Facilities Study Report

For

Physical Interconnection of

PJM Generation Interconnection Request

Project ID AG1-552

Carolina 34.5 kV

AG1-552 Ray Solar, LLC, (hereinafter called "Customer") has submitted an Interconnection Request for a 18MW generation facility to operate in parallel with the distribution system of Virginia Electric and Power Company, doing business as Dominion Energy North Carolina in North Carolina (hereinafter called "Company"). The results of the Facility Study are as follows:

Preface

The intent of the Facilities Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation to the Dominion Energy North Carolina Electric System at a location specified by the Project Developer. As a requirement for interconnection, the PD may be responsible for the cost of constructing: Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the Dominion Energy North Carolina system. All facilities required for interconnection of a generator must be designed to meet the technical specifications for the appropriate ITO.

> **The Facilities Study Cost is an estimated cost only. No engineering has been performed to arrive at the cost and Dominion Energy North Carolina does not guarantee the accuracy or completeness of this cost. The estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. All estimates have been calculated in good faith, however, are non-binding.**

General:

Address of facility: **Old Emporia Rd, NC, 27832**
The installed facilities will have a total capability of: **18 MW**
Substation: **Carolina**
Circuit number: **61 New**
Circuit voltage: **34.5 kV**

Utility Provided Attachment Facilities

- Installation of approximately 300 feet of three (3) phase overhead 477 Al. Primary / 246.9 Al. Neutral conductor
- Installation of G & W Viper Recloser with a SEL651R-2 Recloser Control
- Power Quality Monitor (SEL-735 or equivalent device) at the Point of Common Coupling with all required metering/relay functionality
- Transformer and secondary voltage conductors to provide source voltage for the Utility owned Recloser, PQ Monitor, Metering Equipment, and Transfer Trip Equipment.
- All metering needed for interconnection of generation and auxiliary load
- One Disconnect Switch at the Point-of-Interconnection
- Install a single phase OH transformer to supply power for Recloser, SEL-735R, & Transfer Trip controls and extend #2 Triplex to Recloser & Metering Poles.
- Extend 3 phase, 477 Al. primary/neutral overhead to a new pole and install G&W Viper ST w/SEL 651R-2 Control Recloser.
- Extend 3 phase, 477 Al. primary/neutral overhead to a new pole and install Bi-Directional Primary Metering equipment.
- Extend 3 phase, 477 Al. primary/neutral overhead to a new pole and install 600 amp Disconnects.
- Utility will install new metering equipment, CT's and PT's, the meter cabinet, meter, and connect the customer conductor to utilities 13.2 kV facilities

The estimated cost of the installation of the new attachment facilities to provide the interconnection is
$181,200.00 (with tax $193,884.00)

In addition to the onetime cost equal to the estimated cost of the new attachment facilities there will also be an ongoing monthly charge for the operation and maintenance cost of the attachment facilities equal to 0.28% of the estimated cost of the new attachment facilities (i.e., $181,200 x 0.0028 = $507.36 per month).

Project Developer Requirements (to include but not limited to)

- Installation of road providing accessibility along the Utility interconnection poles suitable for construction and operation vehicle traffic.
- Installation of a gang operated air-break switch or equivalent located 1 span from the point of interconnection providing a visible opening that can be locked and tagged that will be utilized to isolate the PD from the Utility.
- Installation of all conductors, pad mount transformers, and generator breakers between the generating facility and POI.
- Communication lines for all metering.
- Communication circuit(s) for Transfer Trip Scheme, if required, between the DG site and Substation, and between the DG site and inline recloser(s).
- Obtain any required right-of-way for the construction of Utility's facilities necessary for the interconnection of this generator.
- Provide and maintain a telephone line (POTS) to the Utility metering equipment.
- Metering to report real-time to PJM is required when the generation capacity is 10 MW or more total on the circuit.

- All PDs must provide generator status and instantaneous MW output to PJM per Manual 14D of the PJM OATT via communication links when the aggregate generation capacity reaches 10MW or more on a circuit. This communication medium is installed, owned, and maintained by the PD. Contact PJM for additional details concerning the requirement [PJM System Planning Division @ (610) 666-8980].

Utility Provided Distribution Upgrades

AG1-552 proposes to build an 18 MW DER facility located on Old Emporia Road, Gaston, NC. Based on the location the DER site would interconnect to Dominion Energy North Carolina's Carolina Substation on 61_Cir 810 (13.2 kV). However, 18 MW at 13.2 kV would exceed thermal limits of the conductors and switches if connected. Instead, the DER site shall interconnect to Dominion Energy North Carolina's Carolina Substation on 61_Cir NEW (34.5 kV). The site is located approximately 3.5 miles in circuit length away from Carolina Substation. This project is a status "A" and has 0 MW energized ahead of it on the new proposed required transformer. The project requires a new express circuit of 1000 MCM Al. cable and 477 AAC from the station and taking over 1.5 miles of existing circuitry with conversion to 34.5 kV and three-phase reconductoring. A new 20/26.8/33.6 MVA, 34.5 kV, transformer at Carolina Substation will be required to serve this site. New Right-of- Way for approximately .9 miles will be needed to cross the Roanoke River north of the station. The Developer will need to build to the POI off the mainline. Due to the aggregate size of the generation on the circuit, transfer trip will need to be installed on the interconnect recloser between the generation and the breaker.

- Install new 34.5 kV Cir NEW UG Circuit getaway from Carolina TX #2
- Install 1000 MCM Cable under Roanoke River and along Roadway
- Guide Drill with 1000 MCM Cable from Carolina Station to new Riser Pole near O2047MI2500. Approximately 6000 feet (this includes 3000-feet of submersible cable under river).
- Install G&W Recloser near new "Riser" pole O2047MI2500.
- Overbuild existing 13.2 kV circuit from O2047MI2500 to L2000MB8200. Approximately 5000-feet.
- Three-Phase, convert to 34.5 kV, and reconductor (existing Cir 810R145 tap) with 477 AAC from L2100MB6200 to – L2100LM6700 approximately 6,300-feet.
- Replace existing recloser (810R145) with a G&W Recloser on L2000MC1000.
- Install a 1-Ø 500 kVA, 19.9/7.6 kV stepdown transformer near Pole#L2000LM6700.
- Install a 70 A V4E Recloser at Pole#L2000LN5800.
- Convert all service transformers of the formerly Cir 810 taps from the three-phase line being re-conductored and converted.
- Request System Grid Planning to supply LTC settings
- Constructability of upgrades is contingent upon the acquisition of required easements and/or encroachments to this section.

Protection Requirements for Customer 18 MW of Generation

The utility has reviewed the 18.0 MW_{AC} Interconnect Customer (AG1-552) request for installation of parallel generation units located South of 815 Old Emporia Road, Gaston, NC, 27832. The Distributed Energy Resources (DER) owner desires to both export power into the Dominion Energy NC (UTILITY) utility source and provide site power via site solar generation.

This is a UL1741/IEEE 1547 certified inverter-based interconnection consisting of seven (7) Sungrow SG3150U-MV inverters rated 3150 kW, and operating at 630 V_{AC}. The inverter system is in seven (7) blocks of single 3150 kW inverters connected to a 3-phase 3150 kVA pad mounted transformer. All transformers are rated 19.9/34.5kV–630V with a wye- ground/wye (ground facing utility) winding configuration.

Power export is limited to 18.0 MW_{AC} at the POI using a site controller, or by digitally limiting the output of each individual inverter.

The resulting protection requirements are based on the following information:

- No more than 18.0 MW_{AC} of total generation will be in parallel with the utility system at any one time.
- The DER owner's generation facility will be paralleled with the utility system by the following connections:
  - The DER owner's generation facility will be connected to the Carolina Circuit NEW via the new Automatic Line Recloser (ALR) NEWRYYY which is sourced by In-Line recloser NEWRXX, NEWRZZ, CB NEW02, Bus #NEW, Carolina Transformer #NEW and 115 kV Transmission Bus #3 or Transmission Line 1010.
- Transmission Line 1010 has existing or queued project DER totaling 18.0 MW_{AC}. Carolina Transformer #NEW currently has existing or queued project DER totaling 18.0 MW_{AC}. Carolina Circuit NEW distribution facilities has existing or queued project DER totaling 18.0 MW_{AC}.
- Carolina Circuit NEW feeder breaker will have no reclosing enabled.
- Transmission Line 1010 has both time delayed and instantaneous reclosing applied on its terminal breakers.
- DER owner parallel operation will not be limited to any particular time or utility circuit- loading condition; however, DER owner parallel operation will not be permitted during periods when the source circuit is switched into an abnormal configuration.
- The DER owner will be contracting with the utility to export power into the utility distribution system.
- The load data for the pertinent sectionalizing devices are as follows:
  - In-Line Recloser NEWRXX has no available "light" loading data

- In-Line Recloser NEWRZZ has no available “light” loading data
- Carolina Circuit NEW (NEW02) has no available “light” loading data
- Carolina Transformer #NEW has no available “light” loading data
- Transmission Line 1010 has no available “light” loading data

Based on projected minimum loads given for the applicable utility sectionalizing devices, the following minimum "*Light Load to Cumulative Generation Capacity*" ratios will apply for this installation. Transfer trip is required from each zone with a ratio less than 3:1.

Utility Device	*Minimum Ratio*
NEWRXX	0.00
NEWRZZ	0.00
CB NEW02	0.00
Transformer #NEW	0.00
Transmission Line 1010	0.00

Table 1 - *Light Load to Cumulative Generation Ratio*

Based on the size and type of this generation, the applicable utility standards and the minimum load ratios applicable for this installation, the following requirements must be met in their entirety before permission to parallel operations can be granted:

1. Installation of a utility owned Automatic Line Recloser (ALR) at the point of common coupling (PCC) with all required relaying at the DER owner expense.
2. Installation of an additional utility owned protective relaying (SEL-735 Power Quality Package, or similar) at the PCC (Utility Metering Instrument Transformer Cabinet) with all required metering/relay functionality at the DER owner expense. The power source (single phase, 120 V_{AC}) to this Power Monitor shall be supplied from a 2 kVA or larger Station Service (Primary kV – 120 V_{AC}) source (low exposure) independent of any other generation, load or exposure. Such protective relaying should aid in the determination of on-going harmonic levels among other information regarding the interconnection site.
3. Power Quality baseline readings will be required before and after the interconnection is completed in order to monitor the PQ effects of the generation unit and will be obtained at the DER owner’s expense. If there is evidence that the new interconnection is the source of power quality anomalies (as defined by industry standards and based on Good Utility Practice), the DER owner will be required to take the necessary actions to mitigate the issue in a reasonable timeframe. Dominion Energy Virginia (DEV) reserves the right to disconnect the generation via the POI recloser if DEV and Project Developer cannot agree, in a timely manner, on a solution which resolves the PQ issues. Please refer to Appendix 1 for examples of industry Standards and/or Good Utility Practice for power quality.
4. Zero Sequence Sources: The utility does not allow zero sequence (I_0) sources,

like wye- ground/delta transformers, to connect to the distribution grid. The zero sequence sources desensitize protective overcurrent relays on the electric power system. The utility requires a wye-ground/wye with ground facing utility, or wye-ground/wye-ground transformer configuration.

5. Effective Grounding: Due to the step-up transformer configuration being wye-ground/wye (ground facing utility), the utility Electric Power System (EPS) will not be effectively grounded when an upline device opens to clear a fault and the DER remains connected to the islanded segment for a period of time. One of the two following requirements will be needed to mitigate this issue.

    a. Install Direct Pilot Wire Tripping (Transfer Trip) from each of the upline utility devices to the DER site recloser.

    b. A light load to generation ratio greater than 3:1 for the nearest upline device from the POI.

6. Station upgrades listed below are required (if not already existing):

    a. Install SEL-451, DG Relay

    b. Install SEL-735 Transformer meter.

    c. Add Potential Transformers (PT) to 34.5 kV Bus.

    d. (If using Line 1010) Add transmission line transfer trip to Line 1010 to serve as an input to the SEL-451 DER panel relay to send transfer trip to the POI recloser to clear all potential sources to a transmission fault. Ensure that line terminal stations have been upgraded to provide line transfer trip functionality.

    e. Install Direct Pilot Wire Tripping (or Transfer Trip) from each of the upline utility devices: In-Line Recloser NEWRXX, NEWRZZ, CB NEW02, Bus #NEW, and the Carolina Transformer #NEW to the DER site recloser. Transfer trip is required due to the light load to generation ratio being less than 3:1.

    f. Wire the following to serve as input to the SEL-451 DER panel relay to send transfer trip and prevent reclosing of the POI recloser to clear all potential sources to an upstream fault:

        I. Transformer #NEW LORs 86TNEW & 86TNEWBU

        II. 34.5 kV BUS LOR 86BNEW

        III. Transmission Bus #3 LORs 86-1B3 & 86-2B3 (If using Transmission Bus #3)

        IV. Transmission Breaker Failure LORs: Wire all BF relays from transmission Bus#3 (if using transmission Bus#3) that correspond with the LOR's.

The voltage and frequency set points, listed in Table 2, are derived from IEEE-1547-2018. The "*Total Clearing Time (sec)*" listed in Table 2 is a summation of the detection time, field adjustable clearing time, and trip time. The DER owner will be required to apply all the enabled protection settings and not exceed the "*Total Clearing Time (sec)*". The DER owner shall provide detailed, manufacturer-supplied computer simulation models (Aspen OneLiner, PSS/E, and/or PSCAD) of the inverter, to include full control and hardware details, needed to investigate DER impacts.

Currently, this site is intended to operate with utility interactive inverter functionality enabled and with grid support utility interactive inverter functionality disabled. Therefore, the following inverter functions listed in Table 2 are to be disabled: LVRT, HVRT, ZVRT, VAR Support, and Voltage Regulation.

Function		**Set Point**	**Total Clearing Time (sec)**
27	Under-voltage (UV1)	V < 88% nominal voltage	2.0
27	Under-voltage (UV2)	V < 50% nominal voltage	0.160
59	Over-voltage (OV1)	V ≥ 110% nominal voltage	1.0
59	Over-voltage (OV2)	V ≥ 120% nominal voltage	0.160
81U	Under-frequency (UF1)	F < 59.0 Hz	180
81U	Under-frequency (UF2)	F < 57.0 Hz	0.160
81O	Over-frequency (OF1)	F > 61.0 Hz	180
81O	Over-frequency (OF2)	F > 61.8 Hz	0.160
	Overall Anti-Islanding	Disconnect inverter from system (PCC)	0.160
	Steady State Power Factor	UNITY Power Factor	
LVRT	Low Voltage Ride Through	DISABLE	
HVRT	High Voltage Ride Through	DISABLE	
ZVRT	Zero Voltage Ride Through	DISABLE	
	Watt/Var Control	DISABLE	
	Volt/Var Control	DISABLE	
	Volt/Watt Control	DISABLE	
	Frequency/Watt	DISABLE	

Table 2: *DER Inverter Settings*

Since the installation of the utility owned ALR at the PCC, associated relaying, Protective Relaying (SEL-735 Power Quality package, or similar) and the related additional substation work are all provided at the DER owner expense, we will need to work out details to coordinate the planned interconnection with the associated engineering, equipment acquisition and installation times. Please note that the DER owner will not be allowed to interconnect until all the permanent facilities and associated relaying are installed, tested and fully functional.

Should any changes occur in the IEEE guidelines for the interconnection of a DER system and/or changes occur in system conditions (i.e. penetration level of DER on that part of the system), the utility reserves the right to re-evaluate the protection application and require upgrade(s) as it deems necessary for the utility and/or the DER owner. Any necessary upgrades will be assigned according to how the changes impact the DER owner's generation and interconnection to the grid. In accordance with Article 3 of this Interconnection Agreement, the utility reserves the right to require the DER owner to remedy any adverse operating conditions at the DER owner's expense, should they occur.

Finally, please promptly provide us details/confirmation concerning the DER owner's final inverter model (nameplate photos), the applied inverter trip points, and interface transformer specifications (i.e. transformer impedance, load losses, high side fuse make, model, rating, etc.), as soon as possible.

Utility Provided Substation Upgrades

Project AG1-552 provides for the station upgrade to support 18 MW DER facility on a new express circuit.
Install a 115-34.5kV, 33.6 MVA transformer off of line 1010, along with appropriate high-side equipment in the open area next to existing TX #3. Add two breaker positions bay structure for the
34.5KV bus, including station service, potential transformers and cap bank.
Transfer Trip is to be installed to support this distributed generation due to light load to generation ratio. Developer/Operator supplied fiber-based TT communication to DG site is considered for scoping purposes. (DTT medium to be confirmed with PM)
Additionally, add a 115KV switch, upstream of new TX tap, on line 1010 for added operational flexibility.

Purchase and Install Substation Material (Carolina Substation):

1. One (1), 115-34.5kV, 33.6 MVA, Delta-Wye Transformer with LTC
2. Oil containment for the new transformer. (Confirm during detail design)
3. Three (3), 90kV MO, 74kV MCOV, Station Class Surge Arrester
4. Three (3), 30kV MO, 24.4kV MCOV, Station Class Surge Arresters
5. One (1), 115kV, 1200A, 25 kAIC Circuit Switcher (Verify fault values with System protection/Circuit Calculations prior to ordering switcher)
6. One (1), 115kV, 2000A Center Break Switch
7. One (1), 115kV, 2000A Vertical Break Switch

8. One (1), 10k in-lb.,125 VDC Motor Operator
9. One (1), 115kV, 800A Wave Trap
10. One (1), 34.5kV, 40kAIC, 3000A SF6 Circuit Breakers
11. One (1), 34.5kV, 1200A Load Break Disconnect Switch
12. Three (3), 34.5kV, 2000A Hook Stick Disconnects
13. Twelve (12), 34.5kV, 1200A Hook Disconnect Switches
14. Two (2), 34.5kV,1200A End Break Disconnect Switches
15. One (1), 4800kVAR (future 9600kVAR) @ 37.4kV, Capacitor Bank (Detail design to confirm ratings)
16. One (1), 34.5kV, 600A, Cap Switcher.
17. Three (3), 600V, 2000/5, Current Transformers
18. Nine (9), 30kV MO (DI), 24.4kV MCOV, Surge Arresters.
19. Three (3), 34.5kV, 175/300:1, Potential Transformers
20. Two (2), 19.9-.24/.12kV, 167kVA Station Service Transformers
21. Three (3), 34.5kV, SMU-20, 200A-E, Fuse Unit
22. Three (3), 34.5kV, SMU-20, 1A-E, Fuse Unit
23. Two (2), 34.5kV, SMU-20, 10A-K Fuse Unit
24. Five (5), 23kV, 12A-K, BCL Fuses
25. Eleven (11), 34.5kV, SMD-20, 200A, Fuse Mount
26. One (1), UG Circuit Getaway Structure (Verify with Dist. Engineering)
27. Set up floating dead end on line 1010 (By Transmission)
28. Two (2), 34.5 kV Distribution Bays
29. 2 - 2” conduit from control enclosure/cable trough to Dist. Gen. fiber MU box
30. Snake fence as per current engineering standard
31. Cable trough as required.
32. Conductor, connectors, insulators, conduit, control cable, cable trough, foundations, steel structures and grounding connections as per engineering standards

Purchase and Install Relay Material (Carolina Substation):

1. One (1),1221 - SEL 387A/351A/735 Distribution TX Diff w/o L-Bkr Pnl
2. One (1), SPR Relay Auxiliary Package
3. One (1), 4510 - SEL 2411 TX Equipment Annunciator
4. One (1), 4526_A - TX Fiber MU Box
5. One (1), 1112 - SEL 311C Distribution Bus Pnl
6. One (1), 4516 - Three Phase Potential M.U. Box
7. One (1), 4540 - Indoor Distribution Bus Potential Box
8. One (1), 1539 - Single SEL-451 Circuit Panel
9. One (1), 4000 – Station Service Potential Makeup Box
10. One (1), 4018 – 800A Station Service AC Distribution Panel
11. One (1), 4006 – 225A 3Ø Throwover Switch
12. One (1), 4014 – 225A Outdoor Distribution Yard AC NQ
13. One (1), 4304 - Capcon Control (Cap SW) Box
14. One (1), 4202 - Cap Bank C.T. M.U. Box
15. One (1), 1607 – Distributed Generation TT Panel (Fiber)
16. One (1), 4528 – DG Fiber Optic Makeup Box

Purchase and Install Relay Material (DG Site):

1. N/A necessary equipment to be provided and installed by distribution

Relay work at Pecan substation:

1. Enable line transfer trip on line 1010

Schedule Estimate

The total expected time for engineering and construction of all work required will be approximately **48 months** from the execution of an Interconnection Agreement and payment of all required costs.

Appendix 1[1]

IEEE 519: IEEE Standard for Harmonic Control in Electric Power Systems.

IEEE Std. 1547: IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.

IEEE 1453: IEEE Standard for Measurement and Limits of Voltage Fluctuations and Associated Light Flicker on AC Power Systems.

IEEE P519.1: Guide for Applying Harmonic Limits on Power Systems.

IEEE 1159-2019: IEEE Recommended Practice for Monitoring Electric Power Quality.

IEEE 1159.3-2019: IEEE Recommended Practice for the Transfer of Power Quality Data (PQDIF).

IEEE 1250-2018: IEEE Guide for Identifying and Improving Voltage Quality in Power Systems.

IEEE 1409-2012: IEEE Guide for Application of Power Electronics for Power Quality Improvement on Distribution Systems Rated 1 kV Through 38 kV.

IEEE 1668-2017: IEEE Recommended Practice for Voltage Sag and Short Interruption Ride-Through Testing for End-Use Electrical Equipment Rated Less than 1000V .

1 It is DEV expectation that DER Owner / Developer construct its facilities in accordance with applicable specifications that meet or exceed those provided by the National Electrical Safety Code, American National Standards Institute, Institute of Electrical and Electronics Engineers (IEEE), Underwriter's Laboratory, and operating requirements in effect at the time of construction and other applicable national and state codes and standards