



Distributed Generation Interconnection System Impact Study



Vermont Electric Cooperative, Inc.

**North Troy 4.933 MW BESS Project
Project No. 138835**

**Final Report
Revision 0
1/12/2022**

Distributed Generation Interconnection System Impact Study

prepared for

**Vermont Electric Cooperative, Inc.
North Troy 4.933 MW BESS Project
North Troy, Vermont**

Project No. 138835

**Draft Report
Revision 0
1/12/2022**

prepared by

**Burns & McDonnell Engineering Company, Inc.
Wallingford, Connecticut**

TABLE OF CONTENTS

	<u>Page No.</u>
EXECUTIVE SUMMARY	1
1.0 INTRODUCTION	6
1.1 Study Objective.....	6
1.2 Statement of Limitations.....	6
2.0 PROJECT DESCRIPTION	7
2.1 Facility Description.....	7
2.2 North Troy Substation.....	8
2.3 Area Electric Power System	8
2.4 Service Configuration	11
2.5 Monitoring Information	11
3.0 LOAD FLOW ANALYSIS.....	12
3.1 Evaluated Steady State and Long-Term Dynamic Load Flows.....	12
3.2 Steady State Analysis.....	13
3.3 Flicker Analysis	15
3.3.1 Flicker Analysis – Existing Load Variation.....	17
3.3.2 Flicker Analysis – Photovoltaics and Cloud Cover	17
3.3.3 Flicker Analysis – ISO-NE Frequency Regulation Market	17
3.3.4 Flicker Analysis – ISO-NE Voltage Support Market	17
3.3.5 Flicker Analysis – Other Tests and Observations.....	17
3.4 Reverse Power Flow	19
4.0 SHORT CIRCUIT AND SYSTEM PROTECTION ANALYSIS.....	23
4.1 Fault Current Contributions	23
4.2 System Coordination Review	23
4.3 Temporary Overvoltage on Distribution System.....	24
4.4 Temporary Overvoltage on Transmission Supply	24
4.5 Inverter Protection Settings.....	25
4.5.1 Voltage Setting Requirements / Ride through	25
4.5.2 Frequency Setting Requirements / Ride through.....	25
4.6 Disconnect Switch	26
4.7 Unintentional Islanding.....	26
4.8 Direct Transfer Trip	26
4.9 Surge Withstand Capability	26
4.10 Frequency.....	26
4.11 Synchronizing Devices	26
4.12 Protection Scheme Assessment.....	27

5.0	COST ESTIMATE	28
6.0	CONCLUSION	29
7.0	REVISION HISTORY	32
8.0	APPENDIX	33
8.1	Appendix A – Interconnection Application.....	34
8.2	Appendix B – Project One Line Diagrams	38
8.3	Appendix C – Project Site Plan	39
8.4	Appendix D – North Troy Substation Single Line Operating Diagram	40
8.5	Appendix E – Steady State Analysis Results.....	41
8.6	Appendix F – Voltage Flicker Results.....	42
8.7	Appendix G – Short Circuit Results	43
8.8	Appendix H – Long-Term Dynamics Analysis Results	44

LIST OF TABLES

	<u>Page No.</u>
Table 3-1: Load Flow Analysis Scenarios	12
Table 3-2: Long-Term Dynamics Scenarios	13
Table 3-3: Post Project Peak Load Thermal Violations.....	15
Table 3-4: Voltage Flicker Scenario Descriptions	16
Table 3-5: Voltage Flicker Maximum Voltage Magnitude Excursion	16
Table 3-6: Voltage Flicker Analysis Results for AGC Scenarios.....	18
Table 3-7: Tap Changing Summary (6-hour period)	20
Table 3-8: Tap Changing Summary Post-Mitigation (6-hour period)	21
Table 4-1: Short Circuit Study Results	23

LIST OF FIGURES

Page No.

Figure 2-1: North Troy Substation Single Line Operating Diagram9

EXECUTIVE SUMMARY

Burns & McDonnell, working with Vermont Electric Cooperative (“VEC” or “the Company”), has completed the System Impact Study for the interconnection of the Green Mountain Power (“GMP”) North Troy (“Interconnecting Customer”, “Customer”, or “IC”), 4,933.5 kW battery energy storage system (“BESS”) project (“Project”) to the North Troy substation 12.47 kV distribution system, and presents the conclusions of the study herein. The requirements specified are exclusive to this Project and are based upon the information submitted by the Interconnecting Customer at the time the Interconnection Application (“IA”) was submitted and Burns & McDonnell’s understanding of the Company’s system at the time of study. Any further design changes made by the Interconnection Customer post IA without the Company’s and Burns & McDonnell’s knowledge, review, and/or approval may render the findings of this report null and void.

The Project will be located off Veilleux Road in North Troy, Vermont approximately one-half mile from VEC’s North Troy substation. The Project location will be served by the existing North Troy “41-1A” 12.47 kV distribution circuit.

The purpose of this study was to:

- Conduct, as applicable, steady-state, stability, short circuit, and extreme contingency analyses and perform assessments of reliability performance of the Company’s distribution system within the area of interconnection, with and without the proposed Project. The study will determine the incremental impact and any potential adverse impacts associated with the interconnection of the Project to the Company electric power system (“EPS”) and is in compliance with the applicable codes, standards, and guidelines listed below:
 - Vermont Public Utility Commission Rule 5.500
 - IEEE 1547-2018 – IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
 - IEEE 1547.3-2007 – IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected to Power Systems
 - IEEE 1453-2015 – IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems

- ANSI C84.1-2016 – American National Standard for Power Systems and Equipment Voltage Ratings (60 Hz)
 - IEEE Standard C37.90.1-2012 Standard Surge Withstand Capability (“SWC”) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
 - ISO New England (“ISO-NE”) Inverter Source Requirement Document (“SRD”)¹, dated February 6, 2018
- Determine any system modifications required.
 - Evaluate the existing distribution protection scheme to ensure that there is no degradation of reliability to the Company’s customers.
 - Provide a report describing the results of the System Impact Study.

The Project rating of 4,933.5 kW is a maximum (2-hour) rating. For the purposes of the system impact study, analysis was performed at the maximum rating. The existing North Troy substation transformer has a normal and maximum rating of 3,750 kVA and 4,687 kVA, respectively. As a load, at any time the Project has the capability to overload the substation transformer and the Project must be limited during charging to prevent an overload of the substation transformer.

Based on the results of this analysis, the Project cannot be allowed to interconnect without decreasing the charging rate of the BESS to an acceptable level, defined by VEC policies and procedures within the operating limits and available capacity of the North Troy substation transformer. Transformer loading and phase balancing are not static quantities. Loads vary continually and not necessarily in unison since the type of loads vary greatly (e.g. residential as compared to small commercial such as a convenience store, or industrial loads such as a manufacturing plant). Each load type has its own characteristics and timing pattern throughout the day, week, month, and season. Variation in transformer loading imbalance must be considered with respect to loading a transformer to the maximum nameplate rating. This ensures that there is not the risk of overloading one or more windings of the substation transformer. In this case, the North Troy substation transformer has a maximum nameplate rating of 4,687 kVA (4.69 MVA) which limits each

¹ https://www.iso-ne.com/static-assets/documents/2018/02/a2_implementation_of_revised_ieee_standard_1547_iso_source_document.pdf

winding to 1,562 kVA per phase (i.e. $4,687/3$), which is the equivalent of 217 A per phase at 7,200 V. The impact of exceeding the maximum nameplate rating for any single winding results in production of excessive heat. Excessive heat is a serious problem because winding insulation will be damaged if allowed to overheat. Degradation of the winding insulation results in loss of life for the transformer as a whole. If a winding is overloaded enough over time, the insulation will fail resulting in a potentially premature failure of the transformer.

System Modifications:

The System Impact Study found that the interconnection of the Project should have no adverse impacts on the Area EPS safety and reliability, provided the following recommended operating conditions and system modifications to the Company's EPS are implemented:

1. The Company will adjust the time delay settings for the North Troy 41-3A circuit line regulators to address excessive regulator tap change counts.
 - a. Cross Road regulators ("REG-369", "VOLT_89", "VOLT_95") forward and reverse time delay settings must be adjusted from 60 seconds to 75 seconds.
 - b. Armstrong Road regulator ("REG-41451") time delay setting must be adjusted from 40 seconds to 90 seconds.
2. The Company may install a three-phase gang-operated 600 Amp load break switch between the point of interconnection ("POI") and the point of common coupling ("PCC") as an isolation device.
3. The Company will install a three-phase pole-mounted G&W Viper S recloser at the PCC.
4. The BESS will have a three-phase pole mounted primary meter installed upstream of (or on) a new customer riser pole.
5. The Company will upgrade the existing North Troy substation regulators from 167 kVA per phase to 250 kVA per phase, with capability for reverse flow operation.
6. The Company will upgrade approximately 2,700 feet of 1/0 aluminum primary overhead three-phase conductor to 336 ACSR on the 41-1A circuit between North Troy substation and the POI on Veilleux Road.

7. The Company will install approximately 450 feet of 336 ACSR primary overhead three-phase conductor as described for the line extension from Veilleux Road to the Project.

The Interconnecting Customer is responsible for:

1. Procuring and installing all Customer-owned components associated with the Project.
2. All costs associated with system upgrades and rebuilds required to interconnect the Project as described in System Modifications, unless noted as the responsibility of the Company.
3. Providing necessary communications for data reporting.
4. Providing under and over frequency and voltage settings for the inverters prior to the Facilities Study. Inverter settings shall be in compliance with the ISO-NE SRD, IEEE 1547 standard, the NPCC Directory 12 Figure 1 Curve requirements for the Eastern Interconnection, and the Company required specific modification on the inverter over voltage condition setting as noted in Section 4.5.1.
5. Ensuring that the Project complies with ISO-NE SRD, UL 1741 SA, IEEE 1547, and the Vermont Electric Cooperative Interconnection Guidelines at all times.
6. Constraining the BESS inverter(s) to a maximum ramp rate of 7 percent (345 kW) per step change (every four seconds) to mitigate voltage flicker conditions if the Customer chooses to participate in the frequency regulation market.

If the recommended system modifications are made to the VEC North Troy substation, Area EPS, and the Project, the Project should not have a negative impact on system thermal capability and voltage of the Area EPS, under normal steady state and dynamic operating conditions.

If an event occurs with a recorded over-voltage at the PCC exceeding ANSI C84.1 Range A limitations and/or any reported damage of customer equipment, the Company reserves the right to disconnect the Project from the EPS. The developer will be responsible for all associated claims and for mitigation to prevent re-occurrence.

The Company reserves the right to disconnect the Project during times of temporary load transfers or if abnormal conditions develop.

This study has been completed using information provided by the Interconnecting Customer, GMP North Troy BESS, who submitted an Interconnection Application Form file dated June 2, 2021.

In accordance with the Vermont Public Utility Commission Rule 5.500, the Company has completed a System Impact Study to determine the scope of the required modifications to its EPS to provide the requested interconnection service.

1.0 INTRODUCTION

1.1 Study Objective

The primary objective of this distributed generation system impact study (“SIS”) is to provide Vermont Electric Cooperative (“VEC” or “the Company”) with an understanding of any adverse impacts or operating restrictions related to the interconnection of the GMP North Troy (the “Interconnecting Customer”, “IC”, or “Customer”) 4,933.5 kW battery energy storage system (“BESS”) project (“Project”) to the North Troy substation, the 41-1A circuit. Additionally, the system impact study identifies system upgrades and modifications, and the responsible party, to reliably accommodate interconnection of the Project in accordance with Vermont Public Utility Commission Rules and other applicable codes and standards. The conclusions and requirements are based on the information submitted to VEC by the Customer. Design changes made by the Customer without VEC’s and Burns & McDonnell’s knowledge, review, and approval may make the findings in this document null and void.

1.2 Statement of Limitations

In the preparation of this report, the information provided to Burns & McDonnell by Vermont Electric Cooperative was used by Burns & McDonnell to make certain assumptions with respect to conditions which may exist in the future. While Burns & McDonnell believes the assumptions made are reasonable for the purposes of this report, Burns & McDonnell makes no representation that the conditions assumed will, in fact, occur. In addition, while Burns & McDonnell has no reason to believe that the information provided by Vermont Electric Cooperative, and on which this report is based, is inaccurate in any material respect, Burns & McDonnell has not independently verified such information and cannot guarantee its accuracy or completeness. To the extent that actual future conditions differ from those assumed herein or from the information provided to Burns & McDonnell, the actual results will vary from those presented.

2.0 PROJECT DESCRIPTION

2.1 Facility Description

The Project-owned and operated equipment is an inverter-based facility consisting of a 4,933.5 kW BESS system, described in the Project Interconnection Application (Appendix A), and as depicted in the Interconnecting Customer's Site One Line Diagram (Appendix B). As described in the interconnection application one line diagram, the BESS system is expected to operate with a maximum export limit of 4,933.5 kW. A Company-owned and operated G&W Viper S recloser shall be installed at the point of common coupling ("PCC"). The PCC is the point of connection between the area electric power system ("EPS") and the Local EPS and will be designated as the Project side of the Company-installed primary meter. The details for the proposed Project facility are described below based on the interconnection application documents.

GMP North Troy – Battery Energy Storage System (4,933.5 kW Inverter-Based Facility)

The (4,933.5 kW) GMP North Troy BESS Project will consist of three (3) 480 V Tesla Megapack inverters rated at 858 kW and three (3) 480 V Tesla Megapack inverters rated at 786.5 kW. The BESS inverter system is compliant with UL 1741 and IEEE 1547 standards. Additionally, the BESS will include sixty-nine (69) Tesla Battery Megapack modules, rated at 43.6 kW and 174.4 kWh for a total capacity of 3,008.4 kW and 12,033.6 kWh, respectively. Under a 2-hour runtime, each battery module may operate up to a maximum of 84.3 kW (5,816.7 kW) with maximum output limited by the inverter system (4,933.5 kW).

The details and assumptions for the interconnection generator step-up ("GSU") transformer are documented as follows:

- Two (2) 2,500 kVA three-phase, two-winding 12.47kV grounded-wye / 480 V grounded-wye secondary interconnection GSU padmount transformers (XFMR-A and XFMR-B) with an assumed 5.75 percent impedance on a 2,500 kVA base.
- Each transformer must be equipped with tap changing capability.
- Each transformer has an assumed X/R ratio of 8.
- Each transformer is equipped with an AC disconnect and fuses on the primary side.

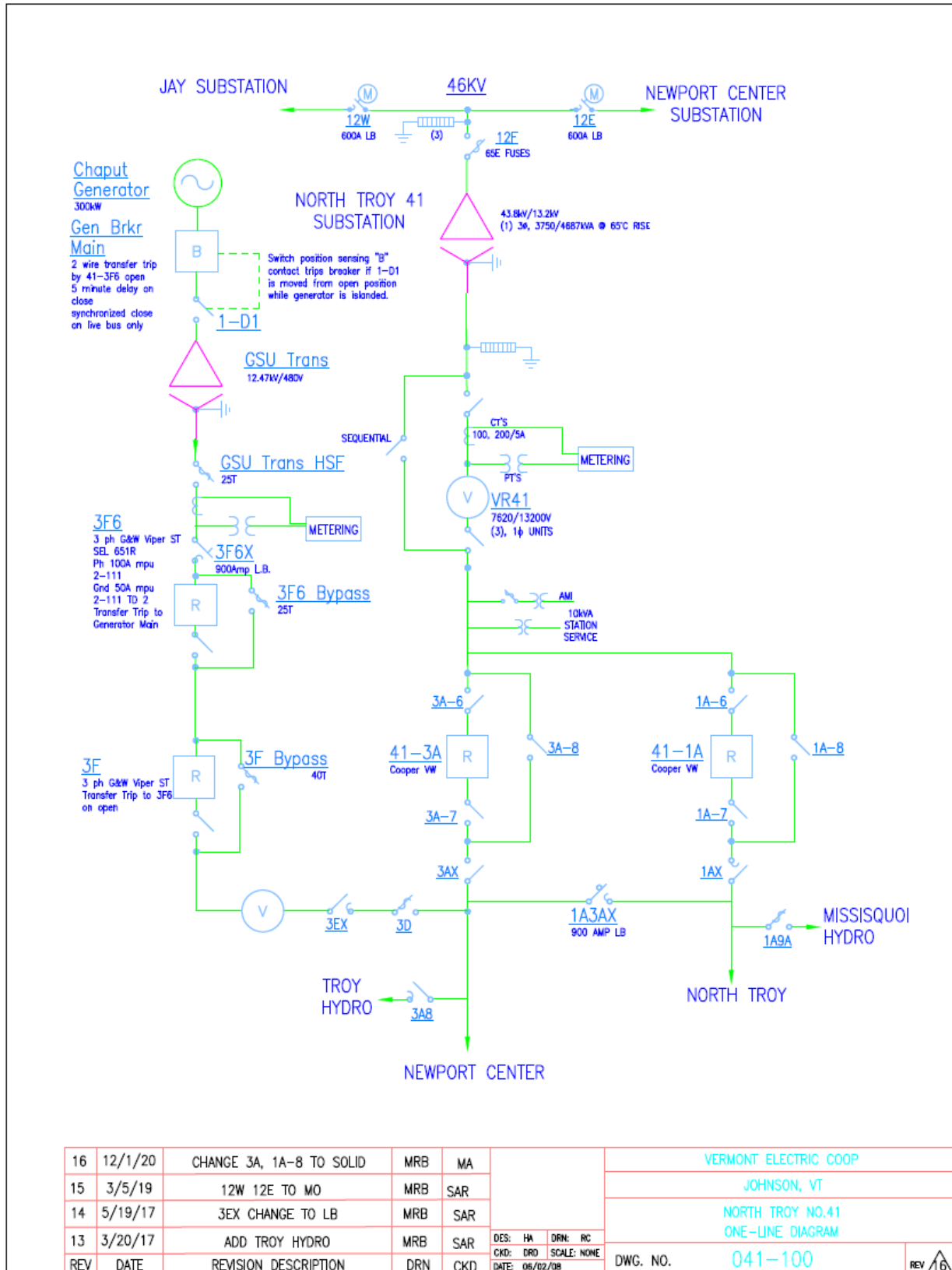
2.2 North Troy Substation

The North Troy substation is a distribution station supplied from the 46 kV system via a radial tap from the “12” Line between Jay substation and Newport Center substation. The North Troy substation currently serves two circuits, 41-1A and 41-3A, via one 43.8 kV/13.2 kV power transformer. The power transformer has a base and maximum nameplate rating of 3,750 kVA and 4,687 kVA, respectively. Voltage is regulated on the substation and downstream circuits via three single phase, 167 kVA (219 Amp) regulators. The peak load on North Troy substation was approximately 2,812 kW, observed on August 12, 2021 at 6:30 PM. The minimum load was observed to be approximately 800 kW on April 19, 2021 at 6:15 AM.

2.3 Area Electric Power System

The Project is proposed to be located off Veilleux Road in North Troy, Vermont, approximately 2,700 feet from the North Troy substation and served from the power transformer, connected via the 12.47 kV grounded-wye primary circuit, 41-1A. The single line operating diagram for the North Troy distribution substation is provided in **Figure 2-1** and in Appendix D.

Figure 2-1: North Troy Substation Single Line Operating Diagram



As of August 18, 2021, the total of installed and proposed distributed generation on the North Troy substation is 5,611 kW, including the project under study. The characteristics of the North Troy substation and the distribution circuits are as follows:

1. The substation voltage is regulated by three (3) single phase 167 kVA (219-Amp) regulators (Voltage = 123.5 V; Bandwidth = 3.0 V; Time Delay = 60s; R = 0; X = 0).
2. The 41-1A circuit has no additional line regulation installed. The 41-3A circuit has the following additional line regulation installed.
 - a. Three (3) single-phase 167 kVA (219-Amp) regulators (Voltage = 121 V; Bandwidth = 3.0 V; Time Delay = 60s; R = 0; X = 0) on Cross Road.
 - b. One (1) single-phase 167 kVA (219-Amp) regulator (Voltage = 123 V; Bandwidth = 4.0 V; Time Delay = 40; R = 0; X = 0) on Armstrong Road.
3. Peak Load Data²
 - a. The peak load on the 41-1A circuit was observed to be 0.989 MW, 0.082 MVar.
 - b. The peak load on the 41-3A circuit was observed to be 1.942 MW, 0.408 MVar.
4. Minimum Load Data²
 - a. The minimum load on the 41-1A circuit was observed to be 0.274 MW, 0.264 MVar.
 - b. The minimum load on the 41-3A circuit was observed to be 0.533 MW, 0.639 MVar.
5. There is approximately 5,248 kW and 363 kW of existing or proposed generation on the 41-1A and 41-3A circuits, respectively.
 - a. During peak load, the distributed resource to load ratio on the 41-1A and 41-3A is estimated to be 5.31:1 (531 percent) and 0.187:1 (18.7 percent), respectively.
 - b. During minimum load, the distributed resource to load ratio on the 41-1A and 41-3A is estimated to be 19.15:1 (1,915 percent) and 0.68:1 (68 percent), respectively.

² Noncoincident peak and minimum loads listed

2.4 Service Configuration

VEC will require the installation of a dedicated three-phase recloser at the PCC. Additionally, the Company requires the interconnection GSU transformers to be equipped with tap changing capability. The tap changing capability of the interconnection GSU transformers for the Project was unable to be confirmed from the IA documents.

The PCC will be designated as the Project side of the Company-installed primary meter. The point of DER connection (PoC) is the point where a DER unit is electrically connected to the Local EPS and meets the requirements of IEEE 1547-2018.

To serve the Customer, a three-phase primary overhead line must be extended to the Project location. VEC will have a revenue grade three-phase primary meter package installed upstream from the Project. All electrical facilities on the Project-side of the PCC will be installed, owned, and operated by the Project.

2.5 Monitoring Information

Per IEEE 1547-2018, Section 10.5, the DER shall be capable of providing monitoring information through a local DER communication interface at the reference point of applicability and shall include at a minimum active power, reactive power, voltage, frequency, operational state of the DER, connection status, alarm status.

The Project will be considered an Independent Power Producer, planning to install a 4,933.5 kW BESS system; therefore, bi-directional metering provisions are required. The Company intends to meet this requirement through bi-directional metering installed at the PCC. Real-time monitoring via a SCADA feed will also be required of this Project due to its significant impact on the dynamic loading condition of the distribution system.

3.0 LOAD FLOW ANALYSIS

The purpose of the load flow analysis was to evaluate thermal loading (current flow), voltage profile, voltage drop, and power factor with and without the interconnection of the Project generator. An objective of the study is to evaluate if the addition of the Project causes voltage violations against ANSI C84.1 criteria, greater than +/- 5% of the nominal voltage (114V – 126V). Prior to adding the Project to the model for the load flow analysis, no pre-existing violations were observed across the circuits.

3.1 Evaluated Steady State and Long-Term Dynamic Load Flows

The power flow analysis was performed using Milsoft WindMil. A model of the North Troy substation 41-1A circuit was revised using data provided by the Company. The analysis included all circuits fed from North Troy substation.

A steady state analysis considered scenarios at minimum and peak load on the North Troy substation distribution circuits. The scenarios were developed considering the following conditions:

- PV: on/off.
- Battery: off/charging/discharging.

The load flow analysis scenarios performed in this study are provided in **Table 3-1**.

Table 3-1: Load Flow Analysis Scenarios

Load Flow Analysis Case	Description	Switched Devices	Load model
Base Case 1 (Pre-Project)	All Existing DER Online	Unlocked	Peak & Min
Base Case 2 (Pre-Project)	All Existing DER Offline	Unlocked	Peak & Min
LF Case 1 (Post Project)	Existing DER Online (Base Case 1) w/ Project BESS 100% Charging	Unlocked	Peak & Min
LF Case 2 (Post Project)	Existing DER Online (Base Case 1) w/ Project BESS 100% Discharging	Unlocked	Peak & Min
LF Case 3 (Post Project)	Existing DER Online (Base Case 1) w/ BESS 100% Charging -> 100% Discharging	Unlocked -> Locked	Peak & Min
LF Case 4 (Post Project)	Existing DER Online (Base Case 1) w/ BESS 100% Discharging -> 100% Charging	Unlocked -> Locked	Peak & Min

In addition to the steady state analysis, time series analysis was conducted, for 6-hour periods, using the Long-Term Dynamics modeling capability of CYME. The objective was to determine compliance with IEEE 1453-2015 flicker recommendations and assess the impact of the Project on device operations. As case inputs to the analysis, 6-hour PV output variability signals were created using historical data provided by the Company, obtained from a local PV site, and 6-hour load profiles for minimum and maximum load conditions were also created, utilizing two years of SCADA data.

The battery was simulated in frequency regulation mode following two types of energy neutral Automatic Generator Control (AGC) options offered by ISO-NE. The first AGC signal modeled was the “continuous” type; the second AGC signal modeled was the “trinary” type using a six-hour portion of the ISO-NE provided sample trinary signal. The modeled AGC set point data does not necessarily reflect actual battery output, only the request from ISO-NE. For the purposes of this study, it was assumed that the battery installation could maintain sufficient state of charge (“SOC”) throughout the time period to meet all requests from the ISO-NE signal. Therefore, the provided AGC set point data was used to create generation curves to reflect no bias battery output during the Long-Term Dynamic analysis. The long-term dynamic scenarios performed in this study are provided in **Table 3-2**.

Table 3-2: Long-Term Dynamics Scenarios

Scenario	Description	Switched device	Load model
LTD1	BESS offline	Unlocked	Peak
LTD2	BESS offline	Unlocked	Min
LTD3	BESS operated by AGC Continuous	Unlocked	Peak
LTD4	BESS operated by AGC Continuous	Unlocked	Min
LTD5	BESS operated by AGC Trinary	Unlocked	Peak
LTD6	BESS operated by AGC Trinary	Unlocked	Min

3.2 Steady State Analysis

The Company is obligated to hold distribution voltages at customer service points to defined limits in ANSI Standard C84.1-2016. Range A of the ANSI standard requires the Company to hold voltage within +/- 5% of nominal at the customer service point. Under normal operating conditions, it is expected that the Company be able to meet its obligations for ANSI C84.1 with the Project at full output, and

the interconnecting circuit in its normal configuration. The Project shall not interfere with the ability to maintain PCC voltage within ANSI Range A and shall not exceed flicker limits defined in IEEE 1453-2015 at the PCC. Additionally, all equipment must operate within thermal ratings. For the purpose of the system impact study, the Project was studied at its maximum capability, 4,933.5 kW.

In the steady state analysis, thermal loading on all conductors and voltage on all nodes were monitored. Prior to the interconnection of the Project, no voltage violations were observed relative to the ANSI C84.1 criteria. Additionally, no thermal violations were observed prior to the interconnection of the Project. In the Post-Interconnection cases, no voltage violations were observed. However, thermal violations were observed on the primary conductor between the POI and the North Troy substation, on the substation regulators, and the substation transformer. A full summary of the steady state analysis results is provided in Appendix E.

As a result of the Project, a three-phase primary overhead line extension will be installed off Veilleux Road in North Troy, Vermont. Currently, there is an existing three-phase primary voltage source adjacent to the proposed Project location. The existing conductor on the 41-1A circuit is 1/0 aluminum between the POI and the North Troy substation. As a result of the analysis performed in this study, it was determined that the existing three phase conductors between the Project and North Troy substation would be insufficient and result in thermal overloads of the conductor. The issue is a direct result of the Project, no such conditions currently exist. To mitigate the issue and provide service to the Project, approximately 2,700 feet of 1/0 aluminum conductor between the POI and North Troy substation must be upgraded to 336 ACSR. Additionally, approximately 450 feet of 336 ACSR should be installed for the line extension between the POI and the PCC. In total, approximately 3,150 feet of three-phase 336 ACSR will be installed to accommodate the interconnecting project. Finally, to facilitate the installation and proposed upgrades, poles will need to be installed and replaced as necessary to meet Company standards for the primary overhead three-phase configuration. Following the upgrades to the three-phase conductors on the upstream sections of the Project, no thermal violations were identified on conductors. However, one equipment location was observed to experience thermal overload, namely the 3-219 Amp substation regulators (Device Number "VOLT_65"). The identified equipment needs to be replaced with 3-328 Amp regulators to accommodate the Project during charging and discharging scenarios. Additionally, during the post-interconnection analysis of the Project, it was determined that with the BESS charging the North Troy

substation transformer may achieve load levels that exceed its maximum nameplate rating (4,687 kVA) by approximately 28 percent under minimum load conditions, and by approximately 88 percent under peak load conditions. Based on the results of this analysis, absent the upgrade of the substation transformer, the Project cannot be allowed to interconnect without limiting the charging rate of the BESS to an acceptable level, defined by VEC policies and procedures within the operating limits and available capacity of the existing North Troy substation transformer. With the Project charging rate limited to the available capacity of the substation transformer and the aforementioned upgrades completed, no thermal violations should be observed on the North Troy substation distribution system. A full summary of the steady state analysis results is included in Appendix E.

Table 3-3: Post Project Peak Load Thermal Violations

Device Id	Equipment	Base Case Loading	Post Interconnection Loading	Rating
VOLT_65	Regulator	50.303%	123.688%	219A
TRAN_87727	Transformer	70.366%	181.943%	217A

3.3 Flicker Analysis

The IEEE Recommended Practice for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems, IEEE Std. 1453-2015 provides guidance on flicker and voltage fluctuations. VEC requires that the Project shall not exceed flicker limits defined in IEEE 1453-2015 at the PCC. This study evaluated the voltage changes between various scenarios when transitioning the battery system from on/off as well as between charging and discharging modes and locking the taps during the transitions. The following scenarios in **Table 3-4** were studied.

Table 3-4: Voltage Flicker Scenario Descriptions

Scenario	Description	DG Status	Regulator	Capacitor
0	Peak/Min	Base (Disconnected)	Step	Last Status
1a	Peak/Min Charging (Offline to Charging)	Base (Disconnected)	Step	Last Status
		Charging	Locked	Last Status
1b	Peak/Min Discharging (Offline to Discharging)	Base (Disconnected)	Step	Last Status
		Discharging	Locked	Last Status
2	Peak/Min Charging to Discharging	Charging	Step	Last Status
		Discharging	Locked	Last Status
3	Peak/Min Discharging to Charging	Discharging	Step	Last Status
		Charging	Locked	Last Status

With the Project operating at maximum capacity and alternating from charging to discharging, the observed element (span_12309) at the POI experienced voltage differences on any phase exceeding a magnitude of 3 percent for both peak and minimum loading cases between post-project (Scenarios 2 and 3) and pre-project (Scenario 0) cases. A summary of the maximum voltage excursion results is provided in **Table 3-5** and a full summary is provided in Appendix F.

Table 3-5: Voltage Flicker Maximum Voltage Magnitude Excursion

Load Model	Scenario	Description	Element Observed	Max % Difference Voltage Magnitude		
				Phase A	Phase B	Phase C
Peak	1a	Offline to Charging	span_12309	3.11%	3.41%	2.99%
	1b	Offline to Discharging	span_12309	0.10%	0.23%	0.03%
	2	Charging to Discharging	span_12309	3.80%	4.34%	3.72%
	3	Discharging to Charging	span_12309	3.92%	4.43%	3.71%
Minimum	1a	Offline to Charging	span_12309	2.59%	2.65%	2.59%
	1b	Offline to Discharging	span_12309	0.01%	0.61%	0.00%
	2	Charging to Discharging	span_12309	3.30%	3.44%	3.27%
	3	Discharging to Charging	span_12309	3.30%	3.44%	3.27%

Additionally, time series analysis was completed for the combinations of load conditions and generation profiles described in Section 3.1, utilizing the Cyme Long Term Dynamics module, to quantify the voltage

flicker magnitudes and frequencies at the PCC. The flicker values were assessed for compliance with the recommended short-term flicker severity (Pst) planning threshold of 0.9 (applicable for medium voltage systems). The time step / voltage change frequency limits for Pst=0.9 were conservatively estimated utilizing the Pst=1 value in IEEE Std. 1453-2015, Table 4 and associated shape factors for square wave periodic changes in IEEE Std. 1453-2015, Annex C, Figure C.1.

3.3.1 Flicker Analysis – Existing Load Variation

The existing load of circuits at North Troy Substation was evaluated following a six-hour trend from the maximum load day, and a six-hour trend from a typical minimum load day. No objectionable voltage flicker was measured at the PCC.

3.3.2 Flicker Analysis – Photovoltaics and Cloud Cover

The existing distributed PV on the feeder was evaluated following a generator curve that was developed using historical measured data from existing Company solar facilities. No objectionable flicker was measured at the PCC.

3.3.3 Flicker Analysis – ISO-NE Frequency Regulation Market

The 4,933.5 kW battery was simulated in the ISO-NE frequency regulation market following a continuous AGC signal and a trinary AGC signal. Objectionable voltage flicker was measured for only the AGC Trinary signal. Thorough analysis was performed to determine an appropriate ramp rate to address the voltage flicker. A ramp rate of 7 percent (345 kW) per step change (every four seconds) must be applied to the Project while operating in the ISO-NE Frequency Regulation Market. An excerpt of the results following the implementation of a 7 percent ramp rate is provided in **Table 3-6**.

3.3.4 Flicker Analysis – ISO-NE Voltage Support Market

Analysis for the ISO-NE Voltage Support Market was not included in the scope of this study.

3.3.5 Flicker Analysis – Other Tests and Observations

Regulator tap changes were monitored on the circuits of North Troy Substation during every long-term dynamic case. Regulator tap change travel issues were observed during this analysis. A summary of the results of the tap change analysis is provided in **Table 3-7**. Setting changes were required to resolve the regulator tap change travel issues. The setting changes are listed as follows.

Regulator Settings:

1. Cross Road (“VOLT_89”, “VOLT_95”, “REG-369”)
 - Voltage = 121 V;
 - Bandwidth = 3.0 V;
 - Forward/Reverse TD = 75 s (previously 60 s);
 - Co-Generation
 - Terminal Regulation (R = 0; X = 0)

2. Armstrong Road (“REG-41451”)
 - Voltage = 123 V;
 - Bandwidth = 4.0 V;
 - Forward TD = 90 s (previously 40 s);
 - Locked Forward
 - Terminal Regulation (R = 0; X = 0)

The results of the analysis following the implementation of revised settings is provided in **Table 3-8**. A full summary of the long term dynamics analysis results is provided in Appendix H.

Table 3-6: Voltage Flicker Analysis Results for AGC Scenarios

BASELINE	0.1 CHANGES PER MINUTE	0.2 CHANGES PER MINUTE	0.4 CHANGES PER MINUTE	0.6 CHANGES PER MINUTE	1 CHANGES PER MINUTE	2 CHANGES PER MINUTE	3 CHANGES PER MINUTE	5 CHANGES PER MINUTE	7 CHANGES PER MINUTE	10 CHANGES PER MINUTE
Maximum Allowable Voltage Fluctuation ³	6.001	3.828	2.972	2.667	2.317	1.879	1.646	1.39	1.24	1.097
LTD1	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
LTD2	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
LTD3	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
LTD4	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
LTD5	PASS	PASS	PASS	PASS	PASS	FAIL	FAIL	FAIL	FAIL	FAIL
LTD6	PASS	PASS	PASS	PASS	PASS	FAIL	FAIL	FAIL	FAIL	FAIL
LTD7 PEAK	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS
LTD7 MIN	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS	PASS

³ Maximum allowable voltage fluctuation at the given frequency

3.4 Reverse Power Flow

The possibility of this interconnection causing reverse power flow was reviewed. When the project is under a full-export (discharging) condition, the export of the Project may contribute to the reverse flow through the substation transformer to the 46 kV. The observed reverse power flow through the North Troy substation transformer and 41-1A recloser was determined to be 4.031 MW and 4.564 MW, respectively, during the minimum load with distributed resources⁴ at 100 percent output. Under a reverse power flow condition, the substation regulators must be equipped for reverse power flow. Due to the observed reverse power flow conditions, additional study should be conducted to review impacts and requirements for the upstream 46 kV system.

⁴ The number of distributed resources included in the analysis is limited to generator locations in the Windmil model with the appropriate settings populated.

Table 3-7: Tap Changing Summary (6-hour period)

Case Name	Description	Device Number	Device type	Tap Location	Phase	Tap Change Count	Minimum Tap	Maximum Tap	Average Tap
LTD1	BESS Offline – Peak	REG-41451	Regulator	Secondary	A	0	5	5	5
		VOLT_95	Regulator	Secondary	A	0	2	2	2
		VOLT_95	Regulator	Secondary	B	1	-2	-1	-2
		VOLT_95	Regulator	Secondary	C	1	-1	0	0
		VOLT_65	Regulator	Secondary	A	0	2	2	2
		VOLT_65	Regulator	Secondary	B	0	2	2	2
LTD2	BESS Offline – Minimum	REG-41451	Regulator	Secondary	A	0	0	0	0
		VOLT_95	Regulator	Secondary	A	0	0	0	0
		VOLT_95	Regulator	Secondary	B	0	0	0	0
		VOLT_95	Regulator	Secondary	C	0	0	0	0
		VOLT_65	Regulator	Secondary	A	0	-3	-3	-3
		VOLT_65	Regulator	Secondary	B	1	-4	-3	-4
LTD3	BESS operated by AGC Continuous – Peak	REG-41451	Regulator	Secondary	A	37	2	7	4
		VOLT_95	Regulator	Secondary	A	25	0	4	1
		VOLT_95	Regulator	Secondary	B	19	-5	-1	-4
		VOLT_95	Regulator	Secondary	C	16	-4	0	-3
		VOLT_65	Regulator	Secondary	A	12	2	5	4
		VOLT_65	Regulator	Secondary	B	14	2	5	4
LTD4	BESS operated by AGC Continuous – Minimum	REG-41451	Regulator	Secondary	A	3	0	3	3
		VOLT_95	Regulator	Secondary	A	3	-6	-3	-6
		VOLT_95	Regulator	Secondary	B	3	-6	-3	-6
		VOLT_95	Regulator	Secondary	C	3	-6	-3	-6
		VOLT_65	Regulator	Secondary	A	2	0	2	2
		VOLT_65	Regulator	Secondary	B	2	0	2	2
LTD5	BESS operated by AGC Trinary – Peak	REG-41451	Regulator	Secondary	A	0	5	5	5
		VOLT_95	Regulator	Secondary	A	0	2	2	2
		VOLT_95	Regulator	Secondary	B	0	-1	-1	-1
		VOLT_95	Regulator	Secondary	C	1	-1	0	0
		VOLT_65	Regulator	Secondary	A	0	2	2	2
		VOLT_65	Regulator	Secondary	B	0	2	2	2
LTD6	BESS operated by AGC Trinary – Minimum	REG-41451	Regulator	Secondary	A	0	0	0	0
		VOLT_95	Regulator	Secondary	A	0	-3	-3	-3
		VOLT_95	Regulator	Secondary	B	0	-3	-3	-3
		VOLT_95	Regulator	Secondary	C	0	-3	-3	-3
		VOLT_65	Regulator	Secondary	A	0	0	0	0
		VOLT_65	Regulator	Secondary	B	0	0	0	0
LTD6	BESS operated by AGC Trinary – Minimum	REG-41451	Regulator	Secondary	A	0	0	0	0
		VOLT_95	Regulator	Secondary	A	0	-3	-3	-3
		VOLT_95	Regulator	Secondary	B	0	-3	-3	-3
		VOLT_95	Regulator	Secondary	C	0	-3	-3	-3
		VOLT_65	Regulator	Secondary	A	0	0	0	0
		VOLT_65	Regulator	Secondary	B	0	0	0	0
LTD6	BESS operated by AGC Trinary – Minimum	REG-41451	Regulator	Secondary	A	0	0	0	0
		VOLT_95	Regulator	Secondary	A	0	-3	-3	-3
		VOLT_95	Regulator	Secondary	B	0	-3	-3	-3
		VOLT_95	Regulator	Secondary	C	0	-3	-3	-3
		VOLT_65	Regulator	Secondary	A	0	0	0	0
		VOLT_65	Regulator	Secondary	B	0	0	0	0

Table 3-8: Tap Changing Summary Post-Mitigation (6-hour period)

Case Name	Description	Device Number	Device type	Tap Location	Phase	Tap Change Count	Minimum Tap	Maximum Tap	Average Tap
LTD1	BESS Offline – Peak	REG-41451	Regulator	Secondary	A	0	5	5	5
		VOLT_95	Regulator	Secondary	A	0	2	2	2
		VOLT_95	Regulator	Secondary	B	1	-2	-1	-2
		VOLT_95	Regulator	Secondary	C	1	-1	0	0
		VOLT_65	Regulator	Secondary	A	0	2	2	2
		VOLT_65	Regulator	Secondary	B	0	2	2	2
LTD2	BESS Offline – Minimum	REG-41451	Regulator	Secondary	A	0	0	0	0
		VOLT_95	Regulator	Secondary	A	0	-2	-2	-2
		VOLT_95	Regulator	Secondary	B	0	-3	-3	-3
		VOLT_95	Regulator	Secondary	C	0	-3	-3	-3
		VOLT_65	Regulator	Secondary	A	0	0	0	0
		VOLT_65	Regulator	Secondary	B	0	0	0	0
LTD3	BESS operated by AGC Continuous – Peak	REG-41451	Regulator	Secondary	A	1	4	5	4
		VOLT_95	Regulator	Secondary	A	9	0	2	1
		VOLT_95	Regulator	Secondary	B	7	-4	-1	-4
		VOLT_95	Regulator	Secondary	C	10	-3	0	-3
		VOLT_65	Regulator	Secondary	A	12	2	5	4
		VOLT_65	Regulator	Secondary	B	14	2	5	4
LTD4	BESS operated by AGC Continuous – Minimum	REG-41451	Regulator	Secondary	A	2	0	2	1
		VOLT_95	Regulator	Secondary	A	3	-5	-2	-4
		VOLT_95	Regulator	Secondary	B	3	-6	-3	-5
		VOLT_95	Regulator	Secondary	C	2	-5	-3	-5
		VOLT_65	Regulator	Secondary	A	4	0	3	2
		VOLT_65	Regulator	Secondary	B	4	0	3	2
LTD5	BESS operated by AGC Trinary – Peak	REG-41451	Regulator	Secondary	A	0	5	5	5
		VOLT_95	Regulator	Secondary	A	0	2	2	2
		VOLT_95	Regulator	Secondary	B	0	-1	-1	-1
		VOLT_95	Regulator	Secondary	C	1	-1	0	0
		VOLT_65	Regulator	Secondary	A	0	2	2	2
		VOLT_65	Regulator	Secondary	B	0	2	2	2
LTD6	BESS operated by AGC Trinary – Minimum	REG-41451	Regulator	Secondary	A	0	0	0	0
		VOLT_95	Regulator	Secondary	A	0	-2	-2	-2
		VOLT_95	Regulator	Secondary	B	0	-3	-3	-3
		VOLT_95	Regulator	Secondary	C	0	-3	-3	-3
		VOLT_65	Regulator	Secondary	A	0	0	0	0
		VOLT_65	Regulator	Secondary	B	0	0	0	0
LTD7	BESS 7% Ramp Rate Restriction – Peak	REG-41451	Regulator	Secondary	A	0	5	5	5
		VOLT_95	Regulator	Secondary	A	0	5	5	5
		VOLT_95	Regulator	Secondary	B	0	2	2	2
		VOLT_95	Regulator	Secondary	C	1	-2	-1	-2
		VOLT_65	Regulator	Secondary	A	3	-2	0	-2
		VOLT_65	Regulator	Secondary	B	0	2	2	2
LTD7	BESS 7% Ramp Rate Restriction – Minimum	REG-41451	Regulator	Secondary	A	0	0	0	0
		VOLT_95	Regulator	Secondary	A	0	-2	-2	-2
		VOLT_95	Regulator	Secondary	B	0	-3	-3	-3
		VOLT_95	Regulator	Secondary	C	0	-3	-3	-3

Case Name	Description	Device Number	Device type	Tap Location	Phase	Tap Change Count	Minimum Tap	Maximum Tap	Average Tap
		VOLT_65	Regulator	Secondary	A	0	0	0	0
		VOLT_65	Regulator	Secondary	B	0	0	0	0
		VOLT_65	Regulator	Secondary	C	0	0	0	0

4.0 SHORT CIRCUIT AND SYSTEM PROTECTION ANALYSIS

A protection review was performed for this proposed interconnection of a 4,933.5 kW BESS project to the Company's 12.47 kV, multi-grounded wye, effectively grounded circuit. This review focused on the system protection scheme and the Project interface and identified distribution system enhancements that may be necessary to complete the interconnection of the Project and its ability to meet IEEE 1547 Standards and Vermont Public Utility Commission Rule 5.500 that are applicable for this interconnection.

4.1 Fault Current Contributions

A short circuit analysis was performed to evaluate the incremental impact of the Project on system protection and adequacy of existing circuit breakers, other fault current interrupting devices, and related equipment on the Company EPS. Short circuit analysis was conducted for the case with the Project offline and with the Project online to evaluate the impact of the Project on fault currents on the 41-1A and 41-3A circuits and North Troy substation. The short circuit study was performed using WindMil. An increase of approximately 5.59 percent was observed in the Maximum LLL current results, while an increase of approximately 3.84 percent was observed in the Maximum LG current. Based on the results of the study, it can be concluded that no device exceeds its interrupting capability. The short circuit study results summary is provided in **Table 4-1** and Appendix G.

Table 4-1: Short Circuit Study Results

Node Id	Feeder Id	Post-Project Case		Pre-Project Case		% increase LLL	% increase LG
		Max of LLL	Max of LG	Max of LLL	Max of LG		
41-7-1A	NORTH TROY	2442.04	2515.48	2312.83	2422.43	5.59%	3.84%
41-7-3A	NORTH TROY	2442.04	2515.48	2312.83	2422.43	5.59%	3.84%
TRAN_87727	NORTH TROY	2442.04	2515.48	2312.83	2422.43	5.59%	3.84%

4.2 System Coordination Review

Per Company requirements, protection studies will demonstrate that the sensitivity of fault detection of the existing line protection is not substantially degraded, the existing speed of fault clearing is not substantially degraded, and the existing coordination margin between relays is not decreased. Existing nondirectional line

relays must not operate for faults external to the line due to the proposed Project's current contribution to the fault.

As part of the protection analysis a system protective device coordination review was completed on the North Troy substation, with and without the Project interconnected. The Project is interconnecting to an existing circuit, 41-1A, and will only have one protective device installed between the Project and the North Troy substation circuit recloser. As a result of the Project, the Company requires a G&W Viper S line recloser be installed at the PCC. The recloser must coordinate with all upstream and downstream protective devices, as applicable.

4.3 Temporary Overvoltage on Distribution System

The aggregate generation exceeds the minimum load on the 41-1A circuit. This condition can cause a temporary overvoltage (TOV) as a result of:

- Ground Fault Over Voltage ("GFOV") – Should a line-to-ground fault occur on the 41-1A that causes the circuit breaker or line reclosers to open, the distribution system downstream of these devices loses its reference to the system neutral. The Project itself is considered as ineffectively grounded with three phase inverter sources. Thus, the neutral can shift and the inverter may not detect and operate in sufficient time to prevent damaging overvoltage to the system.
- Load Rejection Over Voltage ("LROV") The inverters act as a constant current source which can create a transient overvoltage event when a switch opens and forces all of the inverter current through a fixed load impedance.

The required G&W Viper S recloser will protect the EPS against both load rejection and ground fault overvoltage risk. Additionally, the Company requires all inverter-based projects to meet the settings requirements of the ISO-NE SRD ⁵, dated February 6, 2018.

4.4 Temporary Overvoltage on Transmission Supply

The Company requires that the minimum load to generation ratio on transmission systems be greater than 2 (i.e., total generation excluding direct transfer trip) for all distributed resources without direct transfer trip (DTT) from the operating devices under study. Due to the reverse power flow conditions identified in Section

⁵ https://www.iso-ne.com/static-assets/documents/2018/02/a2_implementation_of_revised_ieee_standard_1547_iso_source_document.pdf

3.4, additional analysis is recommended to evaluate the potential impacts and requirements for the 46 kV supply system.

4.5 Inverter Protection Settings

The (4,933.5 kW) GMP North Troy BESS Project will consist of three (3) 480 V Tesla Megapack inverters rated at 858 kW and three (3) 480 V Tesla Megapack inverters rated at 786.5 kW. The BESS inverter system is compliant with UL 1741 and IEEE 1547 standards. Additionally, the BESS will include sixty-nine (69) Tesla Battery Megapack modules, rated at 43.6 kW and 174.4 kWh for a total capacity of 3,008.4 kW and 12,033.6 kWh, respectively. Under a 2-hour runtime, each battery module may operate up to a maximum of 84.3 kW (5,816.7 kW) with maximum output limited by the inverter system (4,933.5 kW).

The Company requires that all inverter-based DER, including this Project, shall be compliant with IEEE Std. 1547-2018 and be certified per the requirements of UL 1741 SA. Specifically, the voltage and frequency settings, including the abnormal performance capabilities (ride through) and other grid support inverter functions setting, shall comply with the Inverter SRD of the ISO-NE, dated February 6, 2018.

4.5.1 Voltage Setting Requirements / Ride through

For three-phase inverters, the Company requires specific modification on the over voltage condition setting of the inverters. As part of the ISO-NE SRD requirement, the Company requires the inverters to enter “momentary cessation” for over voltage conditions while operating in the “Permissive Operation” mode (Table III: Inverters Voltage Ride through Capability and Operational Requirements of ISO-NE SRD). The Company requires the inverters to enter “Permissive Operation with Momentary Cessation” with a Maximum Response Time of 0.1s. If the proposed inverters are not capable of this Maximum Response time, a Category III inverter shall be used instead, which can comply with this requirement. See IEEE Std. 1547-2018 6.4.2 Table 16.

Inverter responses to under voltages while operating in the “Permissive Operation” mode is specified and can be found in ISO-NE SRD document footnotes A and B.

4.5.2 Frequency Setting Requirements / Ride through

In the event of abnormal frequencies, the Project shall cease to energize the area EPS according to the Table II: Inverter’s Frequency Trip Settings of the ISO-NE SRD document requirements.

4.6 Disconnect Switch

Per IEEE 1547-2018 Section 4.8 Isolation device, when required by the Area EPS operating practices, a readily accessible, lockable, visible break isolation device shall be located between the Area EPS and the PCC. The Company may require a 600 A load break switch (or a recloser) be installed as a sectionalizing device for the line extension to the PCC.

4.7 Unintentional Islanding

Per IEEE 1547-2018 Section 8.1 Unintentional Islanding, for an unintentional island in which the DG energizes a portion of the Area EPS through the PCC, the DG interconnection system shall detect the island and cease to energize the Area EPS within two seconds of the formation of an island.

Due to the size of the Project, the Company may require that a DTT scheme be installed, where the North Troy substation 41-1A circuit recloser communicates with the Company owned recloser at the Project PCC. The installation of DTT, along with Company safety practices, will mitigate any islanding risks.

4.8 Direct Transfer Trip

Due to the size of the proposed Project, a Direct Transfer Tripping scheme may be required. Refer to “Section 4.7 Unintentional Islanding” for details.

4.9 Surge Withstand Capability

The surge withstand capability was not included in the scope of this study.

4.10 Frequency

The (4,933.5 kW) GMP North Troy BESS Project will consist of three (3) 480 V Tesla Megapack inverters rated at 858 kW and three (3) 480 V Tesla Megapack inverters rated at 786.5 kW. The BESS inverter system is compliant with UL 1741 and IEEE 1547 standards. Additionally, the BESS will include sixty-nine (69) Tesla Battery Megapack modules, rated at 43.6 kW and 174.4 kWh for a total capacity of 3,008.4 kW and 12,033.6 kWh, respectively. Under a 2-hour runtime, each battery module may operate up to a maximum of 84.3 kW (5,816.7 kW) with maximum output limited by the inverter system (4,933.5 kW). The ISO-NE SRD requires inverters have settings that will address any abnormal (over and under) frequency conditions. The Project must meet the ISO-NE SRD requirements.

4.11 Synchronizing Devices

This section is only applicable to rotating machines and is not applicable for this study.

4.12 Protection Scheme Assessment

A G&W Viper S recloser will be installed at North Troy substation and act as the PCC recloser. Coordination will be required between the North Troy 41-1A circuit recloser and the Project.

5.0 COST ESTIMATE

A cost estimate will be provided by VEC.

6.0 CONCLUSION

In accordance with the Vermont Public Utility Commission Rule 5.500, the Company has completed a System Impact Study to determine the scope of the required modifications to its EPS to provide the requested interconnection service.

This study has been completed using information provided by the Interconnecting Customer, GMP North Troy BESS Project, who submitted an Interconnection Application Form file dated June 2, 2021.

The Project rating of 4,933.5 kW is a maximum (2-hour) rating. For the purposes of the system impact study, analysis was performed at the maximum rating. The existing North Troy substation transformer has a normal and maximum rating of 3,750 kVA and 4,687 kVA, respectively. As a load, at any time the Project has the capability to overload the substation transformer and the Project must be limited during charging to prevent an overload of the substation transformer.

Based on the results of this analysis, the Project cannot be allowed to interconnect without decreasing the charging rate of the BESS to an acceptable level, defined by VEC policies and procedures within the operating limits and available capacity of the North Troy substation transformer. Transformer loading and phase balancing are not static quantities. Loads vary continually and not necessarily in unison since the type of loads vary greatly (e.g. residential as compared to small commercial such as a convenience store, or industrial loads such as a manufacturing plant). Each load type has its own characteristics and timing pattern throughout the day, week, month, and season. Variation in transformer loading imbalance must be considered with respect to loading a transformer to the maximum nameplate rating. This ensures that there is not the risk of overloading one or more windings of the substation transformer. In this case, the North Troy substation transformer has a maximum nameplate rating of 4,687 kVA (4.69 MVA) which limits each winding to 1,562 kVA per phase (i.e. $4,687/3$), which is the equivalent of 217 A per phase at 7,200 V. The impact of exceeding the maximum nameplate rating for any single winding results in production of excessive heat. Excessive heat is a serious problem because winding insulation will be damaged if allowed to overheat. Degradation of the winding insulation results in loss of life for the transformer as a whole. If a winding is overloaded enough over time, the insulation will fail resulting in a potentially premature failure of the transformer.

The System Impact Study found that the interconnection of the Project should have no adverse impacts on the Area EPS safety and reliability provided the following recommended operating conditions and system modifications to the Company's EPS are implemented:

1. The Company will adjust the time delay settings for the North Troy 41-3A circuit line regulators to address excessive regulator tap change counts.
 - a. Cross Road regulators ("REG-369", "VOLT_89", "VOLT_95") forward and reverse time delay settings must be adjusted from 60 seconds to 75 seconds.
 - b. Armstrong Road regulator ("REG-41451") time delay setting must be adjusted from 40 seconds to 90 seconds.
2. The Company may install a three-phase gang-operated 600 Amp load break switch between the point of interconnection ("POI") and the point of common coupling ("PCC") as an isolation device.
3. The Company will install a three-phase pole-mounted G&W Viper S recloser at the PCC.
4. The BESS will have a three-phase pole mounted primary meter installed upstream of (or on) a new customer riser pole.
5. The Company will upgrade the existing North Troy substation regulators from 167 kVA per phase to 250 kVA per phase, with capability for reverse flow operation.
6. The Company will upgrade approximately 2,700 feet of 1/0 aluminum primary overhead three-phase conductor to 336 ACSR on the 41-1A circuit between North Troy substation and the POI on Veilleux Road.
7. The Company will install approximately 450 feet of 336 ACSR primary overhead three-phase conductor as described for the line extension from Veilleux Road to the Project.

The Interconnecting Customer is responsible for:

1. Procuring and installing all Customer-owned components associated with the Project.
2. All costs associated with system upgrades and rebuilds required to interconnect the Project as described in System Modifications, unless noted as the responsibility of the Company.
3. Providing necessary communications for data reporting.

4. Providing under and over frequency and voltage settings for the inverters prior to the Facilities Study. Inverter settings shall be in compliance with the ISO-NE SRD, IEEE 1547 standard, the NPCC Directory 12 Figure 1 Curve requirements for the Eastern Interconnection, and the Company required specific modification on the inverter over voltage condition setting as noted in Section 4.5.1.
5. Ensuring that the Project complies with ISO-NE SRD, UL 1741 SA, IEEE 1547, and the Vermont Electric Cooperative Interconnection Guidelines at all times.
6. Constraining the BESS inverter(s) to a maximum ramp rate of 7 percent (345 kW) per step change (every four seconds) to mitigate voltage flicker conditions if the Customer chooses to participate in the frequency regulation market.

If the recommended system modifications are made to the VEC North Troy substation, Area EPS, and the Project, the Project should not have a negative impact on system thermal capability and voltage of the Area EPS, under normal steady state and dynamic operating conditions.

If an event occurs with a recorded over-voltage at the PCC exceeding ANSI C84.1 Range A limitations and/or any reported damage of customer equipment, the Company reserves the right to disconnect the Project from the EPS. The developer will be responsible for all associated claims and for mitigation to prevent re-occurrence.

The Company reserves the right to disconnect the Project during times of temporary load transfers or if abnormal conditions develop.

7.0 REVISION HISTORY

Version	Date	Description of Revision
Revision 0	01/12/2022	Final Report

8.0 APPENDIX

8.1 Appendix A – Interconnection Application⁶

Vermont Public Utility Commission Attachment 1 to Rule 5.500

STANDARD APPLICATION FOR INTERCONNECTION OF GENERATION RESOURCES IN
 PARALLEL TO THE ELECTRIC SYSTEM OF: Vermont Electric Cooperative
(Name of Utility)

Shaded area to be completed by Interconnecting Utility

Interconnecting Utility: _____
 Interconnecting Utility's Designated Contact Person: _____
 Interconnecting Utility's Address: _____
 Interconnecting Utility's Fax Number: _____
 Interconnecting Utility's E-Mail Address: _____
 Substation _____ Circuit _____ Distribution Transmission

Preamble and Instructions:

An owner of a generation resource who requests interconnection to a State regulated distribution or transmission facility must submit an application to the Interconnecting Utility. An application is accepted as complete when it provides all applicable information required. There is a **\$300.00** Application fee that must be submitted to the Interconnecting Utility along with the Application.

Section 1. Applicant Information

A. Legal Name of Interconnecting Applicant (or, if an Individual, Individual's Name)

Name: Green Mountain Power Corp.
 Mailing Address: 163 Acorn Lane
 City: Colchester State: Vermont Zip Code: 05446
 Facility Location: VEC property adjacent to VEC North Troy substation
(Facility E-911 address)
 Telephone (Daytime): (802) 770 - 4246 (Alternate): (_____) _____ - _____
 Fax Number: _____ E-Mail Address: Kirk.Shields@GreenMountainPower.com

B. Alternative Contact Information (if different from Applicant)

Contact Name: Craig Kieny, VEC
 Contact Title: Authorized Representative
 Address: 42 Wescom Road
Johnson, VT 05656
 Telephone (Daytime): (802) 598 - 3421 (Alternate): (_____) _____ - _____
 Fax Number: _____ E-Mail Address: CKieny@VermontElectric.coop

C. Will the Generation Resource be used for any of the following:

To supply power to internal loads (other than the station itself)? Yes No
 To participate in the SPEED Standard Offer Program? Yes No

D. For generators installed at locations with existing electric service:

(Local Electric Service Provider*) _____
 (Existing Account Number*) _____

E. Additional Information

Requested Point of Interconnection: VEC North Troy substation
 Interconnection Applicant's requested in-service date: October 1, 2022

⁶ Interconnection application may not reflect most recent design revisions.

Section 2. Generator Qualifications

All data applicable only to the generator facility, NOT the necessary interconnection facilities

Energy source:

Solar Wind Hydro Diesel Natural Gas Fuel Oil Other Battery Storage
(state type)

Type of Generator:

Synchronous Induction Inverter (DC Generator or Solar)

Generator Manufacturer: _____
Generator Model Name & Number: _____
Generator Nameplate Rating: _____ kW (Total if multiple units)
Generator Nameplate kVAR: _____
Applicant or Customer-Site Load: _____ kW (if none, so state)
Typical Reactive Load (if known) _____
Maximum Physical Export Capability Requested: _____ kW

Section 3. Generator Technical Information

a. *Induction or Synchronous Generators (for rotating machines)*

Rated Power Factor Leading: _____
Rated Power Factor Lagging: _____
List of Adjustable Set points for the protective equipment or software: _____
Direct Axis Transient Reactance, X'd: _____ P.U.
Direct Axis Unsaturated Transient Reactance, X'di: _____ P.U.
Direct Axis Subtransient Reactance, X"d: _____ P.U.
Generator Saturation Constant (1.0): _____
Generation Saturation Constant (1.2): _____
Negative Sequence Reactance: _____ P.U.
Zero Sequence Reactance: _____ P.U.
kVA Base: _____
RPM Frequency: _____
*Field Volts _____
*Field Amperes _____
*Motoring Power (kW) _____
*Neutral Grounding Resistor (If Applicable) _____
*I22t or K (Heating Time Constant) _____
*Rotor Resistance _____
*Stator Resistance *Stator Reactance _____
*Rotor Reactance*Magnetizing Reactance _____
*Short Circuit Reactance _____
*Exciting Current _____
*Temperature Rise _____
*Frame Size *Design Letter _____
*Reactive Power Required In Vars (No Load) _____
*Reactive Power Required In Vars (Full Load) _____
*Total Rotating Inertia, H: _____ Per Unit on kVA Base

b. For Wind Turbines

Total Number of turbines to be interconnected pursuant to this application: _____
Height to blade tip : _____ Blade diameter _____
Quantity of Turbines _____ Size (KW) Each _____

c. For Solar or DC sources

Inverter Manufacturer, Model Name & Number : _____
Quantity of Inverters _____ Size KW Each _____
Panel Manufacturer, Model Name & Number: _____
Quantity of panels _____ Size (Watts) Each _____
Inverters are UL1741 listed Yes No
Battery Inverters: Tesla Megapack, 3,000 kW / 4-hours (final equipment selection TBD)

Section 4. Interconnection Equipment Technical Data (for generation over 20 KW)

Will a transformer (GSU) be used between the generator and the
point of interconnection? Yes No
Will the transformer be provided by Interconnection Applicant? Yes No
Is the Transformer three phase? Yes No
Is the Transformer pad mounted or Pole mounted? Pad Pole
Transformer Size: _____ kVA Impedance: _____ % on _____ kVA Base
Battery Transformer Size: (1) 2,000 kVA & (1) 1,000 kVA; Impedance: 5.75% on 3,000 kVA Base

Interconnection Voltage (GSU Data)

Transformer Primary: 12,400 Volts Single Phase Delta Wye Grounded Wye
Transformer Secondary: 480 Volts Single Phase Delta Wye Grounded Wye
Other Transformer information _____

Interconnecting Circuit Breaker (if applicable):

Manufacturer: G&W Type: Viper S Load Rating: 800A Interrupting Rating: 12.5 kA
Trip Speed: 3 cycles

Current Transformer (CT) Data (if applicable):

Manufacturer: _____ Type: _____ Accuracy Class: _____ Ratio: _____

Potential Transformer Data (if applicable):

Manufacturer: _____ Type: _____ Accuracy Class: _____ Ratio: _____

Section 5. General Site Information

- a. Enclose copy of site electrical One-Line Diagrams showing the configuration of all
generating facility equipment, current and potential circuits, and protection and control
schemes.
[Note: This one-line diagram must be signed and stamped by a licensed Professional
Engineer if the generating facility is larger than 150 kW.]
b. Enclose copy of any site documentation that describes and details the operation of the
protection and control schemes.
c. Enclose copies of schematic drawings for all protection and control circuits, relay current
circuits, relay potential circuits, and alarm/monitoring circuits (if applicable).
d. Enclose copy of any site documentation that indicates the precise physical location of the
proposed generating facility (e.g. USGS topographic map or other diagram).

Section 6. Check List: Required Fee and EnclosuresIs an application fee enclosed? YesAre One-Line Diagrams enclosed? YesIs site documentation enclosed? YesAre schematic drawings enclosed? Yes NoAre site maps enclosed? Yes**Section 7. Applicant Signature**

I hereby certify that, to the best of my knowledge, all the information provided in the Interconnection Application is true and correct.

Signature of Applicant: Kirk Shields Date: May 11, 2021

8.5 Appendix E – Steady State Analysis Results

RESULTS PROVIDED AS ATTACHMENTS

Filenames:

NorthTroy_Steady_State_Results_rev1

NorthTroy_Thermal_Results_rev1

8.6 Appendix F – Voltage Flicker Results

RESULTS PROVIDED AS ATTACHMENTS

Filenames:

NorthTroy_Voltage_Flicker_Results

8.7 Appendix G – Short Circuit Results

RESULTS PROVIDED AS ATTACHMENTS

Filenames:

NorthTroy_Short_Circuit_Results

8.8 Appendix H – Long-Term Dynamics Analysis Results

RESULTS PROVIDED AS ATTACHMENTS

Filenames:

NorthTroy_LTD_Results_Final_Summary



CREATE AMAZING.

Burns & McDonnell World Headquarters
9400 Ward Parkway
Kansas City, MO 64114
O 816-333-9400
F 816-333-3690
www.burnsmcd.com