PJM Generator Interconnection
V4-068 Murphy 34.5 kV
3.23 MW Capacity / 5 MW Energy
Feasibility Study Report

April 2010
DMS #591801v1

Introduction

This Feasibility Study has been prepared in accordance with the PJM Open Access Transmission Tariff, §36.2, 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 Local and 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

Queue V4-068 is an IC Capacity resource interconnection consisting of a 5 MW solar farm. The IC provided data to support this facility having a Capacity amount above the class average of 19%. Data support a value of 64.6%, or 3.23 MW. V4-068 generation will be located at Murfreesboro, North Carolina. Output from the generation will be connected to the 34.5 kV service, fed from Murphy Substation.

Potential PJM Network Impacts

The queue V4-068 project was studied as a 5 MW Energy (3.23 MW Capacity) injection into ITO's system at Murphy Substation. The project was studied on a Feasibility Study basis which utilizes a DC analysis. Project V4-068 was evaluated for compliance with reliability criteria for summer peak conditions in 2014.

Potential network impacts were as follows:

Generator Deliverability

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

None.

Multiple Facility Contingency

(Double Circuit Tower Line contingencies only for the full energy output. Stuck breaker and bus fault contingencies will be performed for the Impact Study)

None.

Contribution to Previously Identified Overloads

(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)

None.

Short Circuit

None.

System Stability Analysis

Dynamic studies are part of the System Impact Study.

ITO Requirements

IC has requested a Feasibility Study of a 5 MW interconnection for its proposed Murfreesboro, NC facility onto ITO's 34.5 kV distribution system. IC requested that any modifications to existing facilities and any facilities built new to accommodate the interconnection be constructed for a potential final build out capacity of 5 MW. The requested site has ITO's existing 34.5 kV Murphy Substation circuit 310 source (See Figure 1).

Local Facilities and Location

Murphy Substation, located on Main Street, Murfreesboro, NC has an existing 3-phase 34.5 kV Circuit 310 that can be utilized by the IC to interconnect their 5 MW solar farm. Even though IC's summer solar capability factor of 64.6%, or Capacity amount, is less than the full energy capability of the facility, the full 5 MW of energy was used for this study onto the distribution network. The IC's

interconnection is to be located approximately 4.5 circuit miles away from the substation. The smallest conductor in the main line to the interconnection is 3/0 ACSR which is capable of handling 18.7 MVA of load.

Non-Direct Connection Local Upgrades Required

There are no equipment additions required to the existing Murphy Circuit 310 to accommodate IC's proposed interconnection.

ITO Protection Requirements

The protection requirements are based on the following assumptions:

1. No more than 5 MW of total generation will be in parallel with the DNCP system at any one time;

2. The customer's generation will be interconnected via wye-ground – wye-ground connected transformers;

3. The customer's generation facility will be paralleled with the DNCP system by the following connections:

   - The Customer will be connected to Murphy Circuit 310 via the recloser 310R31 and up-line breaker 31022;
   - Murphy Circuit 310 circuit breaker has reclosing times at 10 seconds and 45 seconds after the first trip;
   - Murphy recloser 310R31 has reclosing times at 20 seconds and 35 seconds;
   -

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

   - Murphy Circuit 310 (31022) has a typical "light" loading of 2.03 MVA;
   - Murphy 310R31 has a typical "light" loading of 0.71MVA;
   - customer parallel operation will not be limited to any particular time or utility circuit-loading condition; and
   - the customer will export power into PJM via the ITO distribution system.

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

Utility Device	Minimum Ratio
CB 31022	0.41
310R31	0.14

The minimum ratios applicable for this installation require the customer to have the Direct Pilot Wire Tripping (or Transfer Trip) function installed from the utility device 310R31 and utility device CB 31022 and Substation Transformer #1 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 occur. In addition, the direct tripping function would aid in protecting the customer generator from an out-of-step reclosure of the utility source. **Though not included in this analysis or in the associated Transfer Trip costs, the transmission line light load condition may require the addition of Line Transfer Trip (LTT) at an additional cost.** Line light load conditions occur when the transmission feed is lost to this distribution circuit, the distribution loads are at or under the generation output level and the generator would be carrying all ITO islanded load.

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:

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	

The inverters specified in this interconnection request must be verified to comply with the UL-1741 standard. **IC must provide evidence as part of the System Impact Study submissions.**

Some inverter models have the option of customizing some of their protective or tripping settings such as the Overcurrent or Ground protection. If this is the case, for IC's selected inverters, ITO will also need to know that as part of the System Impact Study submissions so that appropriate setting ranges can be established for application to the inverters.

Harmonics

Harmonics (voltage and current) if not controlled can be a source of problems on the ITO network. Though it is definitive that small scale PV systems (i.e. about 10 kW or less) have little to no significant harmonics 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 less certain. It is a general consensus that a concentration of small sources of harmonic distortion can have a significant effect on the overall ITO network power quality as the effect of harmonics are cumulative and thus making it imperative not to ignore the harmonics in this particular 5 MW interconnection request.

As a result, power quality 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 facility. These data will be obtained at the customer's expense. **If the Total Harmonic Distortion (THD) is greater than or equal to 5% or the harmonic distortion for any single harmonic is greater than or equal to 3%, then IC would be required to add a filtering system to its installation to meet the requirements of IEEE 519.**

New Facilities Required

The new facilities required to provide the interconnection will include:

1. Installation of direct pilot transfer trip capability on the Circuit 310 circuit breaker in Murphy Substation.
2. Installation of direct pilot transfer trip capability on IC generator breaker.
3. Installation of direct pilot transfer trip capability onto Recloser 310 R31 on Pole P0944-HN51.
4. Installation of approximately 800 feet of a three phase overhead line and five poles depending on the location of interconnection.
5. Installation of three phase overhead solid blade disconnects at two separate pole locations.
6. Installation of pole mounted bi-directional metering.

The Feasibility Study estimated cost for the installation of new facilities to provide the interconnection is $197,000.

In addition to the ITO facilities indicated above, to provide a direct pilot 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 recloser, and between the IC's

main generator breaker and the ITO's Murphy Substation. 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.

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 System Impact Study.

Note that in the Protection and Harmonics sections above, there are two possible additional charges for this project: line transfer trip and harmonic filtering. The line transfer trip requirement will be determined in the System Impact Study. The harmonic criteria are discussed above, the but the filter requirement cannot be made until after the system data is obtained. Transfer trip requirements may be reduced or eliminated if the IC equipment adequately protects against islanding.

Figure 1