PJM Generator Interconnection

Y1-086 Tanglewood 230 kV

7.6 MW Capacity / 20 MW Energy

Feasibility Study Report

July 2012
DMS #709367v1A

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Introduction

This Feasibility Study has been prepared in accordance with the PJM Open Access Transmission Tariff, §36.2 and §110, as well as the Feasibility Study Agreement between Interconnection Customer (IC), and PJM Interconnection, LLC (PJM), Transmission Provider (TP). The Interconnected Transmission Owner (ITO) is Virginia Electric and Power Company.

Preface

The intent of this Feasibility Study is to determine a plan, with preliminary cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by IC. As a requirement for interconnection, IC 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 PJM and the underlying system. All facilities required for interconnection of a generation interconnection project must be designed to meet ITO technical specifications.

The Feasibility Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. IC is responsible for its right of way, real estate, and construction permit issues.

General

The queue project Y1-086 was studied as a 20 MW (7.6 MW Capacity) solar injection at Tanglewood 230 kV substation in to the ITO area. The actual Point of Interconnection will be at the distribution substation Morgans Corner, which is fed from Tanglewood 230 kV. Project Y1-086 was evaluated for compliance with reliability criteria for summer peak conditions in 2015. The potential transmission system network impacts were identified as follows:

Network Impacts:

Impactful Contingencies

(The following contingencies resulted in overloads identified below)

None.

Generator Deliverability

(Single or N-1 contingencies for the Capacity portion only of the interconnection)

None.

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Multiple Facility Contingency

(Double Circuit Tower Line Contingencies only with full energy output. Stuck Breaker and Bus Fault contingencies will be applied during the Impact Study)

None.

Contribution to Previously Identified Overloads

(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have % allocation of cost responsibility which will be calculated and reported for the Impact Study.)

None.

Short Circuit

(Report Overdutied breakers here)

No over-duty breakers were identified.

Stability and Reactive Power Requirement

(Results of the dynamic studies should be inserted here)

Not required.

Delivery of Energy Portion of Interconnection Request

PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request. Only the most severely overloaded conditions are listed. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed, which will study all overload conditions associated with the overloaded element(s) identified.

1. The 8LOUDOUN-8BRAMBLETON 500 kV line (from bus 314913 to bus 314933 ckt 1) loads from 106.81% to 106.83% (AC power flow) of its emergency rating (2323 MVA) for the single line contingency outage of CONTINGENCY DESCRIPTION ('WELTONSP_KEMPTOWN'). This project contributes approximately 2.55 MW to the thermal violation.

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CONTINGENCY 'WELTONSP_KEMPTOWN'
  DISCONNECT BRANCH FROM BUS 235634 TO BUS 235636 CKT 1
  END
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   The overload of 500 kV transmission Line #558 section from Brambleton to Loudoun identified above will be resolved when the proposed PJM baseline project b1694 is constructed. The in-service target date is May 2016, and the line will have a rating of 4000 MVA.

ITO Analysis

IC requested a Feasibility Study of a 20 MW interconnection for its proposed Morgans Corner NC facility onto ITO 34.5 kV distribution system. IC requested that any modifications to existing facilities and any facilities built new to accommodate

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the 20 MW interconnection request be constructed for a potential final build out capacity of 20 MW.

Distribution Facilities and Location:

IC is proposing the build of a 20 MW solar farm on Blindman Road. in Elizabeth City, NC; located near old Morgans Corner DP. IC wishes to interconnect to ITO Elizabeth City 34.5 kV Circuit 412. IC site is located in AEMC's territory approximately 13.5 circuit miles away from Elizabeth City Substation. The customer and cooperative will have to build 477 aluminum overhead line to ITO existing facilities which end near Firetower Road.

The majority of the mainline conductor is 336 AAC and 477 aluminum and will not require upgrade. The mainline conductor changes from 477 aluminum to #2 ACSR beyond Morgans Corner Road. This approximately 1 mile of conductor will have to be upgraded.

Modifications Required:

The modifications required to provide the interconnection will include:

- Reconductor one mile of #2 overhead line to 477 aluminum and replace 8 poles.

The estimated cost for this reconductoring will be $248,000.

New Facilities Required:

The new facilities required to provide the interconnection will include installation of the following:

1. one ABB recloser with transfer trip capability;
2. transfer trip capability onto 2 existing reclosers, one circuit breaker and main breakers at generator site;
3. approximately 300 feet of a three phase 477 aluminum overhead line and three poles;
4. three phase overhead solid blade disconnects; and
5. pole mounted bi-directional metering.

The Feasibility Study estimated cost for the installation of new facilities to provide the interconnection is $241,700.

The total estimated cost for all interconnection construction is $489,700.

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Additional Technical Requirements:

IC desires to export power into the ITO system. This is an inverter based interconnection, which consists of twenty (20), 1 MW inverters and twenty (20), 1 MVA rated transformers connected at 34.5/19.9 kV – 480 V (wye-ground - delta). IC is planning the installation of a main breaker at their facility. The resulting protection requirements are based on the following information:

- No more than 20 MW of total generation will be in parallel with the ITO system at any one time;

- The customer's generation facility will be paralleled with the DNCP system by the following connections;

  - IC will be connected to Elizabeth City substation and circuit 412 via a new up-line G&W recloser, up-line recloser 412R6, up-line recloser 412R3 and up-line breaker 41252;
  - Elizabeth City Circuit 412 breaker has reclosing time at 10 seconds and 45 seconds after the first trip;

- The load data for the pertinent sectionalizing devices are as follows:

  - Elizabeth City Transformer #2 typical "light" loading is 6.0 MW;
  - Elizabeth City Circuit 412 typical "light" loading is 5.0 MW;
  - Elizabeth City 412R3 typical "light" loading is 3.8 MW;
  - Elizabeth City 412R6 typical "light" loading is 0.06 MW; and
  - Elizabeth City 412RNEW estimated "light" loading is 0.0 MW.

- Customer parallel operation will not be limited to any particular time or utility circuit-loading condition.
- The customer will be export power into the ITO distribution system.

Based on the minimum loads given for the ITO sectionalizing devices, the following minimum "Local Load to IC Generation Capacity" ratios will apply for this installation:

Utility Device	*Minimum Ratio*
TX #2	0.3
CB 41252	0.21
412R3	0.16
412R6	0.003
412RNEW	0.0

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The minimum ratios applicable for this installation will require IC to have the **Direct Pilot Wire Tripping** (or Transfer Trip) function installed from each of the utility devices: 412RNEW, 412R6, 412R3, CB 41252 and Substation Transformer #2 and Bus #2 to the generation site's lockout (main breaker). Such direct tripping functions should sectionalize the customer generation for any opening of the respective device. The direct trip control feature is meant to ensure that a "prolonged" (or "permanent") islanding condition (with the customer generation supplying utility load in the absence of the utility source) will not be set-up. In addition, the direct tripping function would aid in preventing an out-of-step reclosure of the utility source.

A review of the transmission line light load provided the following information:

- The Line 2021 light load is approximately 6.0 MW; and
- The minimum ratio with respect to the customer generation is 0.3

Such line loading and associated ratio shows a possible risk of Islanding and therefore will require the addition of Line Transfer Trip. Moreover, additional functions are required at the customer main breaker relays in order to provide adequate backup protection. Those functions and their general set point are listed in the following table:

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Function		Set Point	Duration to Generation Cleared (seconds)	
			Preferred	Maximum
27	Undervoltage	90% of nominal operating voltage	Less than 2.0	2.0
59	Overvoltage	106 to 110% of nominal operating voltage	Less than 2.0	2.0
81U	Underfrequency	59.0 to 59.5 Hz	Less than 2.0	2.0
81O	Overfrequency	60.5 to 61.0 Hz	Less than 2.0	2.0
51	Phase Time-delay Overcurrent	Set for minimum, with adequate load allowance	Maintain proper coordination	
51N	Ground Time-delay Overcurrent	Set for minimum, with adequate imbalance allowance	Maintain proper coordination	
67	Directional Phase Time-delay Overcurrent	Set for minimum, with adequate load allowance	Maintain proper coordination	
67N	Directional Ground Time-delay Overcurrent	Set for minimum, with adequate imbalance allowance	Maintain proper coordination	

The inverters specified in this interconnection request have **not yet been proven** to comply with the UL-1741 standard. ITO request that information documenting the selected 1000 kW GE inverter model(s) are UL certified be provided once that information becomes available.

Some inverter models have the option of customizing some of their protective or tripping settings such as the over-current or ground protection. If this is the case, for the IC selected inverters, ITO will also need to know that in advance so that appropriate setting ranges can be established for application to the inverters in a timely manner.

Harmonics (voltage and current) if not controlled can be a source of problems on the ITO system. Though it is definitive that small scale PV systems (i.e. about 10 kW or less) have little to no significant harmonic effects on the system provided their associated converter meet the IEEE standard 519, *Guideline for Harmonic Control and Reactive Compensation of Static Power Converter*, the impacts of larger scale PV systems is far less certain. It is a general consensus that a concentration of small sources of harmonic distortion, as little as they could be, can have a significant effect on the overall ITO system power quality as the effect of harmonics are cumulative thus making it

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imperative not to ignore the harmonics in this particular 20 MW interconnection request.

In Summary, **Power Quality baseline readings** will be required at the Point of Interconnection before and after the interconnection is completed in order to monitor the harmonic effects of the generation unit and will be obtained at the customer's expense. Also, if there is evidence that the Total Harmonic Distortion (THD) is greater than or equal to 5% harmonic distortion for any single harmonic is greater than or equal to 3%, the customer would be required to add a filtering system to its installation to meet the requirements of IEEE 519.

In addition to the ITO facilities indicated above, to provide a transfer trip circuit protection scheme, the IC will be responsible for providing and maintaining communication lines between the IC's main generator breaker and up line reclosers. The IC will also be responsible for providing and maintaining telephone lines to the ITO's metering equipment at the Point of Interconnection. The IC provided 34.5 kV 3-phase circuit will interconnect overhead at the Point of Interconnection which will be the load side terminals of the ITO provided pole mounted bi-directional meter. It will be the IC's responsibility to obtain any required right-of-way between the ITO's existing facilities and the Point of Interconnection.

Finally, a request for model information and evidence of certification of the 1000 kW inverters to the UL1741 standard for use with Distributed Energy Resources is requested. In order to proceed with a Facilities Study, hard evidence of certification to UL1741 will be required.

The estimated time for engineering, material acquisition and construction of this interconnection is approximately eight months. Detailed engineering, costs, material lead times and construction time requirements will be determined as part of the Facility Study.

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