# Feasibility Study for 71G1 Norwich Turnpike Solar LLC 150 kW Project

## Located at 645 Turnpike Road in Norwich, Vermont
## Connected to the GMP 71G1 Circuit at Pole 75, Tag 72938

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This document provides Green Mountain Power's results of its Feasibility analysis for the proposed Project. This Feasibility analysis complies with the Vermont Public Service Board Rule 5.505 (B) Fast Track Screening Criteria. If the proposed Project fails a given criterion, supplemental analysis has been included. To the extent that the supplemental analysis confirms that the Project may have adverse impacts on safety or reliability, further study will be required.

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# SECTION 1

## Project Description and Notes

### Project and Distribution System Description

Norwich Turnpike Solar LLC proposes to install a 150 kW-AC solar project (the Project) at 645 Turnpike Road located in Norwich, Vermont. The Project requests to interconnect to Green Mountain Power (GMP) on the GMP 71G1 distribution circuit in the vicinity of Pole 73, Tag 72938 (the Point of Interconnection or POI). This circuit has a 7.2/12.47 kV grounded-wye configuration and is supplied by the GMP Wilder substation. This substation serves the 71G1, 71G2, and 71G3 circuits via one power transformer. The Project would be located approximately 5.3 circuit miles from the substation. The power transformer at the substation has a base/top nameplate rating of 10/14 MVA whose voltage is regulated via 3-668A bus regulators connected one per phase.

As of May 1st, 2020 the total of installed and proposed distributed generation on the Wilder substation and 71G1 feeder was 3,221 kW and 2,407 kW, respectively, including the Project. All of the above generation resources are inverter based. The existing installed and proposed projects shall be included in the analysis as part of the total or aggregate distributed resources as necessary.

### Substation/Circuit Protection and Loading

| Location | Equipment and Control Type | Maximum Loading (kW)[1] | Minimum Loading (kW)[2] | Generation active & proposed |
|---|---|---|---|---|
| Wilder Substation Transformer | 46 kV 250PM, S&C Fuses | 10,570 1/7/2018 17:45 | 3,170 (30% of peak) | 3,221 |
| 71G1 Circuit | 12.47 kV Cooper VWE Recloser | 5,099 1/1/2018 18:00 | 1,530 (30% of peak) | 2,407 |
| Tag 109723 | 140K Fuse | 2,732 | 820 (30% of peak) | 1,360 |
| Tag 72440 | 100A V4H Hydraulic Recloser | 363 | 109 (30% of peak) | 366 |
| Tag 72488 | 40 K Fuse | 343 | 103 (30% of peak) | 359 |

[1] Circuit level loads are two full years plus current year SCADA, AMI and, MV90 data. The amount of distributed generation on-line at the time of the peak has not been netted out of this figure. Line loads are based on CymDIST load flow calculations.

[2] The minimum daytime loading of the circuit is assumed to be 30% of the peak loading condition due to the "load masking" effects of existing distributed resources

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**Relevant Studies**

There are no relevant studies.

**Existing Materials**

There is an existing CYMDIST unbalanced load flow model.

**Modeling Assumptions:**

- The Project has been studied as being served from its normal feed, in this case the 71G1. The 71G1 might be sourced from other feeders under some conditions. GMP cannot guarantee that the Project will be kept online during these periods of alternate sourcing.
- The modeling for this analysis utilizes the electrical one-line diagram submitted for the Project. The Project proposes to install one 167 kVA 120/240 volt transformer. GMP assumes an impedance of 5.75% for this unit.
- Unless otherwise specified, the power factor for PV projects is assumed to be 100% and the power factor for synchronous and induction generators is assumed to be +/-98%.
- The short circuit contribution from the Project is assumed to be 150% of the Project's AC capacity.
- The minimum daytime loading of the circuit is assumed to be 30% of the circuit peak load, unless otherwise noted.
- The inverter connection type is a single phase, no or low impedance continuous bond to the GMP neutral, also known as an ineffectively grounded connection.
- The inverters shall be required to operate with a total demand distortion (TDD) that complies with IEEE 1547 which references IEEE 519 specifically for harmonic contribution limits.
- Regarding voltage flicker for inverter based PV systems; GMP finds that inrush current is not a significant indicator of sudden voltage drop as it would be for rotating machine generators. To measure the sudden change in voltage, GMP's voltage flicker test for inverter based PV systems shall be used to test the impact of the Project to the distribution circuit. The voltage flicker test will consider the cloud shading effects on the PV modules. The cloud shading effect will consider the output drop of 70% for the aggregate PV systems, i.e. a drop in output from the nameplate ratings to 30% of the nameplate ratings before any voltage regulation can react to the change of voltage. If other PV systems are located within close proximity to the Project being studied, these systems may be included in the voltage flicker test. The percent difference in voltage readings at the Project's POI and at any point in the distribution circuit shall be validated using the GE flicker table. If the cloud shading results in less than a 1.8% change in primary voltage at any point on the distribution circuit, the Project passes the voltage flicker test.
- Further information on GMP assumptions and requirements can be found in the GMP Distributed Resource Interconnection Guidelines at http://www.greenmountainpower.com/upload/photos/426GMP_Interconnection_Guidelines_10.22.15_-_Karly_Carrara.pdf

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# SECTION 2

## Rule 5.505 (B) Criteria and Fast Track Review

Criteria that are not passed will be colored in red**.**

1) **The Interconnection Requester's proposed Generation Resource meets the applicable codes and standards of Section 5.510 of Vermont Public Service Board Rule 5.500 or is certified equipment package under Section 5.511.**

   *The inverters proposed for the Project are twelve (12) Fronius Primo 12.5-1 units. This inverter is compliant with UL1741-SA and IEEE1547.*

   *If another type of inverter is substituted, GMP shall be made aware of this proposed change. Derating of inverters is not considered in the analysis.*

2) **The proposed interconnection point is not at transmission voltage (i.e. not over 23 kV line to line or 11.38 line to neutral).**

   *The Project proposes to interconnect to GMP's distribution circuit which has a voltage level of 7.2/12.47 kV and a four-wire, grounded-wye line configuration. This distribution circuit is not a transmission line.*

3) **For interconnection to a Radial Feeder, the aggregated generation, including the proposed Generation Resource, on the circuit will not exceed 15% of the line section annual peak load as most recently measured at the substation. A line section is that portion of a distribution system connected to a customer bounded by Automatic Disconnect Devices or the end of the distribution line.**

   *The 71G1 circuit peak demand is approximately 5,100 kW. Including the proposed Project, there would be approximately 2,412 kW of existing and proposed DG on this circuit.*
   *2412 / 5100 = 47.3%*

   *The Project fails this criterion.*

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4) **The aggregated generation, including the proposed Generation Resource, on a distribution circuit will not contribute more than 10% to the distribution circuit's maximum fault current at the point on the high voltage (primary) level nearest the proposed interconnection point.**

*The maximum available fault current at the POI, without distributed generation, is calculated as 841 amps (single-phase fault). With all distributed generation on-line, the maximum fault current at the POI increases to 942 amps (single-phase fault). The aggregate generation contributes 10.7 % of the circuit's maximum fault current at the POI.*

*The Project fails this criterion.*

5) **The aggregated generation, including the proposed Generation Resources, on a distribution circuit will not cause any distribution protective devices and equipment (including, but not limited to, substation breakers, fuse cutouts, and line reclosers), or customer equipment on the system to exceed 85% of the short-circuit interrupting capability; nor is the Generation Resource proposed for a circuit that already exceeds 85% of the short-circuit interrupting capability.**

*The maximum fault current contribution from the aggregate generation does not exceed 85% of the short-circuit interrupting capability of any existing protective device or equipment with the exception of one 100A V4H hydraulic line recloser located at Tag 39423. This is a preexisting condition and is not the Project's responsibility to mitigate.*

6) **For interconnection of a proposed single-phase or effectively-grounded three-phase Generation Resource where the primary distribution System is three-phase, four-wire, the Generation Resource will be connected line-to-neutral. For interconnection of a proposed single-phase or three-phase Generation Resource where the primary distribution system is three-phase, three-wire, the Generation Resource will be connected line-to-line.**

*This circuit is a three phase, four wire multi-grounded neutral system, otherwise known as "effectively grounded wye". The proposed project will be connected through a grounded wye-grounded wye transformer. The Project connection is considered as ineffectively grounded with three phase inverter based sources.*

*GMP requires the inverters used for the Project to comply with the "Inverter Source Requirement Document of ISO New England". As part of the ISO-NE SRD requirement, GMP requires the Project 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). GMP requires the inverters to enter "Permissive Operation with Momentary Cessation" with a Maximum Response 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 2018 6.4.2 Table 16. Inverter responses to under voltages while operating in the "Permissive Operation" mode are specified and can be found in ISO-NE SRD document footnotes A and B.*

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7) **Voltage drop due to starting the proposed generator is within acceptable limits, meaning that inrush current, due to starting the proposed Generation Resource up to once per hour, is not greater than 3% of the available fault current. Voltage drop due to starting the proposed Generation Resource more than once per hour meets a tighter inrush-current tolerance, to be determined by the Interconnecting Utility.**

   *The test for voltage drop is discussed above in Section 1 under Modeling Assumptions. For cloud shading, the maximum voltage change is 0.78%.*

8) **For any single Generation Resource, the available utility short circuit current at the Point of Interconnection divided by the rated output current of the Generation Resource is no less than:**
   a) **50 for Generation Resource of less than 100 kW;**
   b) **40 for Generation Resources from 100 kW to less than 500 kW; and**
   c) **20 for Generation Resources equal to or greater than 500 kW.**

   *The maximum available fault current at the POI is calculated as 942 amps line to ground. The rated output current of the Project is 21 amps. The ratio of fault current to Project output current is 45, which is greater than the required 40 for generation resources from 100 kW to less than 500 kW.*

9) **Aggregate generation, including the Generation Resource, on a circuit will not exceed 2 MVA in an area where there are known or posted transient stability limitations to generating units located in the general electrical vicinity (e.g. three or four busses from the point of interconnection).**

   *GMP is not aware of transient stability limitations in this area.*

10) **No System Upgrades, in excess of limited preparation that do not necessitate a Facilities Study, are required to facilitate the interconnection of the Generation Resource.**

   *This criterion cannot be determined by Section 2 alone, see the Supplemental Review (Section 3) and the Conclusion (Section 4).*

11) **For interconnection of the proposed Generation Resource to the load side of spot network protectors, the proposed Generation Resource utilizes inverter-based equipment and aggregate generation, including proposed Generation Resource, will not exceed the smaller of 5% of a spot network's maximum load or 50 kW. Synchronous generators cannot be connected to a secondary network.**

   *There are no spot networks on the GMP system.*

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**12) If the Generation Resource is to be connected on a shared, single-phase secondary, aggregate generation capacity on the shared secondary, including the proposed generation, will not exceed 20 kVA.**

*Not Applicable. The Project is interconnecting to a new service.*

**13) If the Generation Resource is single-phased and is to be interconnected on a center tap neutral of a 240 volts service, its addition will not create an imbalance between the two side of the 240 volt service of more than 20% of the service transformer nameplate.**

*Not Applicable. The Project is connecting line to line (at 240V) aka balanced across the single phase service.*

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# SECTION 3

## Supplemental Review

This section assesses whether failed criteria in Section 2 can be addressed, to ensure safe and reliable interconnection of the Project, using known solutions that would not require a System Impact Study. This supplemental review may also address potential issues that are not covered in the existing fast track criteria, such as islanding, transmission impacts, steady state voltages, and protection.

## Fast Track Summary

The Project did not pass the following criteria:

**Criterion 3** – Temporary Over Voltage (TOV), Protection Device Loading & Coordination, Reverse Flow, Transmission, Voltage, Thermal Loading, Islanding, and Impact to other Utilities.
**Criterion 4** – Protection Device Loading & Coordination
**Criterion 6** – Temporary Over Voltage (TOV)
**Criterion 10** – System Upgrades

Further analysis is described below.

**Protection Device Loading & Coordination: FAIL**

This test considers whether the total generation beyond a protective device can cause enough current flow that would erroneously cause the protective device to operate. Loading results due to generation when considering a worst case with load = 0% and generation at 100% are discussed below.

- Station High Side Fuses – 250PM, S&C power fuse (limit 250A @ 46kVLL) – about 40.4A of reverse flow at 46 kV – **PASS**
- Circuit Recloser (71G1) – 350A phase pick up (limit 350/1.5 = 233A) – 141A of reverse flow – **PASS**
- Line Fuse @ 71G1 Tag 109723 – 140K (140A limit) – 103A of reverse flow – **PASS**
- Line Recloser @ 71G1 Tag 72440 – 100A V4H (100A limit) – 49A of reverse flow – **PASS**
- Line Fuse @ 71G1 Tag 72488 – 40K (40A limit) – 48A of reverse flow – **FAIL**

The existing protective devices on the 71G1 were reviewed to ensure proper coordination with the additional generation. Due to overloading, the 40K line fuse at Tag 72488 must be upgraded to a 50K. This will also ensure proper coordination with the Project's GSU transformer's fuse.

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**Thermal Loading: PASS**

This test considers whether current flow due to generation can result in thermal overloads on equipment including, but not necessarily limited to, overhead conductors, cables, switches, fuses, sectionalizers, reclosers, breakers, regulators, and, reactors. The thermal overload limits are set by the GMP Interconnection Guidelines.

- The highest generation (100% generation, 0% load) results in about 141A of reverse flow on the 71G1 circuit. The smallest conductor in route back to the substation from the Project has an ampacity of 240A (1/0 AAAC, 240A x 90% = 216A limit). This conductor is adequate.
- The substation bus regulators are rated for 668A. At 100% generation and 0% load, there would be about 199A of reverse flow through the substation regulators. The substation regulators are adequate for the reverse flow through the substation.

**Substation and Transmission Capacity**: **PASS**

This test considers whether current flow due to generation can overload the substation transformer, high-side fusing (or breaker) or, the transmission line entering the substation. After review, GMP found no overloads. In the most conservative case of peak generation and no load, aggregate generation can cause 3,221 kVA of reverse flow through the substation transformer.

**System Voltages: PASS**

**Steady state voltage: PASS**

This test considers whether there could be reverse power flow on any regulators, and if so, whether they are capable of proper regulation in the reverse direction. This test also considers whether there are any other steady state voltage issues (i.e. within ANSI limits)

- **Reverse flow controls**: **PASS** – There is one line regulator between the Project and the Wilder Substation (Tag 72436); it is programmed for reverse flow. Currently, the Wilder substation bus regulators are not programmed for reverse flow. The substation regulator controls are in the process of being replaced and programmed for reverse flow; this is not the responsibility of the Project.

- **Voltage levels: PASS** – In the most conservative case of peak generation and no load, simulated steady state voltages exceed ANSI limits. Increasing load to 30%, however, removes the elevated voltages. Loads at 30% of peak are the expected daytime low load levels. As a result, voltages are expected to remain within ANSI limits.

- **Voltage imbalance: PASS** – All sections of the 3ph line serving 3ph or 2ph load are less than 3% before and after the Project.

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**Ground Fault Over Voltage (GFOV): PASS**

- **GFOV on the distribution system**: **PASS**
  The possibility of GFOV on the Distribution System is of concern when there is a reverse of power through a 3 phase protective device. DGFOV can also occur with no reverse flow when the minimum load to generation ration is less than 2. Based on the minimum load on the circuit and the aggregate generation there is reverse flow possible.

  *Due to the interconnection configuration being a single phase transformer, this is not a concern.*

- **GFOV on the sub-transmission**: **PASS**
  This issue has been resolved at the Wilder substation.

- **GFOV beyond a stepdown**: **PASS**
  There are no transformers, stepdown or otherwise, between the Project and the station bus excluding the Project's local GSU.

**Flicker Voltage Fluctuation – PASS**

- **Natural transients** (fast moving cloud cover): **PASS** – This test considers whether voltage fluctuation due to rapidly moving clouds is within limits. This issue was covered under Criterion 7. For cloud shading the maximum change was 0.78%.

- **Generator Reconnection: PASS** – Unless otherwise specified, DG assumed come on line at 5 min after good grid voltage is sensed with an output from 0% to 100%. Elevated voltages were observed during generator reconnection simulation.

  GMP requires the Project's inverters reconnect using a Soft-Start Ramp rate of 2% of maximum current output per second with a modified reconnection time of 6 minutes.

- **Generator Synchronization: PASS** – This generation connects to GMP via an inverter which complies with IEEE & UL standards.

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**Unintentional Islanding: PASS**

GMP considers whether the proposed Project, along with other generation on a circuit, is capable of supporting an unintentional island. To test for the possibility of unintentional islanding, GMP employs the following test:[3]

- First, GMP ensures that the Project's inverters meet applicable standards for anti-islanding. After review, GMP finds that the Project's inverters conform to standards UL1741 and IEEE1547. Accordingly, these inverters would cease operation for a fault on the Affected System.

- Second, GMP checks for the presence of rotating machines on the Affected System. The formation of an unintentional island is considered to be feasible when: 1) an upstream protective device opens; 2) the system downstream from this protective device includes aggregate generation that exceeds 67% of minimum load; and 3) and at least 25% of this aggregate generation is comprised of rotating machines. After review, GMP finds that there are no rotating machines (generators) on this system.

**Impact to Other Utilities: PASS** – No other utility is impacted by this project.

[3] GMP recognizes that, even if a project passes its Fast Track anti-islanding test, it is theoretically possible for an unintentional island to form. Specifically, an unintentional island could form in the very rare instance that: 1) a circuit switching device is opened in a *non-fault* situation; 2) at the moment of switching, downstream of this device, there is a near-perfect match between real power generation and load; and 3) at the moment of switching, downstream of this device, there is a near-perfect match between reactive power generation and load. GMP notes that from a worker and public safety perspective, this situation is analogous to that of a customer's back-up generator inadvertently feeding back onto a part of the distribution system that may otherwise be considered to be de-energized. As a result, and to maximize safety, GMP relies on its existing operational practices to protect the public and its workers. Among these is the practice that, at all times, lines are considered to be energized until a qualified GMP employee is on site to verify that the line has in fact been de-energized and is safe to be approached.

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# SECTION 4

## Conclusion

The Project can move forward without a System Impact and because of the nature of the required upgrades listed below, a Facilities Study is not required.

Unresolved issues from section 3 (Project responsibility):

1) Construction of a short line extension. The poles and conductors need to be accessible by GMP trucks and the exact location of the take-off pole and line extension poles to be determined by site visit with the Distribution Designer. The Project is responsible for this cost.

2) Upgrading the line fuse at Tag 72488 from a 40K to a 50K.

3) GMP requires the Project's inverters reconnect using a Soft-Start Ramp rate of 2% of maximum current output per second. A modified reconnection time of 6 minutes is required.

4) GMP requires the inverters used for the Project to comply with the "Inverter Source Requirement Document of ISO New England". As part of the ISO-NE SRD requirement, GMP requires the Project 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). GMP requires the inverters to enter "Permissive Operation with Momentary Cessation" with a Maximum Response 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 2018 6.4.2 Table 16. Inverter responses to under voltages while operating in the "Permissive Operation" mode are specified and can be found in ISO-NE SRD document footnotes A and B.

Upgrades not resulting from the Project but are required before interconnection (GMP or other project's responsibility):

1) None

It should be noted that the lead time for certain materials can be as long as 26 weeks. It must also be recognized that there are construction projects that could impact the time frame for a new project's ability to come on line.