GREEN MOUNTAIN POWER
Generating Possibilities Together

January 26, 2021

Putney Green Acres Solar LLC
15 Railroad Row
White River Junction, VT 05001

RE: Interconnection of Putney Green Acres Solar LLC at River Road in Putney, VT

To Whom It May Concern,

Green Mountain Power (GMP) is providing this letter pursuant to VT PUC Rule 5.107(C)(10)(a) which stipulates that ground mounted photovoltaic net metered generation systems in excess of 150 kW must

> *"…file as part of the application a letter from the electric company stating that the proposed net-metering system may be safely interconnected with the company's distribution grid without having an adverse impact on system stability or reliability. The letter must also describe all improvements to the grid necessary to interconnect the net-metering system."*

The 500 kW Putney Green Acres Solar LLC photovoltaic generation project proposed for construction at River Road in Putney, VT may be interconnected with the GMP distribution system without adverse impact on system stability and reliability provided that the requirements outlined in the December 23, 2020 GMP Feasibility Study are met.

Sincerely,

Michael Butler
Distributed Generation Coordinator
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Rutland, VT 05701
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Enclosure:
GMP Feasibility Study

Feasibility Study for Putney Green Acres Solar, LLC 500 kW project

Located on South River Rd. Putney, Vermont
Connected to the GMP 69K2 Circuit near Tag 20505

Randy Schramm

12/23/2020

Document Revision No.	Date	Author	Comments
0	11/20/2020	Randy Schramm	Creation of the document

This document provides Green Mountain Power's results of its Feasibility Study for the proposed Project. This Feasibility Study complies with the Vermont Public Service Board Rule 5.505 (B) Fast Track Screening Criteria. If the proposed Project fails a given criterion, further analysis has been included. To the extent that the Feasibility Study 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

Putney Green Acres, LLC proposes to install a 500 kW-AC/ 745.2 kW-DC solar project (the Project) in Putney, Vermont. The Project requests to interconnect to Green Mountain Power (GMP) on the GMP 69K2 distribution circuit in the vicinity of Tag 20505 (the Point of Interconnection or POI). This circuit has a 4.8/8.32 kV grounded-wye configuration and is supplied by the GMP #69 Putney substation. This substation serves the 69K2, 69K1 and 69K3 circuits. The Project would be located approximately 1.41 circuit miles from the substation (after a 3 phase extension). The power transformer at the substation has a base/top nameplate rating of 10,000/14,000 kVA and the voltage is regulated via 3-648 amp regulators connected to the distribution bus.

As of September 28, 2020 the total of installed and proposed distributed generation on the 69K2 is 1,095.49 kW including this Project, 1,708.41 kW on the 69K1 circuit and 0 kW on the 69K3 circuit.

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 Date & Time	Maximum Loading (kW)[1]	Minimum Loading Date & Time	Minimum Loading (kW)[2]	Total Generation proposed & connected
Putney Substation (3 circuits)	69 kV 150 PM Fuses	11/04/2018 1:30	7,243	30% of peak	2,173	2,803.90 kW
69K2	8.32 kV electronic recloser	07/20/2019 12:45	1,539	30% of peak	462	1,095.49 kW (including this 500 kW project)
69K1	8.32 kV electronic recloser	01/04/2018 18:00	3,572	30% of peak	1,072	1,708.41 kW
69K3	8.32 kV electronic recloser	11/04/2018 1:30	2,984	30% of peak	895	0 kW
Tag 528347	25 K fuse	07/20/2019 12:45	34	30% of peak	10	500 kW (including this 500 kW project)

[1] Circuit level loads are from January 1, 2018 to May 6, 2020 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. Further analysis on minimum daytime loading, if required, would be examined as part of the Section 3 Supplemental Analysis or as part of a System Impact Study.

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Relevant Studies

There are no outstanding relevant studies.

Existing Materials

There is an existing CYMDIST unbalanced loadflow model.

Modeling Assumptions:

- This Project has been studied as being served from its normal feed, in this case the Putney 69K2. There are alternate supplies to this location and in the event of a resupply situation the Project *may* need to be taken off line for the duration of the resupply. The developer can request additional analysis to assure the proposed project can be fed from the alternate supplies with no adverse impacts. The developer would bear the cost of any additional studies.
- The modeling for this analysis utilizes the electrical one-line diagram submitted for the Project. The Project proposes that GMP install 3-167 KVA 12470GRDY/7200-480Y/277 volt pole mounted transformers with an assumed impedance of 3 %. 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 three phase, no or low impedance continuous bond to the GMP neutral, also known as an ineffectively grounded or three-wire 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 PV system being studied (if another PV system(s) is located within close proximity of the Project being studied, this system(s) may be included in the voltage flicker test), 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. 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.**

   Inverters proposed are Chint Power Systems inverters CPS SCA50KTL-DO/US-480 V2.0 (10@50 kW). These are compliant with UL 1741 SA and IEEE 1547.

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

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 69K2 distribution circuit, which has a voltage level of 4.8/8.32 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 69K2 circuit peak demand is approximately 1,539 kW. Including the proposed Project, there would be approximately 1,095.49 kW of existing and proposed DG on this circuit 1,095 kW/1,539 kW=71.15%.

   The project fails this criterion.

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 2,317 amps (three-phase fault) and 1,711 amps (single-phase fault). With all distributed generation on-line, the maximum fault current at the POI increases to 2,378 amps (three-phase fault) and 1,726 amps (single-phase fault). The aggregate generation contributes 2.63 % of the circuit's maximum fault current at the POI.

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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 cause the fault current to go over 85% of the short-circuit interrupting capability of the existing line protective devices and equipment.

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 "grounded wye". The proposed project will be connected through a grounded wye-grounded wye transformer. This Project connection is considered as ineffectively grounded with three phase inverter based sources.

GMP requires the inverters used for this 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.

This Project will also be required to have a PCC recloser due to possible reverse flow through a 3 phase protective device (the substation recloser).

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 1.0 %, which is acceptable.

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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 1,711 amps line to ground. The rated output current of the Project is 34.7 amps per phase. The ratio of fault current to Project output current is 49.31, which is greater than the required 20 for generation resources equal or greater 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.**

    See supplemental review to this Feasibility Study (section 3) and 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.

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 three-phase.

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 three-phase.

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SECTION 3

Supplemental Review

This section assesses whether failed criteria identified 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 6 – TOV
Criterion 10 – System upgrades

Further analysis is described below.

Protection Device Loading & Coordination: PASS

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. This test considers a worst-case scenario of no load with generation at 100%. The results are presented below:

- Station high side fuses (serves 69K2, 69K1 and 69K3) – 150a pf power fuse (limit 150a @ 69kVLL) – about 23 amps of reverse flow at 69 kV (see station capacity), therefore no problem.
- Station recloser (69K2) – 420a phase pick up (limit 420/1.5 = 280a) – 76 amps of reverse flow, therefore no problem.
- Line fuse- Tag 20464 – existing 25 K will be 3 new 80 amp Type K - 35 amps of reverse flow, therefore no problem.

The single phase fuse will be changed to a set of 3 - 80 K fuses at tag 20464.

The existing and new protective devices on the 69K2 were reviewed with the additional generation. After the above changes the addition of the Project does not cause a mis-coordination.

Thermal Loading: PASS

This test considers whether current flow on a circuit 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. After review, GMP found no thermal overload issues resulting from this interconnection.

The maximum amps flowing due to generation (0% load and 100% generation) on the 69K2 circuit is 76 amps. There is no conductor from the Project to the substation with an ampacity rating less than this value.

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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. When all feeders connected to the station are considered, a total of 2.804 MW of reverse flow would occur if the load was at 0% while the generation was at 100%. The top nameplate rating of substation transformer is 14 MVA so this amount of generation is not a concern in terms of capacity. After review, GMP found no overloads.

System Voltages: **FAIL**

Steady state voltage: **Fail**

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. voltages that fall outside of the limits specified by ANSI C84.1)

- **Reverse flow controls**: Pass- There is one set of regulators between the Project and the substation transformer. The substation regulators. These regulators will need to be set for co-generation operation.
- **Voltage levels:** Fail - In the conservative case of peak generation and minimal load, steady state voltages are found to be within ANSI limits. There are instances the voltage may go above the ANSI limits unrelated to this project. There are 3 line regulators, one on each phase on the 69K2 circuit that will require a settings change.
- **Voltage imbalance:** Pass – All sections of the three-phase line serving three-phase or two-phase load are less than 3% before & after this Project.

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

- **GFOV on the distribution system**: **Fail**

  The possibility of GFOV on the distribution system (DGFOV) is of concern when there is a reverse of power through a three-phase protective device. DGFOV can also occur with no reverse flow when the minimum load to generation ratio is less than 2. Based on the actual minimum load on the circuit and the aggregate generation the ratio of 2 is not met and there is also the possibility of reverse flow through the substation breaker.

  This Project is required to meet the requirements of Criterion 6 as well as install a PCC recloser as referenced in Criterion 6 which will also address the concerns regarding the possibility of DGFOV.

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- **GFOV on the Subtransmission**: **Pass**

  The possibility of ground fault over voltage on the transmission supply (TGFOV) is a concern when there is a reverse flow of power onto the subtransmission system that cannot be dampened during line-to-ground faults on the subtransmission. This GFOV can also occur with no reverse flow when the minimum load to generation ratio, for the section of the transmission system at issue is less than 2.

  The measured minimum daytime[3] load to total generation ratio on the Putney substation is less than 2. This was referred to National Grid (the transmission system owner) for review. National Grid has reported that their review shows there is no study required.

- **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. Voltage fluctuation due to rapidly moving clouds is within limits. GMP does not believe it is necessary to do the IEEE 1453 flicker calculation because if it meets Criterion 7 with the more conservative IEEE Standard 141-1993 calculation (GE flicker curve), it would have to meet the IEEE 1453 calculation. GMP has made the decision to continue its use of the GE flicker curve because it is more conservative and efficient to apply.

- **Generator Reconnection: PASS**

  Traditionally, inverter-based distributed generation is assumed to reconnect to a system, following the operation of a protective device that caused the generation to go off-line, five minutes after healthy grid voltage is detected. GMP is concerned however that simultaneous reconnection of substantial amounts of distributed generation can result in temporary high voltages and excessive voltage regulator operation. To limit these impacts, distributed generation connected to a given substation should 1) reconnect in a staggered manner that, with an appropriate buffer, avoids the five minute default timing of inverters that have previously been installed on the system and 2) reconnect via a graduated output ramp-up.

  This Project is required to comply with the ISO- NE SRD for gradual ramp rate of 2% of maximum current output per second with a modified reconnection time of 6.5 minutes from the default reconnection time following the detection of healthy voltage.

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

[3] Daytime 9AM-4PM.

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Unintentional Islanding: PASS

GMP considers whether the proposed Project, along with other distributed energy resources (DER) on the Affected System, is capable of supporting an unintentional island. To test for the possibility of unintentional islanding, GMP employs the following test:[4]

- 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 UL 1741 and IEEE 1547.

- Second, GMP considers the size of the Project, and for each line segment upstream of the Project, considers the aggregate amount of DER on that line segment, the percentage of this DER that is rotating machine or non-certified, and the line segment's minimum load.
    - After review, GMP finds no significant risk of unintentional islanding.

Impact to Other Utilities: PASS

The project was referred to National Grid and they concluded there is no further review or study required.

[4] GMP recognizes that, even if a project passes its 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 GMP System Impact Study. In addition because of the fairly routine nature of the required distribution upgrades listed below, a Facilities Study will not be required.

Unresolved issues from section 3 (Project responsibility):

1) Upgrade approximately 5,141' of single phase line to 3 phase 1/0 6201 AAAC poly line from tag 20472 to tag 20505.

2) Construction of a 3 phase line extension (portion underground below the highway) of approximately 1,700' and the installation of 3- 167 KVA transformer's. This Project will also be required to install a PCC recloser complete with SCADA communications. The poles, conductors and transformers 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. The Project will also be responsible for the recurring monthly cost of the SCADA communications to the PCC recloser.

3) Adjust the substation regulators to enable co-generation settings.

4) GFOV on the distribution- GMP requires that the site comply with Criterion 6. GMP also requires the inverters used for this 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.

5) Adjust the generator reconnection time from the default setting to 6.5 minutes and then apply the ISO-NE SRD gradual ramp rate of 2% of maximum current output per second.

6) The Project is required to provide a Notice to Proceed letter with the appropriate GMP Distribution Designer when the Project is physically ready for interconnection to Green Mountain Power's Electrical system.

The cost of measures 1-6 above are the responsibility of the Project. These costs will be developed per the applicable GMP tariff.

Upgrades not resulting from the Project but required before interconnection (Prior project or GMP responsibility):

1) Adjust the single phase line regulator settings for co-generation at tag 20700, 20845 and 22101.