RRS-SC-5

VILLAGE OF ENOSBURG FALLS
ELECTRIC LIGHT DEPARTMENT

INTERCONNECTION & SYSTEM IMPACT STUDY

ENCORE RENEWABLE ENERGY
3.201 MWDC / 2.375 MWAC
SOLAR ARRAY

REVISION 0 – FINAL

MAY 17, 2023

PLM

ELECTRIC POWER ENGINEERING

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Revision History:

Rev 0 May 17, 2023 – Final (no changes per client review)

VILLAGE OF ENOSBURG FALLS ELECTRIC LIGHT DEPARTMENT
INTERCONNECTION & SYSTEM IMPACT STUDY
ECNORE RENEWABLE ENERGY 2.375 MWAC SOLAR ARRAY

1.0 EXECUTIVE SUMMARY

Encore Renewable Energy proposes to install a 3.201 MWDC / 2.375 MWAC solar array connected to the Village of Enosburg Falls Electric Light Department (VOEF) medium voltage distribution system. The project is located on Reservoir Rd near an existing 12.47 kV overhead line owned by VOEF. A system impact study was performed and the following is noted:

- From a thermal standpoint, the interconnecting VOEF 12.47 kV distribution system is unable to accommodate the solar generation facility as presently arranged. The following items within the series circuit path between the interconnecting substation and the project site are limiting:
    a. 3-333 kVA step down transformers to serve 2.4 kV delta load in the center of the village.
    b. 3-100 kVA step up transformers to serve 12.47 kV load on Water Tower Rd beyond the village center.
    c. Multiple main line 2.4 kV fuses rated for less than the project's predicted output.
    d. #6 AWG copper overhead line conductor.
- Under steady-state conditions, voltage on the VOEF 12.47 kV system as presently arranged will not be within acceptable ANSI C84.1 limits. Severe voltage rise would occur when the facility is exporting power and connected to the system as presently arranged.
- Based on predicted hourly solar output from PVWatts and the previous five years of hourly system load data, when the solar is operating during periods of light load, there is a chance the proposed PV facility will cause a backfeed beyond the limits of the VOEF system.
- Voltage regulators at the VOEF 46-12.47GRDY/7.2 kV substation do not and should not use line drop compensation. Line drop compensation causes the voltage regulators to actively adjust output voltage based on load levels. With distributed energy resources in operation, changes in load could occur often. Frequent and large changes to load would be detrimental to regulator wear and tear due to increased tap operations. Further, customer voltage performance may suffer. A simple setting that fixes the bus voltage 2-3% above nominal values at the substation, regardless of load, is preferred.
- VOEF load and total system generation levels at times may be closely matched on the interconnecting substation and on the interconnecting 12.47 kV feeder. Sustaining an unintentional island is more likely under these conditions.
- With the interconnection of the proposed PV facility the ratio of total installed generation on the VOEF Substation to total system load will exceed 2:3 at times. Additional, review is required to identify whether 3V0 / 59N protection will be required.
- Neither a light daytime load case or a heavy load case (with PV offline) causes the voltage regulators at the VOEF substation to reach the upper or lower end of their regulation range (+/- 10%).

The following recommendations are noted:

- Verify that the 1G5 substation PCD 2000 relay is programmed according to Table 4.3-1
- Program the new line recloser on Water Tower Rd (see system improvement recommendations below) according to Table 4.3-2
- Program the VOEF PCC recloser according to Table 4.3-3.
- Program the solar inverters with voltage and frequency protection according to Table 4.4-1.
- Program the inverter to provide volt-var support in accordance with Table 4.1.2-1
- Verify with the transmission company (VEC) that their meter is capable of bi-directional operation. Note they may have additional requirements to accommodate this installation as an affected system.
- VOEF Required System Improvements
    - Common Items (Budgetary Cost Estimate = $1,746,000):
        - Reconductor the 1/0 AL, #2CU, and #6CU from the end of the existing 4/0 AAC spacer cable on Main St to the Reservoir Rd tap off Water Tower Rd. The smaller wire should all be replaced with VOEF's standard 4/0 main line conductor.
        - Reconductor on Reservoir Rd to the project site with VOEF's standard 1/0 AL side tap wire size.
        - Install solid blades in lieu of the existing 25A K-link fuses at the tap to Reservoir Rd from Water Tower Rd.
        - A recloser should be installed at the tap to Water Tower Rd from Elm St to maintain existing levels of sectionalization and limit exposure to remote line faults on Reservoir Rd for customers in the village center.
        - The 2.4kV, 300 kVAR capacitor bank on Water Tower Rd should be relocated to Orchard St to maintain existing levels of reactive power compensation.
        - Review 46 kV equipment ratings and insulation coordination to determine if mitigation is required. For this study VOEF provided PLM with a simplified, hand sketch of the major substation components and their respective ratings. A detailed review of equipment ratings, BIL, etc. is not possible with the level of detail. Additional work is required to gather the necessary information and determine the optimal method for mitigating these concerns. If mitigation is required one of the following is recommended:
            - Install voltage sensing on the 46 kV incoming transmission line and a 59N relay. Wire the relay to trip the 12.47 kV circuit reclosers inside the VOEF substation.
            - VOEF's most recent integrated resource plan (IRP) filing indicates that when the VOEF substation was rebuilt in 2003 fiber communications was added. It is not clear from the IRP what the fiber communications is used for and where it is run to beyond the VOEF substation itself. If fiber communications exists between the VOEF substation and remote transmission substations, implementing a transfer trip scheme to open the 12.47 kV circuit reclosers for a loss of the transmission supply may be

less expensive to implement than adding local voltage sensing and the associated relaying equipment.

- Additional System Improvements – Option 1 (Budgetary Cost Estimate = $310,000):
  - Convert the existing 2.4 kV delta overhead line on Main St from the Jolley store to the three 100 kVA step-up transformers located near the intersection of the 115 kV transmission line and Water Tower Rd (address is 209 Water Tower Rd). This area to be converted includes the 2.4 kV side tap on VT-108 N.
  - Transfer the converted 12.47 kV equipment to the 1G5, Main St feeder. The 2.4 kV on Orchard Street will remain. The existing 2.4 kV line from Orchard St onto Main St should be cut and dead-ended before the tap to Main St.
- Additional System Improvements – Option 2 (Budgetary Cost Estimate = $226,500):
  - Reconductor the overhead line on Depot St with VOEF's standard 4/0 mainline conductor and replace fused cutouts at the tap to Depot St with solid blades.
  - Convert the existing 2.4 kV delta overhead line from the intersection of Elm St and Pleasant St to the three 100 kVA step-up transformers located near the intersection of the 115 kV transmission line and Water Tower Rd (address is 209 Water Tower Rd). This area to be converted includes the 2.4 kV side tap on VT-108 N.
  - Transfer the overhead line beyond the intersection of Elm St and Pleasant St to the 1G5 feeder

- To ascertain greater cost-certainty for estimates and finalize the scope of system improvements a Facilities Study is recommended should the developer wish to proceed with the interconnection.

2.0 PROJECT DESCRIPTION

Encore Renewable Energy proposes to install a 3.201 MWDC / 2.375 MWAC solar array on Reservoir Rd in the vicinity of an existing 12.47kV overhead line.

The developer has proposed the following equipment as shown in Exhibit 2:

- Utility (VOEF to own everything up to the customer side of the utility primary metering pole):
  - A new line extension from the existing overhead to the project's point of interconnection.
  - A new pole with 15 kV class utility recloser.
  - A new pole with utility primary revenue metering.
- Developer
  - A new pole with 600A, gang operated air break switch (customer main disconnect)
  - A new pole with customer primary check metering.
  - A new pole with three (3) 300A solid blade switches and primary power cable riser.
  - Underground cable and conduit from the riser pole to a padmounted generator step up transformer.
  - A 2,500kVA, loop feed, padmounted, 12,470GRDY/7,200-600GRDY/346V generator step-up transformer with nominal impedance of 5.75% per IEEE C57.12.34.
  - 3000A, 600V, 3-phase, 60Hz, AC switchboard
  - Nineteen (19) Chint Power Systems model CPS-SCH125KTL-DO/US-600 125 kW inverters.
  - 5,298 PV modules, ET solar part number ET-M772BH540TW

As a result of the analysis contained herein, the additional scope below is required to interconnect the proposed solar generation.

- Common Items:
  - Reconductor the 1/0 AL, #2CU, and #6CU from the end of the existing 4/0 AAC spacer cable on Main St to the Reservoir Rd tap off Water Tower Rd. The smaller wire should all be replaced with VOEF's standard 4/0 main line conductor.
  - Reconductor on Reservoir Rd to the project site with VOEF's standard 1/0 AL side tap wire size.
  - Install solid blades in lieu of the existing 25A K-link fuses at the tap to Reservoir Rd from Water Tower Rd.
  - A recloser should be installed at the tap to Water Tower Rd from Elm St to maintain existing levels of sectionalization and limit exposure to remote line faults on Reservoir Rd for customers in the village center.
  - The 2.4kV, 300 kVAR capacitor bank on Water Tower Rd should be relocated to Orchard St to maintain existing levels of reactive power compensation.
  - Review 46 kV equipment ratings and insulation coordination to determine if mitigation is required for overvoltage due to neutral shift / transient ground fault overvoltage. For this

study VOEF provided PLM with a simplified, hand sketch of the major substation components and their respective ratings. A detailed review of equipment ratings, BIL, etc. is not possible with the level of detail. Additional work is required to gather the necessary information and determine the optimal method for mitigating these concerns. If mitigation is required one of the following is recommended:

  - Install voltage sensing on the 46 kV incoming transmission line and a 59N relay. Wire the relay to trip the 12.47 kV circuit reclosers inside the VOEF substation.

  - VOEF's most recent integrated resource plan (IRP) filing indicates that when the VOEF substation was rebuilt in 2003 fiber communications was added. It is not clear from the IRP what the fiber communications is used for and where it is run to beyond the VOEF substation itself. If fiber communications exists between the VOEF substation and remote transmission substations, implementing a transfer trip scheme to open the 12.47 kV circuit reclosers for a loss of the transmission supply may be less expensive to implement

- Additional System Improvements - Option 1:

  - Convert the existing 2.4 kV delta overhead line on Main St from the Jolley store to the three 100 kVA step-up transformers located near the intersection of the 115 kV transmission line and Water Tower Rd (address is 209 Water Tower Rd). This area to be converted includes the 2.4 kV side tap on VT-108 N.

  - Transfer the converted 12.47 kV equipment to the 1G5, Main St feeder. The 2.4 kV on Orchard Street will remain. The existing 2.4 kV line from Orchard St onto Main St should be cut and dead-ended before the tap to Main St.

- Additional System Improvements – Option 2:

  - Reconductor the overhead line on Depot St with VOEF's standard 4/0 mainline conductor and replace fused cutouts at the tap to Depot St with solid blades.

  - Convert the existing 2.4 kV delta overhead line from the intersection of Elm St and Pleasant St to the three 100 kVA step-up transformers located near the intersection of the 115 kV transmission line and Water Tower Rd (address is 209 Water Tower Rd). This area to be converted includes the 2.4 kV side tap on VT-108 N.

  - Transfer the overhead line beyond the intersection of Elm St and Pleasant St to the 1G5 feeder.

    - than adding local voltage sensing and the associated relaying equipment.

Figure 1 – Existing System

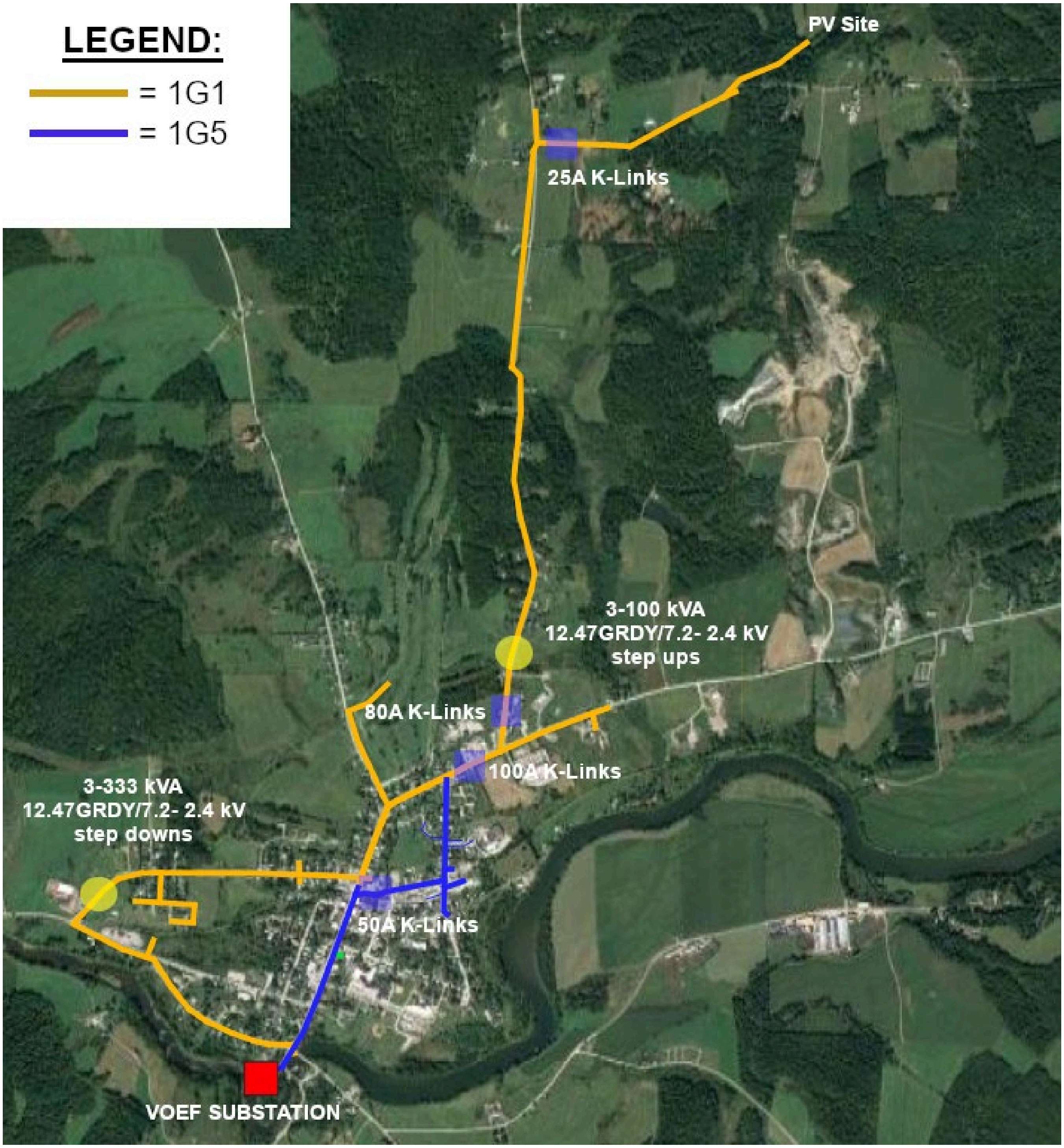


Figure 2 – Option 1

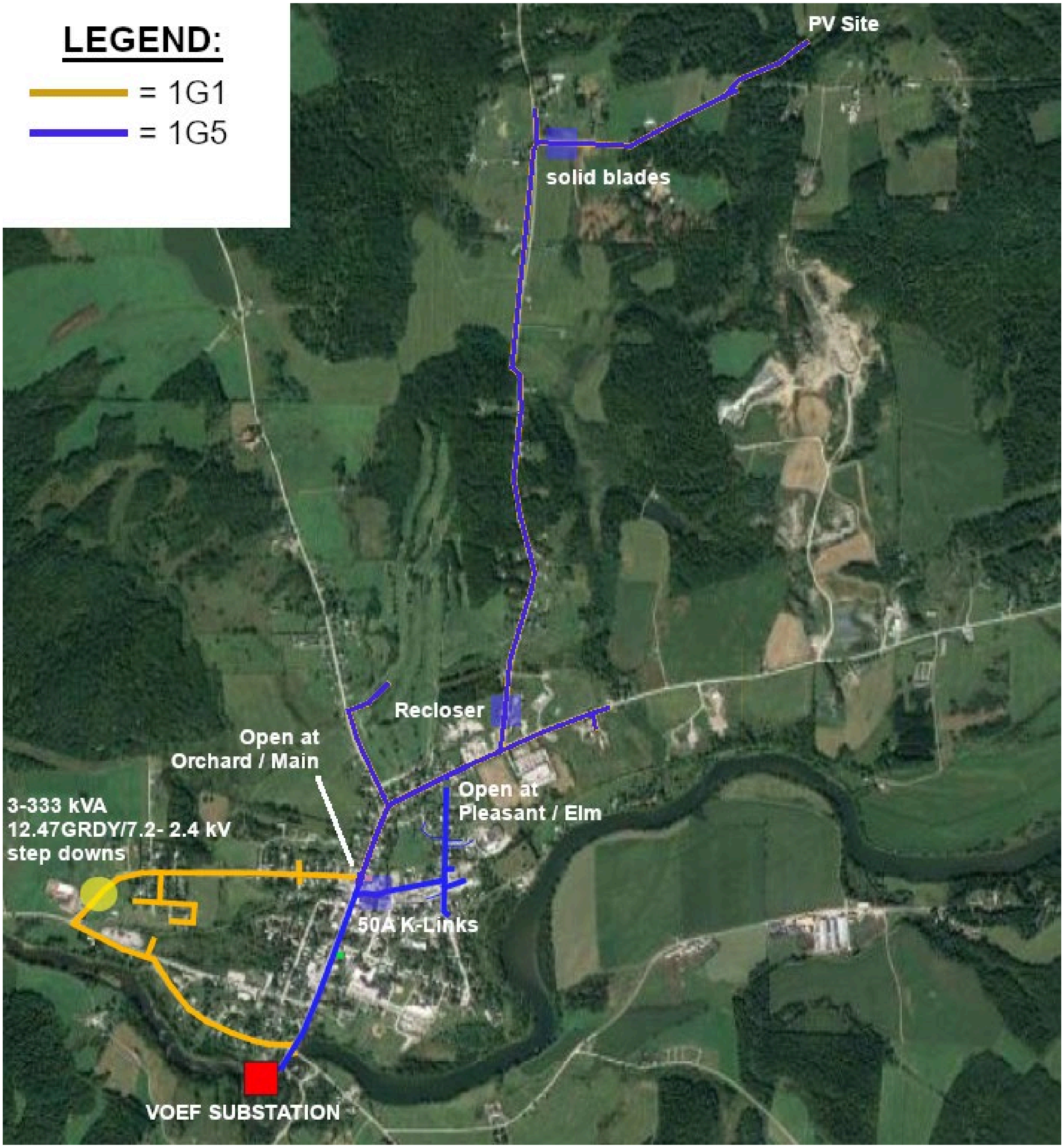
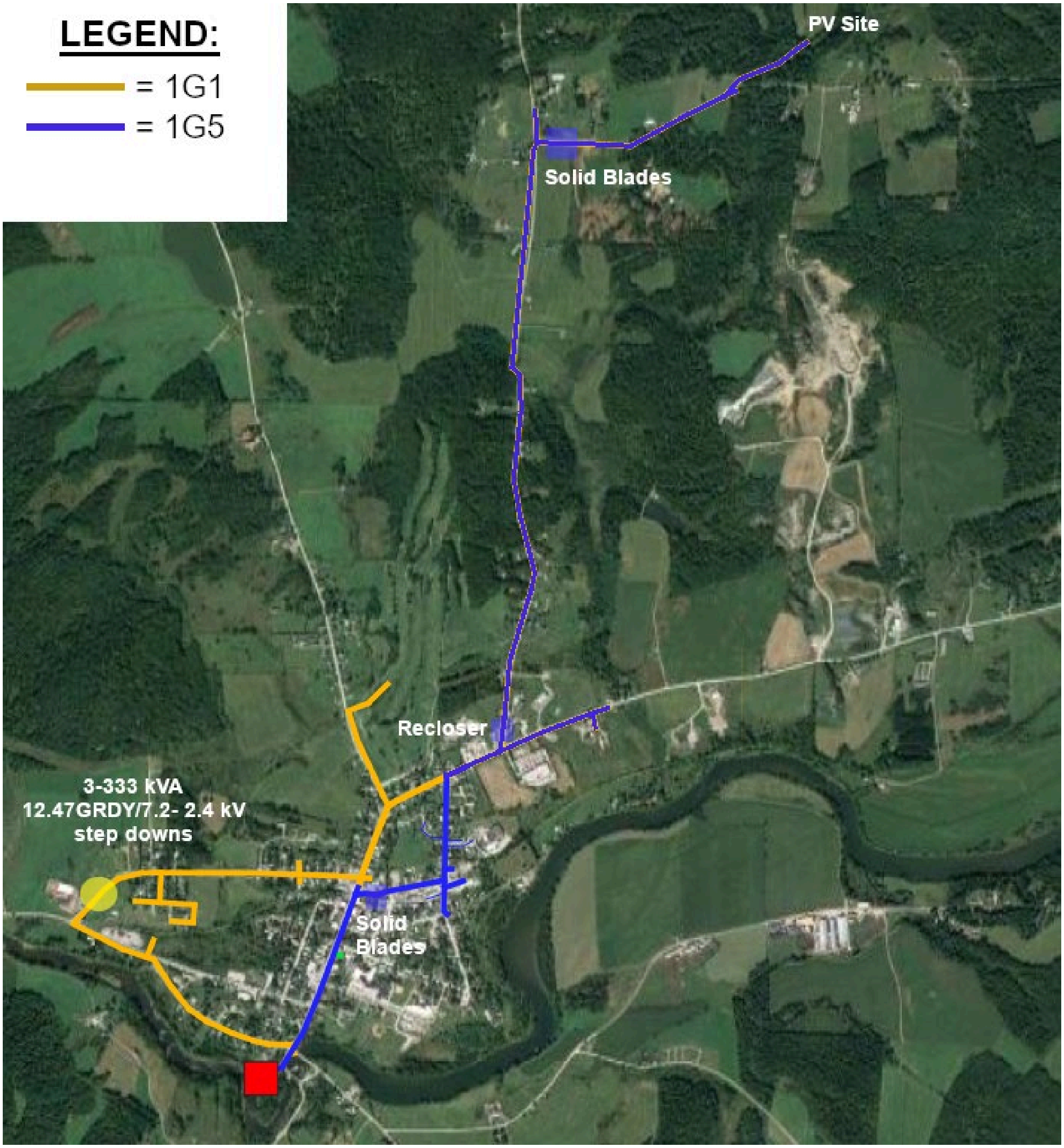


Figure 3 – Option 2



3.0 VILLAGE OF ENOSBURG FALLS ELECTRIC LIGHT DEPARTMENT SYSTEM DESCRIPTION

The Village of Enosburg Falls Electric Light Department (VOEF) is a municipal utility providing service to the Village of Enosburg Falls and portions of six surrounding towns: Bakersfield, Berkshire, Enosburgh, Fairfield, Franklin, and Sheldon.

VOEF's distribution system presently serves approximately 1,740 customers in a 65 square mile service territory. The system is comprised of 102.1 miles of line at 12.47 kV and 3.53 miles of line at 2.4 kV for a total of 105.63 miles of distribution level line. The system is radially supplied at 46 kV from VEC. VOEF owns the radial 1-mile 46 kV sub-transmission line from where it is tapped between Highgate and Newport and the VOEF distribution substation.

The VOEF substation was rebuilt in 2003 in conjunction with VELCO. It consists of a single 46-12.47GRDY/7.2 kV, 55°C/65°C rise, 7.5/8.4 MVA power transformer protected by primary side fuses. On the secondary side of the power transformer, 12.47 kV bus voltage is controlled using 3-250 kVA step-type voltage regulators. Five 12.47 kV feeder positions exist with the following circuit designations:

1G1 – St Albans St

1G2 – Cheese Plant

1G3 – Sampsonville / West Enosburg

1G4 – Hydro Generation

1G5 – Main St

All feeders are protected by circuit reclosers with ABB PCD 2000 controllers.

4.0 ANALYSIS

This review used IEEE Standard 1547, "Standard for Interconnecting Distributed Resources with Electric Power Systems" (2018) and IEEE Standard 1547.7-2013, "Guide for Conducting Distribution Impact Studies for Distributed Resource Interconnection." An analytical model containing the proposed solar, VOEF substation, 1G1 feeder, and 1G5 feeder was built in ASPEN DistriView (v11.4) and was used to simulate the load flow and short circuit effects the proposed solar facility may have on the VOEF system.

4.1 LOAD FLOW ANALYSIS

Hourly VOEF purchased power data from 2017 through 2021 was used to study the anticipated impact of the proposed solar generation under peak and light load conditions as highlighted in the table below.

Table 4.1-1
VOEF System Demand Pre- and Post-Facility

Demand without Proposed PV		Demand with Proposed PV[1]	
Minimum	Maximum	Minimum[1]	Maximum[2]
1,636 kW	4,937 kW	-227 kW	4,880 kW

1. Calculated using NREL's PVWatts tool.

Maximum VOEF system demand with the proposed solar is predicted to decrease by a small amount. The minimum load however is predicted to be significantly lower and in fact be negative (-277 kW).

The proposed PV facility would cause multiple devices in the series path back to the substation to have line current in excess of rated capacity. Limiting elements include:

1. 2400 V conductors (2375 kW at 2400V is equal to approximately 571A of current).
2. 2400V to 12.47 kV step up and step down transformers.
3. 2400V 100A and 80A fuse installations.
4. 12.47 kV 25A fused cutouts.
5. 12.47 kV #6 CU bare overhead line.

System improvements required in Section 2 alleviate these capacity concerns. Analysis performed in the subsequent sections of this report all presume the required system improvements have been implemented.

During light-load conditions, the addition of the proposed PV may cause backfeeding into the Enosburg Falls Substation and onto the 46 kV system. We suspect that metering and is capable of bidirectional operation. (VOEF should confirm with the transmission provider, VEC). From a protection standpoint, the 12.47 kV relays at the VOEF Substation have no reverse power or directional overcurrent elements. In addition, the 46 kV protection is provided by simple fuses which are non-sensitive to minor reverse power flows. Existing substation equipment can accommodate backfeeding from a capacity standpoint.

Review of the commercial aspect of reverse power flow scenarios is beyond the scope of this technical review. However, to give a sense of the likelihood, the table below lists the approximate number of hours per year of potential backfeeding based on five years of historical hourly system load data and estimated hourly PV system output as calculated from NREL’s PVWatts tool.

Table 4.1-2

Net power flow direction	Annual Hours of Potential Backfeeding
Into the VOEF system	2.8 hours per year (0.03%)
Out of the VOEF system	8757.2 hours per year (99.97%)

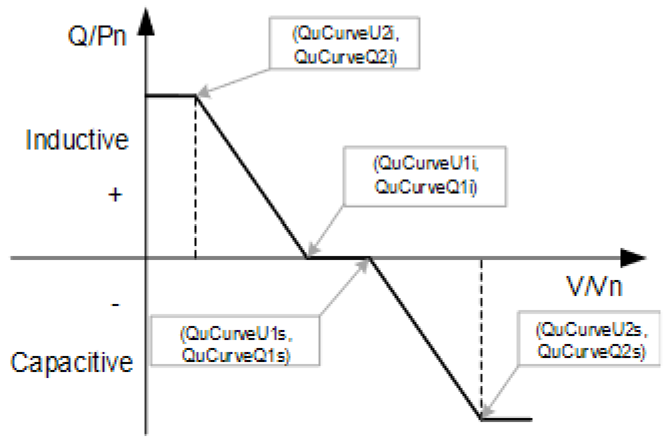
4.1.1 UNINTENTIONAL ISLANDING

Load on the VOEF 12.47 kV feeder connected to the proposed PV facility may at times be closely matched to the PV output level, making it possible that an unintentional island could exist on the feeder after opening of the associated utility 12.47 kV circuit breaker. The inverters proposed at the PV facility are listed with UL 1741 and are equipped with active and passive anti-islanding protective functions per IEEE 1547 that detect loss of the utility source and trip within two seconds. Therefore, reclosing of any devices that could be connected to the proposed PV facility should have reclosing times in excess of two seconds or have reclosing voltage supervision or voltage blocking. Reclosing times of equipment at the VOEF Substation are all in excess of two seconds (5 seconds 1st shot, 10 seconds 2nd shot, Reset 60 seconds). Based on this, remediation for out-of-phase reclosing is not required.

The need for direct transfer trip (DTT) was reviewed using “Suggested Guidelines for Assessment of DG Unintentional Islanding Risk,” published by Sandia National Laboratories. A multipart screen test was applied and it was determined that DTT is this instance is not required because the ratio of rotating-machine distributed generation to inverter-based distributed generation on the interconnected feeder is not greater than 25%.

4.1.2 POWER FACTOR

Most commercially available inverters today are capable of operating at a wide range of power factors, either fixed or variable based on voltage or other factors. However, most utilities prefer the inverters operate at a fixed unity power factor to minimize the impact on utility reactive power compensation strategies. However, based on the size and location of the proposed PV on the VOEF system, we recommend this facility operate at a variable power factor between 0.95 lagging and 0.95 leading to provide voltage support (see section 4.1.3 for the justification). The proposed Chint Power Systems inverters for this project are capable of varying their reactive power input/output based on inverter terminal voltage.



The following inverter settings are recommended for this installation:

Table 4.1.2-1

Voltage Setpoint	Voltage Value	Reactive Setpoint	Reactive Value	Operation
V1	95%	Q1	30%	Reactive Power Injection (~0.95 PF)
V2	97%	Q2	0%	Unity Power Factor
V3	103%	Q3	0%	Unity Power Factor
V4	105%	Q4	30%	Reactive Power Absorption (~0.95 PF)

Note, VOEF should reserve the right to modify power factor programming depending on future VOEF requirements. Having this flexibility to change the settings or inverter control strategy is important due ISO-NE Operating Procedure 17, where hourly power factor data is measured against target values.

The proposed PV facility will impact VOEF's system power factor. When, for example, the PV is operating at a unity power factor, its output will reduce the real power demand as seen on the VOEF system, but reactive power demand will be mostly unchanged.

An illustrative, simplified example of the proposed facility's impact to system power factor performance when operating at a unity power factor is shown below. With non-unity power factor operation, the reactive power consumed or generated to provide voltage support could make the overall system power factor appear better or worse depending on system conditions at the time.

No PV Facility

Total System Real Power Demand = 5,000 kW
Reactive Power Demand = 1,000 kVAr lagging

$$Power\ Factor = \frac{5000}{\sqrt{5000^2 + 1000^2}} = 0.98\ lagging$$

PV Output at Rated Capacity and Unity Power Factor

Real Power Demand = (5000–2375) kW = 2,625 kW
Reactive Demand = 1,000 kVAr lagging

$$Power\ Factor = \frac{2625}{\sqrt{2625^2 + 1000^2}} = 0.93\ lagging$$

4.1.3 STEADY-STATE VOLTAGE (NORMAL SYSTEM CONFIGURATION)

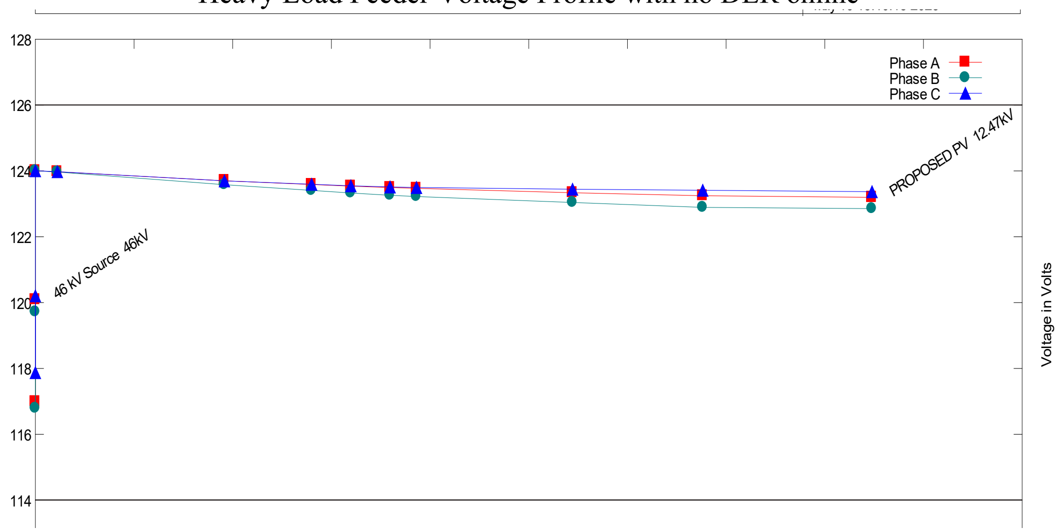
Two scenarios were modeled:

1. Peak load with no solar or other generation online
2. Minimum daytime load with maximum output at the proposed PV facility and all other existing DG.

Voltage analysis carried out in this section assumed the system improvements described in Section 2 had been implemented. Note the impedance difference between options 1 and 2 is negligible.

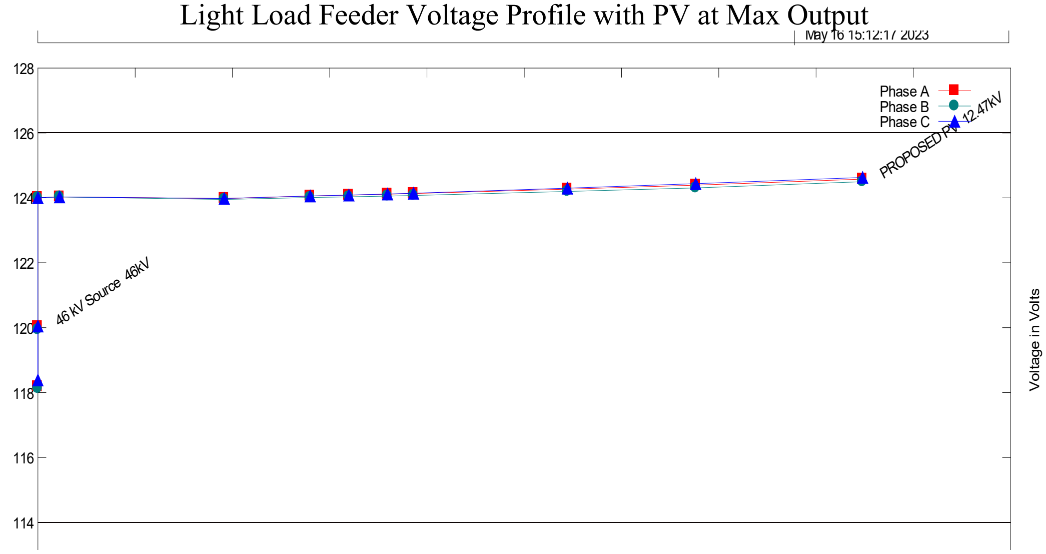
- Heavy Load – Low Voltage Check: The potential for low steady-state utility voltage is greatest when the solar is offline coincident with heavy load conditions. A load flow analysis was performed to determine if the substation voltage regulators were within +/-10% of their neutral tap positions. In addition, the voltage profile of the 12.47 kV feeder supplying the proposed PV facility was reviewed and it was determined that voltages were within ANSI C84.1, Range A as shown in Figure 4.1.3-1.

Figure 4.1.3-1
Heavy Load Feeder Voltage Profile with no DER online



- Light Load – High Voltage Check: The potential for high steady-state utility voltage due to the proposed PV facility is greatest when it is at maximum output during utility minimum daytime load conditions. To evaluate potential for high voltage concerns a 2.375 MW inverter-based generator is added to the model with loads allocated to reflect light load conditions. Reactive power input/output is modeled as a spot load based on PCC voltage magnitude to reflect inverter performance with volt/var support functionality enabled. A load flow analysis is performed to determine if the substation voltage regulators are within +/- 10% of their neutral tap position. The voltage profile of VOEF 12.47 kV supply feeder was reviewed and it was determined that voltages were within ANSI C84.1, Range A as in Figure 4.1.3-2.

Figure 4.1.3-2
Light Load Feeder Voltage Profile with PV at Max Output



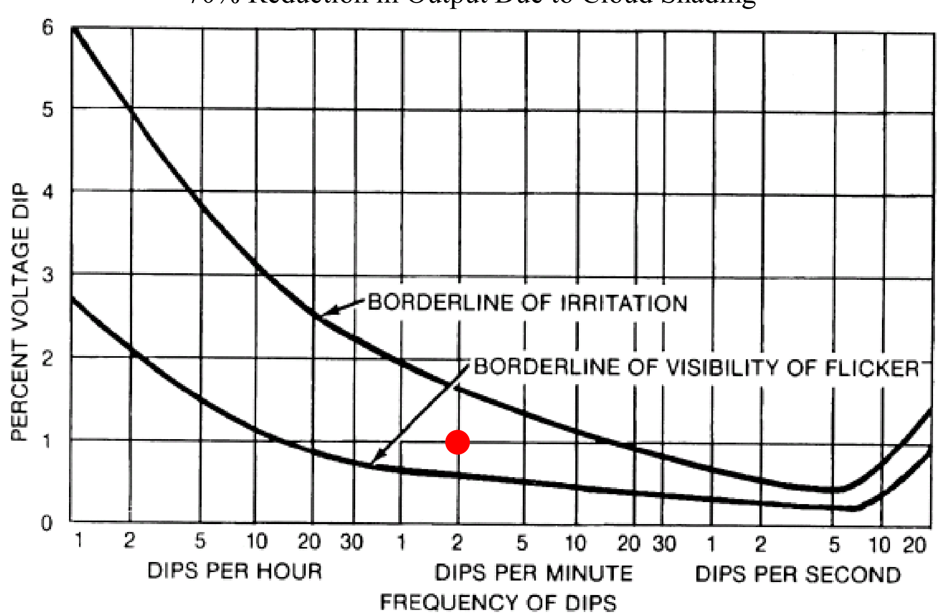
4.1.4 FLICKER AND LTC IMPACTS

The limitation of acceptable voltage flicker caused by distributed energy resources is defined by IEEE Standard 1547-2018, which states that flicker is only objectionable when it either causes a modulation of the light level of lamps sufficient to be irritating to humans or causes equipment misoperation per the flicker standard per IEEE 1453-2015. To evaluate the potential for voltage flicker, the effect of a rapid change from full PV output at 2.375 MW to 30% output due to cloud shading (and vice versa) was considered. This was performed by solving a load flow with the proposed PV facility operating at maximum output then solving a load flow with the output reduced to 30%. This analysis was performed with the system improvements noted in Section 2 having been modeled. The change in voltage at the PCC was used as the basis for flicker analysis, the results of which are summarized below:

- PCC voltage with PV output at full rated 2.375 MW capacity = 1.049 (disabled the volt/var support for this analysis)
- PCC voltage with PV output suddenly reduced to 0.7125 MW = 1.039
- Net Change = 1.0%

The GE Flicker Curve, Figure 1, is a legacy curve still widely used in the industry. It is admittedly conservative for predicting flicker resulting from inverter based generation. The GE flicker curve was created based on square wave modulation shaped voltage magnitude changes and the effect of these sudden changes on incandescent bulbs. Neither of which are entirely accurate assumptions to use for inverter based DER and the compact fluorescent and LED lighting technologies most widely used today. Because using the GE flicker curve for analyzing the impacts of inverter based generation is conservative it is still a useful screening tool to determine whether additional analysis is required. The 1.0% voltage change associated with a 1.66 MW change in PV facility output occurring as often as every 30 seconds is well below the borderline of irritability, as shown in Figure 4.1.5-1. Additional flicker analysis and/or mitigating system improvements are not required.

Figure 4.1.5-1
G.E. Flicker Curve
70% Reduction in Output Due to Cloud Shading



4.2 SHORT CIRCUIT ANALYSIS

The proposed PV facility is inverter-based and is therefore current-limited during a VOEF fault condition. For 12.47 kV faults on the VOEF system, we assume a worst-case three-phase fault contribution from the PV facility at $t=0^+$ is approximately 150% of the facility's AC rated output, which, at 12.47 kV, is 165A. The PV facility contribution for 12.47 kV ground faults is negligible. Fault simulations were performed using the above assumptions and the Aspen DistriView software and base case system model developed for this study. The results are summarized below.

With the proposed PV facility not connected and System Improvements in Section 2 having been implemented:

- The approximate three-phase fault current at the PCC is 1,258 amps at 12.47 kV
- The approximate single-line-to-ground fault current at the PCC is 1,037 amps at 12.47 kV

With the proposed PV facility connected and System Improvements in Section 2 having been implemented:

- The approximate three-phase fault current at the PCC is 1,422 amps at 12.47 kV.
- The approximate single-line-to-ground fault current at the PCC is 1,037 amps at 12.47 kV

The proposed PV facility does not cause any protective device or circuit equipment to exceed 90% of its short-circuit interrupting capability. The PV is inverter-based and therefore is current limited during fault conditions.

4.2.1 EFFECTIVE GROUNDING

IEEE C62.91.1 states that a system is effectively grounded if the coefficient of grounding (COG) is less than 0.8. The COG is defined as:

$$\frac{V_{L-N\text{ (unfaulted phase)}}}{V_{L-L\text{ (nominal)}}} = \mathrm{COG}$$

Computer modelling of a line-to-ground fault during pre-facility conditions indicates the COG at the PCC is 0.664. With the proposed PV facility interconnected and modeled as a voltage-controlled current source, the COG is 0.585 and therefore remains effectively grounded. Under normal system conditions, the PCC is effectively grounded both before and after interconnection. Supplemental grounding transformers are not required.

4.2.2 TEMPORARY OVERVOLTAGE

There are two types of temporary overvoltage that are of concern for distributed generation interconnections: overvoltage due to load rejection and overvoltage due to neutral displacement (others commonly refer to this as transient ground fault overvoltage, or TGFOV).

Overvoltage due to load rejection can occur when the part of a distribution feeder containing generation and some equal or smaller amount of load becomes disconnected from the grid, resulting in a high generation to load ratio in the islanded section of line. During the brief period before anti-islanding protection detects loss of the utility source, a transient overvoltage can occur as the current output from generators is temporarily fed into the local load. Load rejection can also lead to an undervoltage in islands that have less generation sources. Standard overvoltage protection for inverter based distributed generation includes a trip setting that will disconnect the generation for any voltage in excess of 120% of nominal within 160 milliseconds. Additionally, a large mismatch between generation and load, like what would cause the most sever overvoltage due to load rejection, is likely to trip the solar inverter even more quickly based on active anti-islanding technology.

The most common place for overvoltage due to neutral shift to be of concern is for the transmission system. A ground fault on the transmission system will cause remote protective devices to operate and isolate the faulted line section. Most substation transformers, including the VOEF unit, are configured delta on the transmission side and grounded wye on the distribution side. If distributed generation at the VOEF remains energized after remote transmission breakers have opened, the ground fault will be fed from the delta winding of the substation transformer. Due to the transformer's configuration, it cannot contribute zero sequence ground fault current to single line to ground faults on the 46 kV transmission line, and the voltage on the unfaulted phases may potentially rise to levels that exceed insulation ratings and cause damage to the substation and transmission line equipment. The worst case would involve line to neutral connected equipment seeing full line-line voltage for the duration of the event.

Figure 4.2.2-1
1LG Fault on Utility Side of Generator Step-Up Transformer with Ungrounded Primary

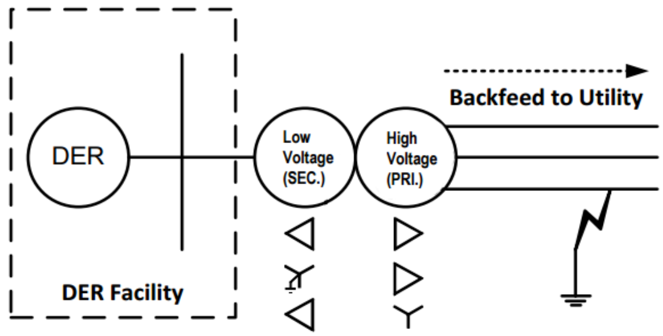
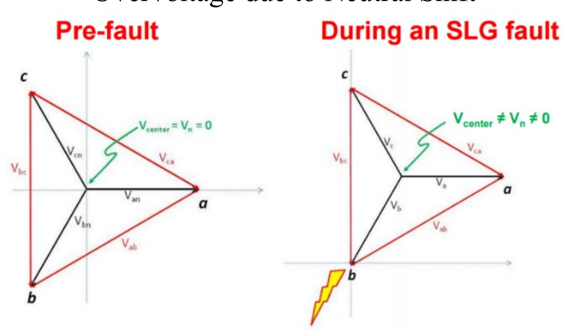


Figure 4.2.2-2
Overvoltage due to Neutral Shift



This overvoltage concern is somewhat mitigated if the generation to load ratio is sufficiently low. When there is less generation than load in the islanded section of line, the reduction in positive sequence voltage caused by the load rejection will offset the increase in zero sequence voltage caused by the neutral shift. The degree to which overvoltage due to neutral displacement is offset is dependent on the generation to load ratio. A maximum generation to load ratio of 2:3 ensures overvoltage due to neutral displacement will not cause voltage on the unfaulted phases from exceeding 120% of nominal line to neutral values. System peak load on the Enosburg distribution system is just under 5 MW. Even ignoring all existing the DG, the addition of the proposed 2.375 MW PV facility will cause the generation to load ratio on the system to exceed 2:3 during periods of light load. In fact, our load analysis indicates there may be a handful of hours during the year when the total system load on the VOEF system is less than generation resulting in reverse power flow into the 46 kV transmission system. To address concerns related to overvoltage due to neutral displacement we recommend the following:

- Review 46 kV equipment ratings and insulation coordination to determine if mitigation is required. For this study VOEF provided PLM with a simplified, hand sketch of the major substation components and their respective ratings. A detailed review of equipment ratings, BIL, etc. is not possible with the level of detail. Additional work is required to gather the necessary information and determine the optimal method for mitigating these concerns. If mitigation is required one of the following is recommended:
    - Install voltage sensing on the 46 kV incoming transmission line and a 59N relay. Wire the relay to trip the 12.47 kV circuit reclosers inside the VOEF substation.
    - VOEF's most recent integrated resource plan (IRP) filing indicates that when the VOEF substation was rebuilt in 2003 fiber communications was added. It is not clear from the IRP what the fiber communications is used for and where it is run to beyond the VOEF substation itself. If fiber communications exists between the VOEF substation and remote transmission substations, implementing a transfer trip scheme to open the 12.47 kV circuit reclosers for a loss of the transmission supply may be less expensive to implement than adding local voltage sensing and the associated relaying equipment.
- A budget placeholder of $100,000 is included in the system improvement costs. Specifics for implementing this protection will be developed in a Facilities Study should the developer elect to proceed with this interconnection.

4.3 VOEF PROTECTION & CONTROL

Protection for feeder phase and ground faults between the VOEF Substation and first protective device on the overhead distribution system is provided via a circuit recloser with ABB PCD 2000 controller inside the VOEF substation. The existing standard overcurrent relay settings for VOEF feeders are noted in Table 4.3-1. (These settings should be verified with VOEF.)

Table 4.3-1

VOEF 12.47 kV Feeders - Existing Substation Relay Settings

	Inst	Pickup	Time Delay/Mult.	Curve
Phase Overcurrent	---	300 A	2.0	PCD 2000 EI
Ground Overcurrent	---	150 A	3.0	PCD 2000 EI

To maintain existing levels of sectionalizing and selectivity on the VOEF distribution system a line recloser at the tap to Water Tower Rd so as not to introduce miles of additional line exposure for customers located in the heart of the village. The new recloser is presumed to have an SEL 651R relay which is standard for many of the local utilities. To coordinate with protection at the proposed PV facility and upstream protection at the VOEF substation, this new recloser should be programmed according to Table 4.3-2.

Table 4.3-2

Water Tower Rd 12.47 kV Recloser - Recommended Overcurrent Relay Settings

	Inst	Pickup	Time Dial	Curve
Phase Overcurrent	---	280 A	1.5	Ext. Inverse (U4)
Ground Overcurrent	---	140 A	1.5	Ext. Inverse (U3)

At the proposed PV Facility PCC VOEF will install another recloser. This recloser should be programmed according to Table 4.3-3.

Table 4.3-2
PV 12.47 kV Recloser - Recommended Overcurrent Relay Settings

	Inst	Pickup	Time Dial	Curve
Phase Overcurrent	---	200 A	1.5	Ext. Inverse (U4)
Ground Overcurrent	200 A	100A	1.0	Ext. Inverse (U3)

TCC plots demonstrating coordination between VOEF devices is shown in Exhibit 3.

4.4 PV FACILITY PROTECTION & CONTROL

Drawings for the proposed PV facility depict the following customer owned overcurrent protective devices at the point of interconnection:

1) Transformer internal bayonet style fusing

2) 3000A main breaker in customer switchboard

The project's inverters will provide protection for voltage and frequency deviations. IEEE 1547 is the standard for frequency and voltage protection requirements. This standard was revised in 2018 to allow for improved DER ride-through capability. However, until testing and certification procedures have been updated to accommodate the new standard, the ISO-NE Planning Advisory Committee has issued a document with recommended interim settings to be used for all inverter-based generation, which are recommended for the proposed inverters, as shown below:

Table 4.4-1
Recommended Inverter Settings

Protective Element	Recommended Setting[1,2,3]
Undervoltage Fast Pickup Undervoltage Fast Total Clearing Undervoltage Slow Pickup Undervoltage Slow Total Clearing	V ≤ 50% 1.1 seconds V ≤ 88% 2.0 seconds
Overvoltage Slow Pickup Overvoltage Slow Total Clearing Overvoltage Fast Pickup Overvoltage Fast Total Clearing	V ≥ 110% 2 seconds V ≥ 120% 0.16 seconds
Over frequency Fast Pickup Over frequency Fast Total Clearing Over frequency Slow Pickup Over frequency Slow Total Clearing	62 Hz 0.16 seconds 61 Hz 300 seconds
Underfrequency Fast Pickup Underfrequency Fast Total Clearing Underfrequency Slow Pickup Underfrequency Slow Total Clearing	56.5 Hz 0.16 seconds 58.5 Hz 300 seconds

1. Percent of the nominal voltage, where applicable
2. ISO-NE settings are within the acceptable ranges of IEEE 1547-2018.
3. Underfrequency settings comply with NERC's PRC-006-NPCC-1.
4. No adjustment is made for operating time of the inverter because it is a solid-state device.

The developer has indicated that the inverters comply with IEEE Standard 1547 and UL Standard 1741, which define protection requirements including anti-islanding, ceasing to energize a circuit when the circuit is de-energized, and ceasing to operate after a time delay when the voltage and/or system frequency are outside preset limits.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are noted:

- Verify that the 1G5 substation PCD 2000 relay is programmed according to Table 4.3-1
- Program the new line recloser on Water Tower Rd (see system improvement recommendations below) according to Table 4.3-2
- Program the VOEF PCC recloser according to Table 4.3-3.
- Program the solar inverters with voltage and frequency protection according to Table 4.4-1.
- Program the inverter to provide volt-var support in accordance with Table 4.1.2-1
- Verify with the transmission company (VEC) that their meter is capable of bi-directional operation. Note they may have additional requirements to accommodate this installation as an affected system.
- VOEF Required System Improvements:
    - Common Items (Budgetary Cost Estimate = $1,746,000):
        - Reconductor the 1/0 AL, #2CU, and #6CU from the end of the existing 4/0 AAC spacer cable on Main St to the Reservoir Rd tap off Water Tower Rd. The smaller wire should all be replaced with VOEF's standard 4/0 main line conductor.
        - Reconductor on Reservoir Rd to the project site with VOEF's standard 1/0 AL side tap wire size.
        - A recloser should be installed at the tap to Water Tower Rd from Elm St to maintain existing levels of sectionalization and limit exposure to remote line faults on Reservoir Rd for customers in the village center.
        - The 25A K-links at the tap to Reservoir Rd from Water Tower Rd should be replaced with 300A solid blades.
        - The 2.4kV, 300 kVAR capacitor bank on Water Tower Rd should be relocated to Orchard St to maintain existing levels of reactive power compensation.
        - Review 46 kV equipment ratings and insulation coordination to determine if mitigation is required. For this study VOEF provided PLM with a simplified, hand sketch of the major substation components and their respective ratings. A detailed review of equipment ratings, BIL, etc. is not possible with the level of detail. Additional work is required to gather the necessary information and determine the optimal method for mitigating these concerns. If mitigation is required one of the following is recommended:
            - Install voltage sensing on the 46 kV incoming transmission line and a 59N relay. Wire the relay to trip the 12.47 kV circuit reclosers inside the VOEF substation.
            - VOEF's most recent integrated resource plan (IRP) filing indicates that when the VOEF substation was rebuilt in 2003 fiber communications was added. It is not clear from the IRP what the fiber communications is used for and where it is run to beyond the VOEF substation itself. If fiber communications exists between the VOEF substation and remote

transmission substations, implementing a transfer trip scheme to open the 12.47 kV circuit reclosers for a loss of the transmission supply may be less expensive to implement than adding local voltage sensing and the associated relaying equipment.

- Additional System Improvements – Option 1 (Budgetary Cost Estimate = $310,000):
  - Convert the existing 2.4 kV delta overhead line on Main St from the Jolley store to the three 100 kVA step-up transformers located near the intersection of the 115 kV transmission line and Water Tower Rd (address is 209 Water Tower Rd). This area to be converted includes the 2.4 kV side tap on VT-108 N.
  - Transfer the converted 12.47 kV equipment to the 1G5, Main St feeder. The 2.4 kV on Orchard Street will remain. The existing 2.4 kV line from Orchard St onto Main St should be cut and dead-ended before the tap to Main St.
- Additional System Improvements – Option 2 (Budgetary Cost Estimate = $226,500):
  - Reconductor the overhead line on Depot St with VOEF's standard 4/0 mainline conductor and replace fused cutouts at the tap to Depot St with solid blades.
  - Convert the existing 2.4 kV delta overhead line from the intersection of Elm St and Pleasant St to the three 100 kVA step-up transformers located near the intersection of the 115 kV transmission line and Water Tower Rd (address is 209 Water Tower Rd). This area to be converted includes the 2.4 kV side tap on VT-108 N.
  - Transfer the overhead line beyond the intersection of Elm St and Pleasant St to the 1G5 feeder.

- To ascertain greater cost-certainty for estimates and finalize the scope of system improvements a Facilities Study is recommended should the developer wish to proceed with the interconnection.

Exhibit 1 – Village of Enosburg Falls Substation One-Line Diagram

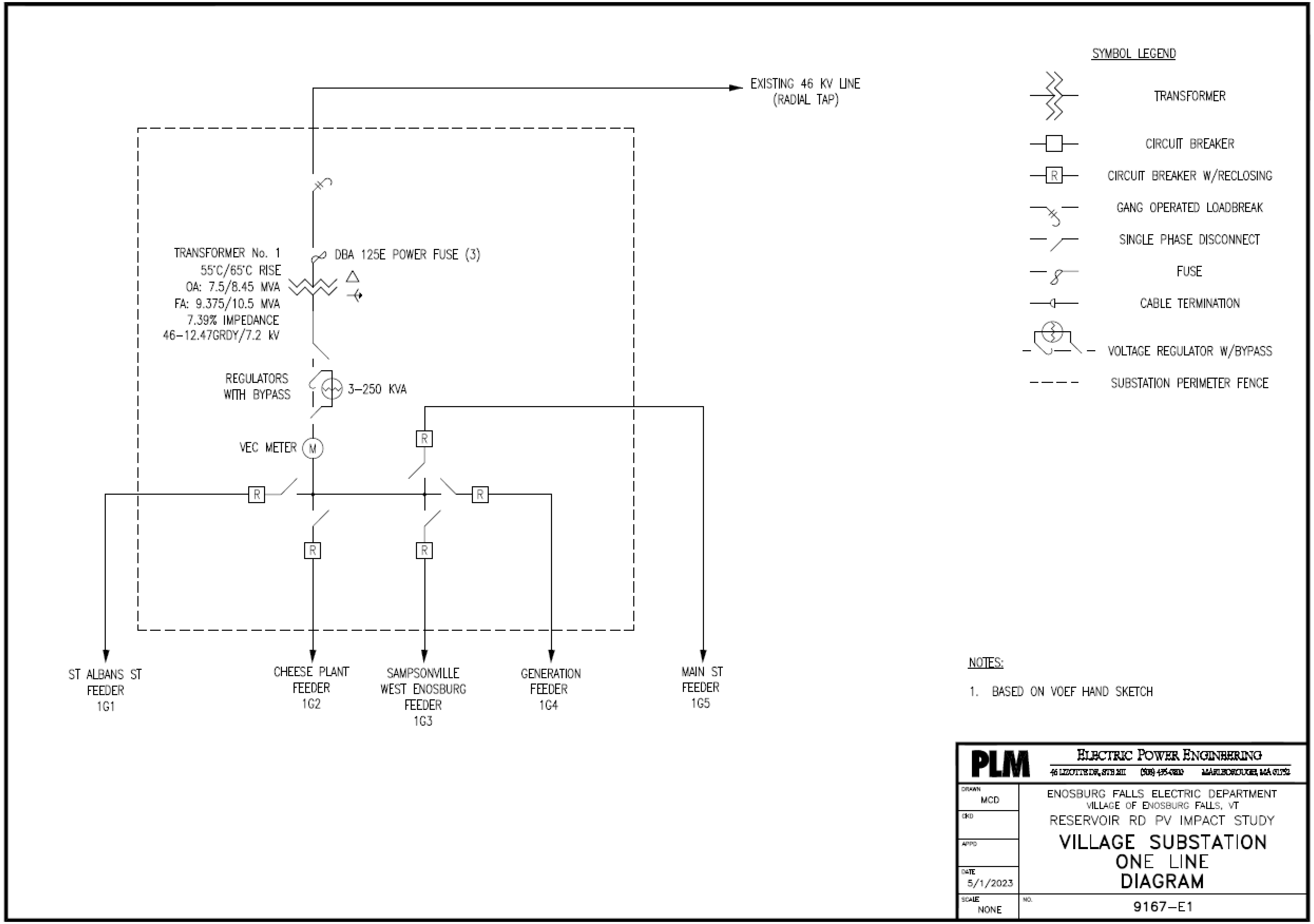
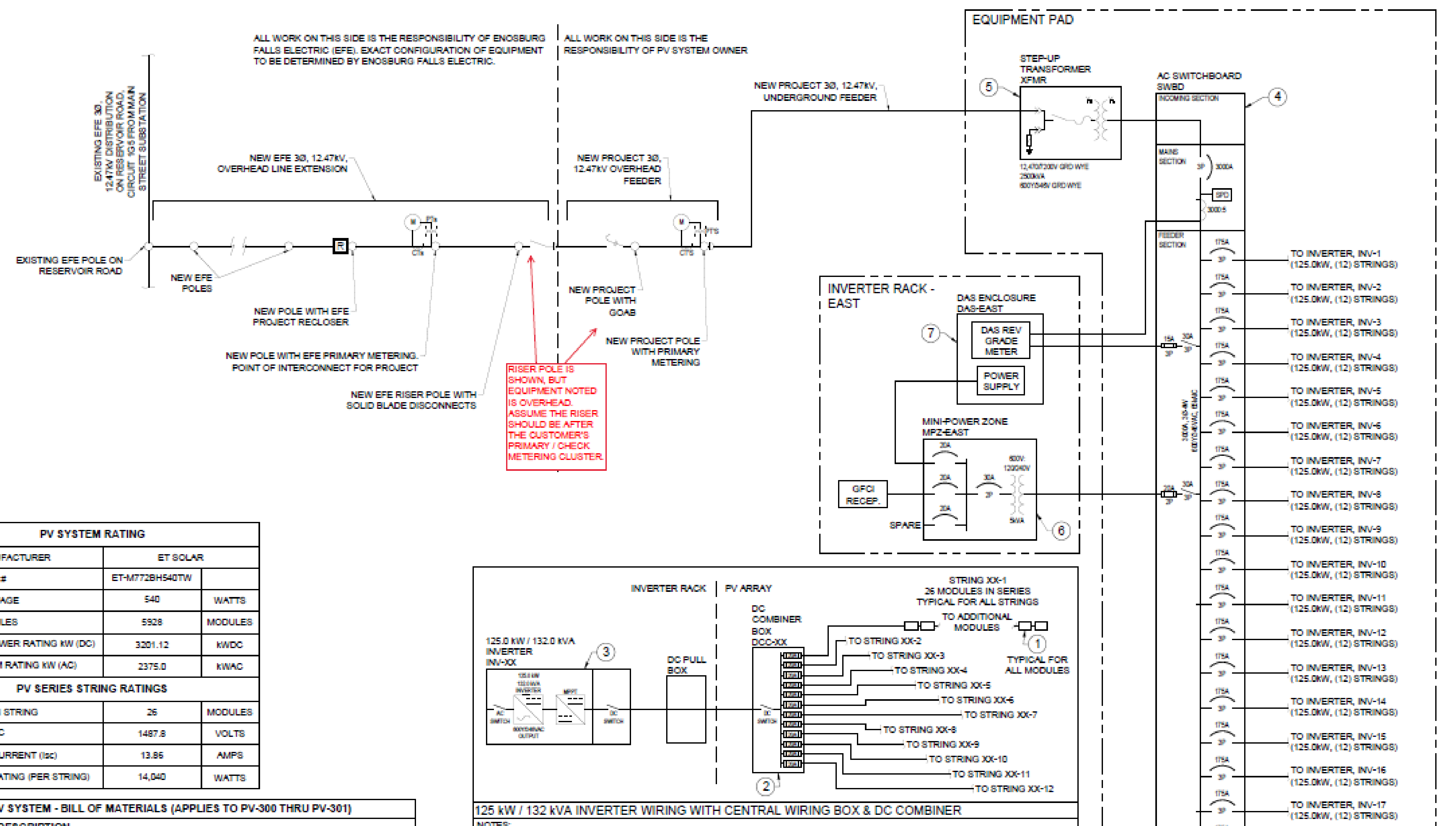

EXISTING 46 KV LINE
(RADIAL TAP)
TRANSFORMER No. 1
55°C/65°C RISE
OA: 7.5/8.45 MVA
FA: 9.375/10.5 MVA
7.39% IMPEDANCE
46-12.47GRDY/7.2 kV
DBA 125E POWER FUSE (3)
REGULATORS
WITH BYPASS
3-250 KVA
VEC METER
M
R
ST ALBANS ST
FEEDER
1G1
CHEESE PLANT
FEEDER
1G2
SAMPSONVILLE
WEST ENOSBURG
FEEDER
1G3
GENERATION
FEEDER
1G4
MAIN ST
FEEDER
1G5
SYMBOL LEGEND
TRANSFORMER
CIRCUIT BREAKER
CIRCUIT BREAKER W/RECLOSING
GANG OPERATED LOADBREAK
SINGLE PHASE DISCONNECT
FUSE
CABLE TERMINATION
VOLTAGE REGULATOR W/BYPASS
SUBSTATION PERIMETER FENCE
NOTES:
1. BASED ON VOEF HAND SKETCH
PLM
ELECTRIC POWER ENGINEERING
DRAWN
MCD
CKD
APPD
DATE
5/1/2023
SCALE
NONE
ENOSBURG FALLS ELECTRIC DEPARTMENT
VILLAGE OF ENOSBURG FALLS, VT
RESERVOIR RD PV IMPACT STUDY
VILLAGE SUBSTATION
ONE LINE
DIAGRAM
NO.
9167-E1

Exhibit 2 – Developer Drawings



NOTES:
1. CONFIGURATION SHOWN IS TYPICAL FOR 125kW INVERTERS.

PV SYSTEM RATING		
MODULE MANUFACTURER	ET SOLAR	
MODULE PART #	ET-M772BH540TW	
MODULE WATTAGE	540	WATTS
TOTAL # MODULES	5928	MODULES
TOTAL STC POWER RATING kW (DC)	3201.12	kWDC
TOTAL SYSTEM RATING kW (AC)	2375.0	kWAC
PV SERIES STRING RATINGS		
# OF SERIES IN STRING	26	MODULES
MAX Voc @ -28C	1487.8	VOLTS
MAX STRING CURRENT (Isc)	13.86	AMPS
STC POWER RATING (PER STRING)	14,040	WATTS

PV SYSTEM - BILL OF MATERIALS (APPLIES TO PV-300 THRU PV-301)

ITEM	QTY	DESCRIPTION
1	5928	PV MODULE, 540 WATT, MONOCRYSTALLINE, BIFACIAL, (144) HALF-CELLS, ET SOLAR MODEL ET-M772BH540TW, MODULE SPECS: Vmp = 41.64; Imp = 12.97; Voc = 49.6; Isc = 13.86
2	19	DC COMBINER BOX, 1500VDC, 275A, (12) DC INPUTS, LOAD BREAK DISCONNECT NEMA 3R ENCLOSURE, SOLARBOS OR EQUAL
3	19	PV INVERTER, 125.0 kW (132 kVA @ PF>0.95), 860-1450 VDC INPUT, 870-1300 VDC MPPT, CENTRALIZED WIRE-BOX, 600Y/342V 3-PHASE GROUNDED WYE OUTPUT, CHINT POWER SYSTEMS MODEL CPS-SCH125KTL-DO/US-600
4	1	AC SWITCHBOARD: 600Y/346V; 3Ø-4W; 3000A RATED BUS; 65kAIC RATING; 3000A-3P MAGNUM SB MAIN BREAKER SBS-C30 (FIXED-MANUAL), 3000A TRIP, DIGITRIP 520MC LSIG, 100% RATED, ARMS; (20) 400A-3P FRAME, 175A-3P TRIP, MOLDED CASE TYPE KDC, 65kAIC, THERMAL MAG, MANUAL OPERATION, FIXED MOUNTING; (1) 30A/30A-3P FDPW FUSED BRANCH SWITCH; INTEGRATED SPD SURGE PROTECTION, 160kA PER PHASE WITH DISCONNECT; 10kV ELBOW MOUNTED ARRESTERS; NEMA 3R ENCLOSURE.
5	2	STEP-UP TRANSFORMER; SOLAR RATED; 2500kVA; 12,470Y/7,200V GRD WYE PRIMARY, 600Y/346V GRD WYE SECONDARY; LOOP-FEED, 200A RATED BUSHING WELLS; ELBOW MOUNTED 10kV LIGHTNING ARRESTORS ON THE WEST TRANSFORMER; 5.75% IMPEDANCE.
6	2	MINI-POWER ZONE, 600V PRIMARY, 120/240V 1Ø-3W SECONDARY, 5KVA, 12-CIRCUIT, NEMA 3R ENCLOSURE
7	2	DATA ACQUISITION SYSTEM (DAS), TO INCLUDE: INVERTER DIRECT MONITORING; POWER METER; WEATHER STATION WITH POA IRRADIANCE, CELL TEMP, AMBIENT TEMP SENSORS.

INVERTERS - INPUT & OUTPUT RATINGS		
INVERTER DESIGNATION	INV-1 THRU INV-19	
INVERTER SIZE	125	kW
MODULE WATTAGE	540	WATTS
MODULES PER STRING	26	MODULES
QTY OF PARALLEL STRINGS	12	STRINGS
DC OPERATING INPUT VOLTAGE	1082.6	DC VOLTS
DC OPERATING INPUT CURRENT	155.6	DC AMPS
MAXIMUM SYSTEM VOLTAGE @-28C	1487.8	DC VOLTS
MAXIMUM SHORT CIRCUIT CURRENT	207.9	DC AMPS
INVERTER OUTPUT VOLTAGE	600	AC VOLTS
INVERTER RATED OUTPUT CURRENT	127.0	AC AMPS

NOT FOR CONSTRUCTION

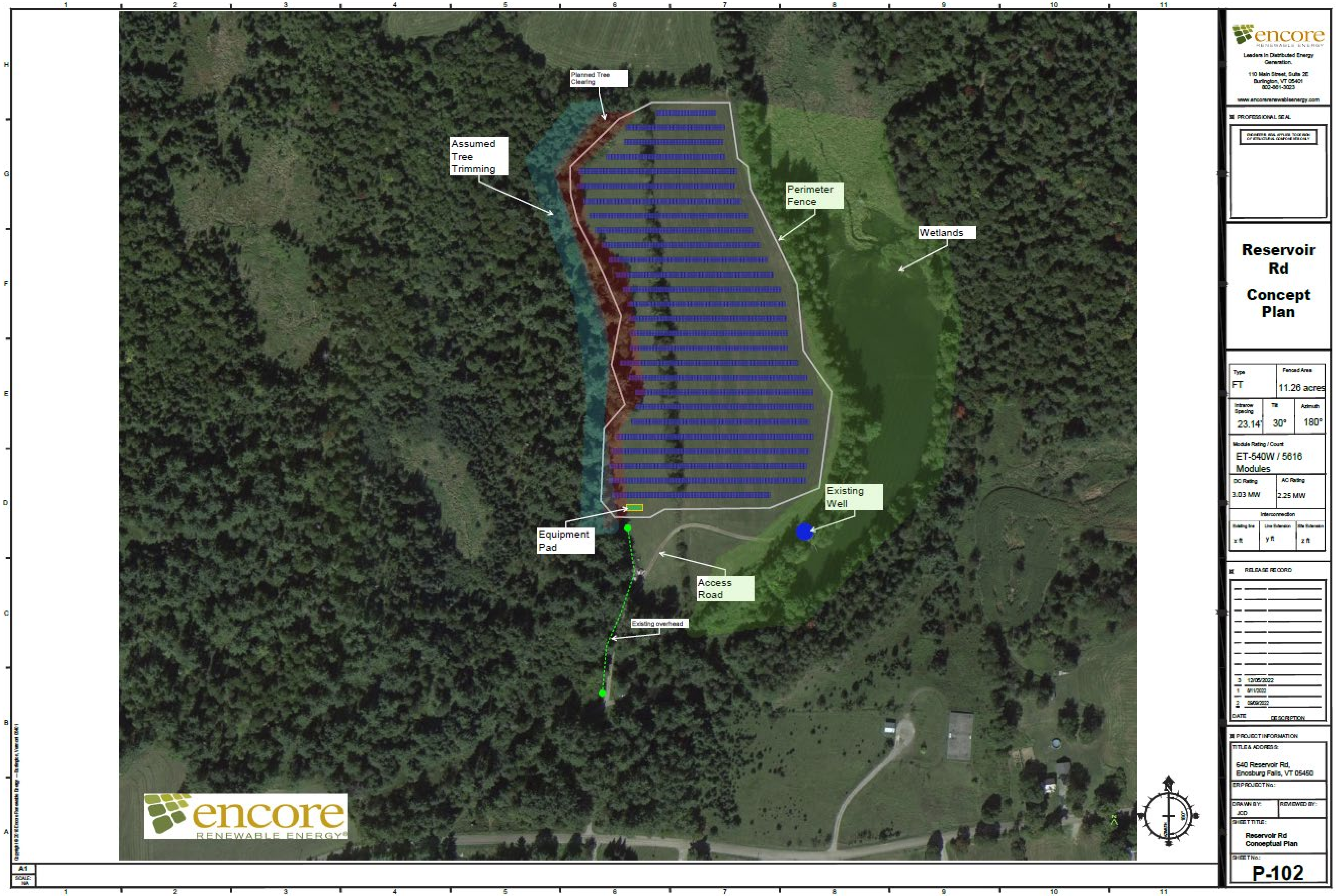
SOLAR POWER ENGINEERING
272 SPRING HOLLOW LANE
MONTPELIER, VT 05602
802.595.5510

RESERVOIR ROAD SOLAR, LLC
2.375 MWAC PV PROJECT
640 RESERVOIR ROAD
ENOSBURG FALLS, VERMONT 05450

DATE:	01/19/2023
PROJ NO.:	ERE_RRS_0123
SCALE:	NONE
DRAWN BY:	BPB
REVISIONS	
ISSUED FOR INTERCONNECT	01/19/2023

ONE-LINE DIAGRAM

PV-300


Planned Tree Clearing
Assumed Tree Trimming
Perimeter Fence
Wetlands
Existing Well
Equipment Pad
Access Road
Existing overhead
encore
RENEWABLE ENERGY
Leaders in Distributed Energy Generation.
110 Main Street, Suite 2E
Burlington, VT 05401
www.encorerenewableenergy.com
PROFESSIONAL SEAL
Reservoir Rd
Concept Plan
Type
FT
Fenced Area
11.26 acres
Interrow Spacing
23.14'
Tilt
30°
Azimuth
180°
Module Rating / Count
ET-540W / 5616 Modules
DC Rating
3.03 MW
AC Rating
2.25 MW
Interconnection
x ft
y ft
z ft
RELEASE RECORD
DATE
DESCRIPTION
PROJECT INFORMATION
TITLE & ADDRESS:
640 Reservoir Rd,
Enosburg Falls, VT 05450
ERP PROJECT No.:
DRAWN BY:
JCD
REVIEWED BY:
SHEET TITLE:
Reservoir Rd
Conceptual Plan
SHEET No.:
P-102
A1

CPS

Datasheet

125kW, 1500Vdc String Inverter for North America

CPS SCH125KTL-AIO/US-600

The 125kW high power CPS three phase string inverter is designed for ground mount applications. The unit is a high performance, advanced and reliable inverter designed specifically for the North American environment and grid. High efficiency at 99.1% peak and 98.5% CEC, wide operating voltages, broad temperature ranges and a NEMA Type 4X enclosure enable this inverter platform to operate at high performance across many applications. The CPS 125kW product ships with a non-separable Standard Wire-box, fully integrated with a DC disconnect switch. The Standard Wire-box inlcudes touch safe positive polarity fusing for up to 20 strings. The CPS Flex Gateway enables communication, controls and remote product upgrades.

Key Features

- NFPA 70, 2017 compliant
- Touch safe DC Fuse holders adds convenience and safety
- CPS Flex Gateway enables remote FW upgrades
- Integrated DC disconnect switch
- 1 MPPT with 20 fused inputs for maximum flexibility
- Copper and Aluminum compatible AC connections
- NEMA Type 4X outdoor rated, tough tested enclosure
- Advanced Smart-Grid features (CA Rule 21 certified)
- kVA Headroom yields 100kW @ 0.9PF and 125kW @ 0.95PF
- Generous 1.5 DC/AC Inverter Load Ratio
- Selectable Max AC Apparent Power of 125/132kVA
- Standard 5 year warranty with extensions to 20 years

125KTL-AIO/US-600 Standard Wire-box

Chint Power Systems America
6800 Koll Center Parkway, Suite 235 Pleasanton, CA 94566
Tel: 855-584-7168 Mail: AmericaSales@chintpower.com Web: www.chintpowersystems.com

CPS

Technical Data

Model Name	CPS SCH125KTL-AIO/US-600
DC Input	
Max. PV Power	187.5kW
Max. DC Input Voltage	1500V
Operating DC Input Voltage Range	860-1450Vdc
Start-up DC Input Voltage / Power	900V / 250W
Number of MPP Trackers	1
MPPT Voltage Range[1]	870-1300Vdc
Max. PV Input Current (Isc x1.25)	275A
Number of DC Inputs	20 PV source circuits, pos. fused
DC Disconnection Type	Load-break rated DC switch
DC Surge Protection	Type II MOV (with indicator/remote signaling), Up=2.5kV, In=10kA (8/20uS)
AC Output	
Rated AC Output Power	125kW
Max. AC Output Power[2]	125kVA (132KVA @ PF>0.95)
Rated Output Voltage	600Vac
Output Voltage Range[3]	528-660Vac
Grid Connection Type[4]	3Φ / PE / N (Neutral optional)
Max. AC Output Current @600Vac	127.2A
Rated Output Frequency	60Hz
Output Frequency Range[3]	57-63Hz
Power Factor	>0.99 (±0.8 adjustable)
Current THD	<3%
Max. Fault Current Contribution (1-cycle RMS)	41.47A
Max. OCPD Rating	200A
AC Surge Protection	Type II MOV (with indicator/remote signaling), Up=2.5kV, In=10kA (8/20uS)
System	
Topology	Transformerless
Max. Efficiency	99.1%
CEC Efficiency	98.5%
Stand-by / Night Consumption	<4W
Environment	
Enclosure Protection Degree	NEMA Type 4X
Cooling Method	Variable speed cooling fans
Operating Temperature Range	-22°F to +140°F / -30°C to +60°C (derating from +113°F / +45°C)
Non-Operating Temperature Range[5]	-40°F to +158°F / -40°C to +70°C maximum
Operating Humidity	0-100%
Operating Altitude	8202ft / 2500m (no derating)
Audible Noise	<65dBA@1m and 25°C
Display and Communication	
User Interface and Display	LED Indicators, WIFI + APP
Inverter Monitoring	Modbus RS485
Site Level Monitoring	CPS Flex Gateway (1 per 32 Inverters)
Modbus Data Mapping	SunSpec/CPS
Remote Diagnostics / FW Upgrade Functions	Standard / (with Flex Gateway)
Mechanical	
Dimensions (WxHxD)	42.7x24.3x11.2in (1085x616x283.5mm)
Weight	158lbs / 72kg
Mounting / Installation Angle	15 - 90 degrees from horizontal (vertical, angled)
AC Termination	M8 Stud Type Terminal Block (Wire range: #6 - 500MCM AWG CU/AL, Lugs not supplied)
DC Termination[6]	Screw Clamp Fuse Holder (Wire range: #12 - #6AWG CU) - Standard Wire-box
Fused String Inputs	15A or 20A fuses provided (SKU specific)
Safety	
Safety and EMC Standard	UL1741-SA-2016, CSA-C22.2 NO.107.1-01, IEEE1547a-2014; FCC PART15
Selectable Grid Standard	IEEE 1547a-2014, CA Rule 21, ISO-NE
Smart-Grid Features	Volt-RideThru, Freq-RideThru, Ramp-Rate, Specified-PF, Volt-VAr, Freq-Watt, Volt-Watt
Warranty	
Standard	5 years
Extended Terms	10, 15 and 20 years

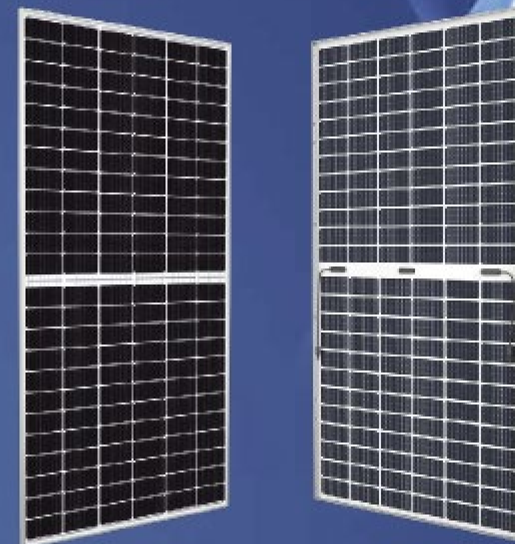
1) See user manual for further information regarding MPPT Voltage Range when operating at non-unity PF
2) "Max. AC Apparent Power" rating valid within MPPT voltage range and temperature range of -30°C to +40°C (-22°F to +104°F) for 125KW PF ≥0.95
3) The "Output Voltage Range" and "Output Frequency Range" may differ according to the specific grid standard.
4) Wye neutral-grounded, Delta may not be corner-grounded.
5) See user manual for further requirements regarding non-operating conditions.
6) Wire-box only includes fuses/fuseholders on the positive polarity, compliant with NEC 2017, 690.9 (C).

EliTe

PREC BIFACIAL

PV MODULE

ET-M772BH525TW 530W
ET-M772BH530TW 535W
ET-M772BH535TW 540W
ET-M772BH540TW 545W
ET-M772BH545TW 550W



KEY FEATURES

- Enhanced safety by excellent fire resistance
- Perfect for sandy, snowy and high latitude regions
- Bifacial technology enables additional energy harvesting from rear side(up to 25%)
- Lower operating temperature, more reliable
- Cut cell, Less internal power loss, Less mismatch loss

WARRANTY

IEC61215
IEC61730
UL61215
UL61730

12 YEARS Guarantee on product material and workmanship

30 YEARS linear power output warranty

ETECTRICAL SPECIFICATIONS

Module Type	ET-M772BH530TW ET-M772BH530TB		ET-M772BH535TW ET-M772BH535TB		ET-M772BH540TW ET-M772BH540TB		ET-M772BH545TW ET-M772BH545TB		ET-M772BH550TW ET-M772BH550TB	
Maximum Power -P_{mp} (W)	530	398	535	401	540	405	545	409	550	349
Open Circuit Voltage -V_{oc} (V)	49.30	46.20	49.45	46.24	49.60	46.28	49.75	46.32	49.90	46.16
Short Circuit Current -I_{sc} (A)	13.72	11.29	13.79	11.38	13.86	11.46	13.93	11.54	14.00	11.20
Maximum Power Voltage -V_{mp} (V)	41.31	37.18	41.47	37.24	41.64	37.30	41.80	37.36	41.96	37.12
Maximum Power Current -I_{mp} (A)	12.83	10.69	12.90	10.77	12.97	10.86	13.04	10.94	13.11	11.03
Module Efficiency STC-η_m (%)	20.5%		20.7%		20.8%		21.0%		21.3%	
Power Tolerance (W)	(0 , +4.99)									
Pmax Temperature Coefficient	-0.350%/°C									
Voc Temperature Coefficient	-0.290 %/°C									
Isc Temperature Coefficient	+0.048 %/°C									

STC: Irradiance 1000 W/m ² module temperature 25°C AM=1.5

REAR SIDE POWER GAIN (ET-M772BH535TW)

Power Gain	10%	15%	20%	25%
Maximum Power -P_{mp} (W)	589	615	642	669
Open Circuit Voltage -V_{oc} (V)	49.06	49.06	49.06	49.06
Short Circuit Current -I_{sc} (A)	15.13	15.81	16.50	17.19
Maximum Power Voltage -V_{mp} (V)	42.67	42.67	42.67	42.67
Maximum Power Current -I_{mp} (A)	13.79	14.42	15.05	15.68

MECHANICAL SPECIFICATIONS

External Dimension	2279 x 1134 x 35mm
Weight	28kg
Solar Cells	PERC Mono crystalline 182 x 91 mm (144pcs)
Front Glass	3.2mm AR coating tempered glass
Frame	Anodized aluminium alloy
Junction Box	IP68, 3 diodes
Output Cables	4.0 mm², Portrait:350mm(+)/250mm(-) Or customized
Connector	MC4 Compatible

APPLICATION CONDITIONS

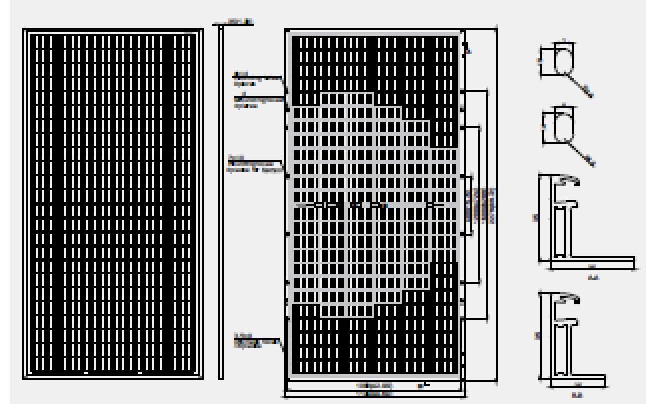
Maximum System Voltage	1500VDC
Maximum Series Fuse Rating	30A
Operating Temperature	-40~+85 °C
Nominal Operating Cell Temperature	45±2 °C

PACKING MANNER

Container	40'HQ
Pieces per Pallet	31
Pallets per Container	20
Pieces per Container	620

PHYSICAL CHARACTERISTICS

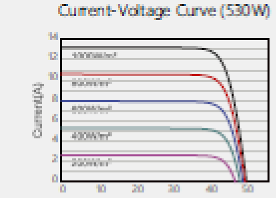
Unit:mm



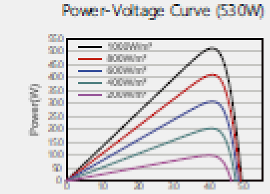
* The above drawing is a graphical representation of the product. For engineering quality drawings please contact ET Solar.

CURVE

Current-Voltage Curve (530W)

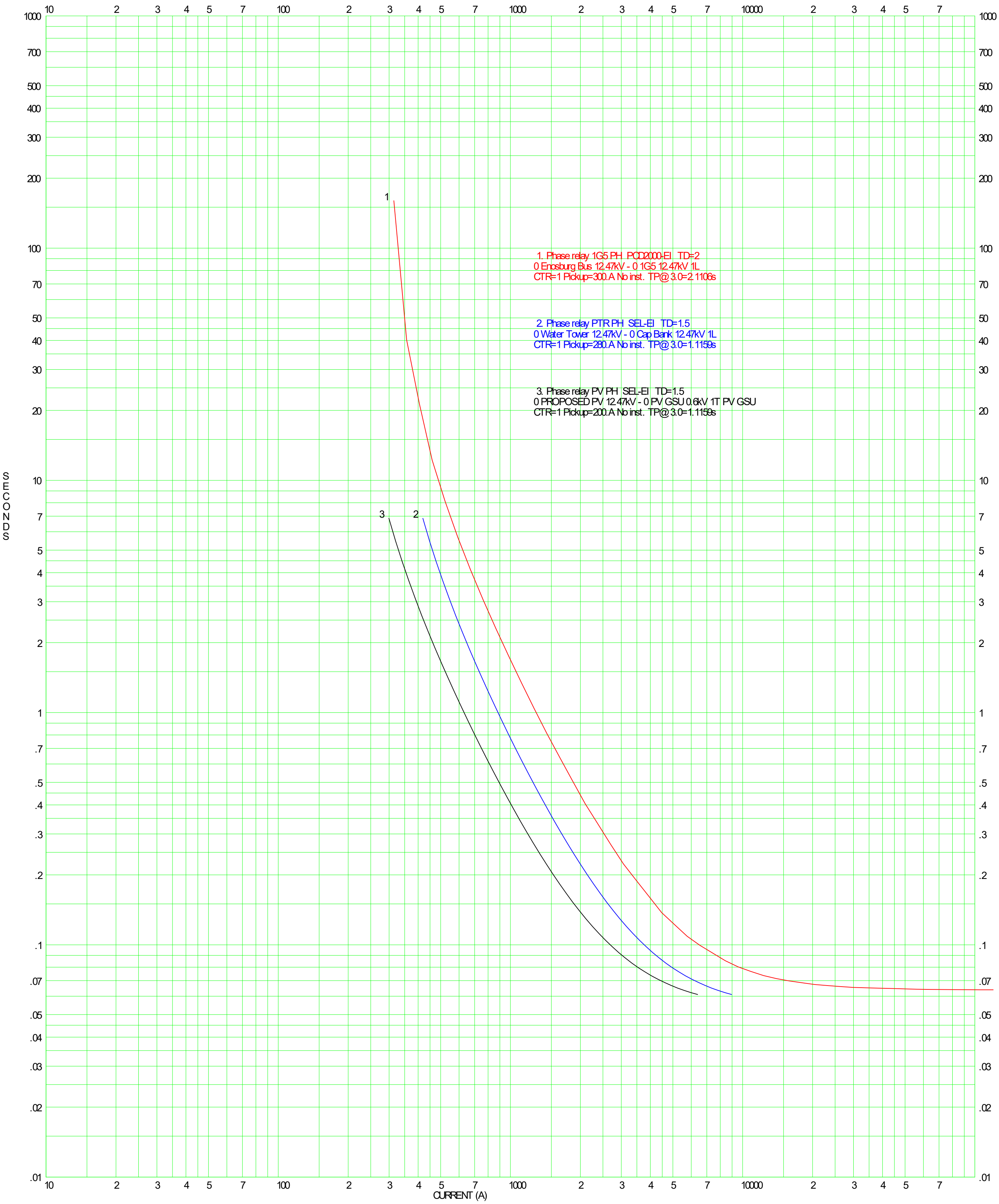


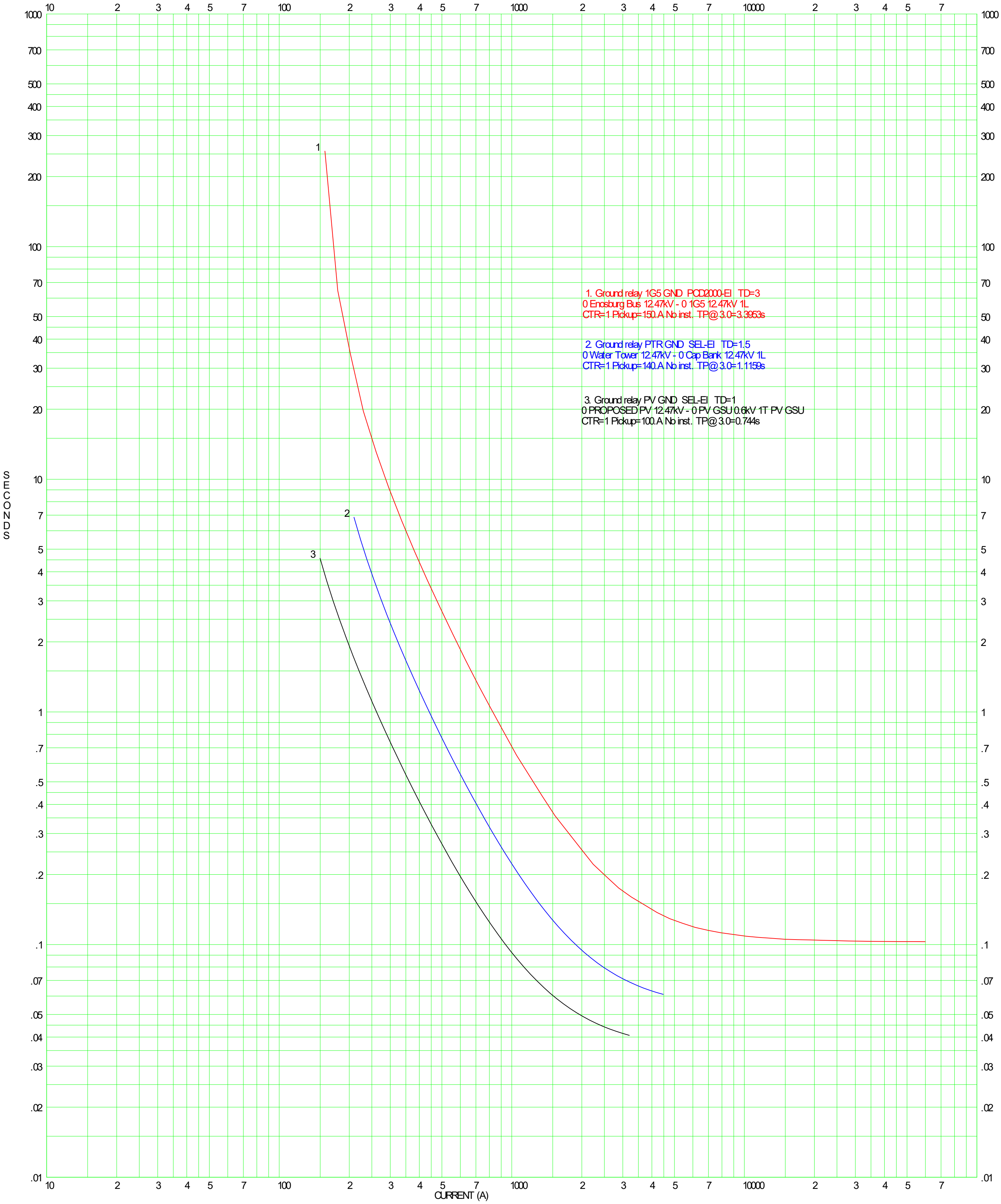
Power-Voltage Curve (530W)



Note: the specifications are obtained under the Standard Test Conditons (STCs): 1000 W/m² solar irradiance, 1.5 Air Mass, and cell temperature of 25°C. The NOCT is obtained under the Test Conditions: 800 W/m², 20°C ambient temperature, 1m/s wind speed , AM 1.5 spectrum.
Please contact support@etsolar.hk for technical support. The actual transactions will be subject to the contracts. This parameters is for reference only and it is not a part of the contracts.
The specifications are subject to change without prior notice.

Exhibit 3 – Time Overcurrent Curves


1. Phase relay 1G5 PH PCD2000-EI TD=2
0 Enosburg Bus 12.47kV - 0 1G5 12.47kV 1L
CTR=1 Pickup=300.A No inst. TP@3.0=2.1106s
2. Phase relay PTR PH SEL-EI TD=1.5
0 Water Tower 12.47kV - 0 Cap Bank 12.47kV 1L
CTR=1 Pickup=280.A No inst. TP@3.0=1.1159s
3. Phase relay PV PH SEL-EI TD=1.5
0 PROPOSED PV 12.47kV - 0 PV GSU 0.6kV 1T PV GSU
CTR=1 Pickup=200.A No inst. TP@3.0=1.1159s
SECONDS
CURRENT (A)


1. Ground relay 1G5 GND PCD2000-EI TD=3
0 Enosburg Bus 12.47kV - 0 1G5 12.47kV 1L
CTR=1 Pickup=150.A No inst. TP@3.0=3.3953s
2. Ground relay PTR GND SEL-EI TD=1.5
0 Water Tower 12.47kV - 0 Cap Bank 12.47kV 1L
CTR=1 Pickup=140.A No inst. TP@3.0=1.1159s
3. Ground relay PV GND SEL-EI TD=1
0 PROPOSED PV 12.47kV - 0 PV GSU 0.6kV 1T PV GSU
CTR=1 Pickup=100.A No inst. TP@3.0=0.744s
SECONDS
CURRENT (A)