP will pilot a number of distribution automation and system management technologies through its Rutland Grid Innovation project (RGI). Planned for implementation in 2015 and 2016, RGI will use advanced technologies to improve system reliability, reduce system losses, and better prepare the Rutland area to accept increasing amounts of renewable energy. The specific elements of RGI include the following:

- Micro Grid: GMP will interconnect the 2 MW Stafford Hill Solar project to a Dynapower 2 MW/3.4 MWh energy storage unit to create a micro grid. During outages, this micro grid will have the ability to configure itself into an intentional island to provide emergency service for a high school/emergency center, local gas stations, and a fire station. GMP will also take advantage of the ISO-NE ancillary grid services markets to participate in the frequency regulation market. The energy storage installation will be utilized to provide peak shaving during high load periods.

- Fault Detection Isolation and Recovery (FDIR): GMP will install fault detection, isolation, and recovery capability on nine circuits supplied by three substations in the Rutland area. Through the intelligent control of 18 reclosers at selected sectionalizing and tie points, the system will quickly isolate problems and restore power after the occurrence of faults on the system.

- Integrated Volt/VAR Control (IVVC): IVVC will function to reduce feeder losses and energy consumption (conservation voltage regulation) by minimizing the average voltage at all locations while maintaining end-of-line voltages within acceptable operating limits. IVVC will be integrated with AMI metering to control transformer load tap changers, switch capacitors, and compensate for detected low voltages. As part of RGI, an IVVC pilot program will be conducted in 2015 and 2016 on the South Rutland substation #72 circuit, a 12.47 kV circuit that serves a mix of residential and commercial customers in South Rutland and North Clarendon. This circuit also hosts the 2 MW Clarendon Solar project. Among the data to be collected from this pilot program will be the applicability of IVVC to circuits containing distributed solar generation, and relatedly, the applicability of IVVC as a tool to maintain voltage stability for areas containing high concentrations of DG. If operationally successful and cost-effective, GMP plans to expand IVVC to other parts of its system. The results of this pilot program, together with possible plans for the expansion of IVVC, will be reported in GMP's next IRP in 2017.

- Customer Education: GMP plans to install an innovative display at its downtown Rutland Energy Innovation Center to highlight the real-time configuration of the grid, demonstrate outage restoration, and show the penetration of local renewable generation flows.

- Network Management System (NMS): GMP will install a suite of applications to assist system operators with the tools they need to perform switching, effectively manage distribution load flows, and forecast future load flows on the network. The NMS will have the capability to manage hundreds of key data points on the system, process the information in real time, and aid in the optimization of the grid and the integration of distributed energy resources. These tools will be critical to the oversight and control of the elements listed above.

To implement RGI, GMP plans to install the NMS and associated field devices, hardware, and communications capability in 2015 and 2016. A significant aspect of the innovation associated with RGI is the overlap of various project technologies throughout the Rutland area. While GMP has already piloted certain elements of RGI, this project will be a proving ground where GMP attempts to standardize the installation and control of these technologies. If successful, RGI will allow grid innovation to expand to other communities throughout Vermont in a cost effective and efficient manner.