Generator Interconnection
System Impact Study Report

Carteret County, NC – 120.8 MW
Queue #297
Original Submittal – Revision 1

October 28, 2013
Duke Energy Progress
Transmission Department
PURPOSE

The purpose of this study is to assess the impacts of a combined wind/solar farm interconnection request on the reliability of the Duke Energy Progress (DEP) transmission system with respect to power-flow, stability, short circuit, and power factor requirements issues. The proposed project was studied as a Network Resource Interconnection. Estimates of the cost and time required to interconnect the generation as well as to resolve the impacts as determined in this system impact analysis are also included. The DEP internal system analysis consists of an evaluation of the internal DEP transmission system utilizing documented transmission planning criteria. The request is described in Table 1 below.

Table 1: Request

<table>
<thead>
<tr>
<th>DEP Generator Interconnection Queue No.</th>
<th>MW</th>
<th>In-Service Date</th>
<th>County</th>
<th>Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queue #297</td>
<td>120.8</td>
<td>12/31/14</td>
<td>Carteret County, NC</td>
<td>Havelock – Morehead Wildwood 230 kV Line</td>
</tr>
</tbody>
</table>

The 120.8 MW total is comprised of 42 Nordex N117 2.4 MW wind turbines and 20 Solaron inverters rated at 1 MW each. Interconnection to DEP's breaker station is via a customer supplied 230 kV tap line. A Scoping Meeting was held on January 23, 2013.

ASSUMPTIONS

The following system impact study results are from the DEP internal power-flow models that reflect specific conditions of the DEP system at points in time consistent with the generator interconnection requests being evaluated. The cases include the most recent information for load, generation additions, transmission additions, interchange, and other pertinent data necessary for analysis. Future years may include transmission, generation, and interchange modifications that are not budgeted for and for which no firm commitments have been made. Further, DEP retains the right to make modifications to power-flow cases as needed if additional information is available or if specific scenarios necessitate changes. For the systems surrounding DEP, data is based on the ERAG MMWG model. The suitability of the model for use by others is the sole responsibility of the user. Additional assumptions are addressed in the following results for each area of analysis (i.e. power-flow, stability, and short circuit).

The results of this analysis are based on Interconnection Customer’s queue requests including generation equipment data provided. If the facilities’ technical data or interconnection points to the transmission system change, the results of this analysis may need to be reevaluated.

This study was based on the following assumptions:

- The Customer would have one interconnect point to a new breaker station off the Havelock – Morehead Wildwood 230 kV Line.
- The Customer would construct, own and operate the electrical infrastructure that would connect their generation to the new breaker station off the Havelock – Morehead Wildwood 230 kV Line, including any step up transformers and lines from...
the generation project, but excluding the 230 kV circuit breaker in the new breaker station.

RESULTS

**Power-flow Analysis Results**
Facilities that may require upgrade within the first three to five years following the in-service date are identified. Based on projected load growth on the DEP transmission system, facilities of concern are those with post-contingency loadings of 95% or greater of their thermal rating or low voltage of 0.92 pu and below, for the requested in-service year. The identification of these facilities is crucial due to the construction lead times necessary for certain system upgrades. This process will ensure that appropriate focus is given to these problem areas to investigate whether construction of upgrade projects is achievable to accommodate the requested interconnection service.

As requested, the 120.8 MW wind farm was studied interconnected to a new breaker station off the Havelock – Morehead Wildwood 230 kV Line. Contingency analysis study results show that interconnection of this generation facility does not result in any thermal issues on the DEP system.

**Stability Analysis Results**
A stability evaluation was performed to determine the impact of the proposed generation addition on the DEP transmission system and other nearby generation. The proposed 120.8 MW addition is comprised of 100.8 MW of wind generation and 20 MW of solar generation. The wind generation consists of 42 Nordex N117 wind turbines rated at 2.4 MW each. The solar generation consists of a solar collector array with 20 Solaron inverters rated at 1 MW each. Each solar inverter has a 1.12 MVA capacity at 1.0 per unit voltage. The wind turbines and solar inverters are connected via a single 34.5 kV collector array to a single 34.5/230 kV step-up transformer. For modeling purposes the wind turbines and solar inverters were represented as one lumped equivalent wind generator and one lumped equivalent solar generator, each connected via an individual step up transformer to the 34.5 kV collector system, which in turn is connected to the transmission system via an individual 34.5/230 kV step up transformer.

A number of representative faults were simulated at the POI and at nearby substations to determine stability and voltage and frequency ride through capabilities. The results of the evaluation did not identify any stability related problems.

Note that the dynamic models used for both the Nordex wind turbines and the Solaron inverters did not have an “automatic voltage regulator voltage control” mode. Additional discussions will be needed to determine how this function will be implemented in the installed machines and how to more appropriately model this required function. If the Customer provided data or new information on the actual operating limitations of the wind and solar machines change the stability performance, these results will need to be reevaluated.
**LGIP Power Factor Requirements**

DEP's generator interconnection requirements stipulate that proposed generation additions be capable of delivering the proposed power to the point of interconnection at a 0.95 lagging power factor.

The Customer provided data for the wind turbines, solar inverters, transformers and 34.5 kV collector array configuration were used to evaluate the capability to meet the 0.95 lagging power factor requirement. The results of this analysis indicate that the proposed installation, as a whole, does not meet the power factor requirement. Individually, the solar inverters appear to be capable of meeting the requirement but the wind machines do not appear to be capable of meeting the requirement. Additionally, based on the dynamic models provided, it is not clear that either the wind or solar units can be operated in the “automatic voltage regulator- voltage control” mode. This would also be a requirement since dynamic reactive power support is necessary (i.e. the proposed generation should be capable of providing reactive power immediately and automatically in response to voltage perturbations on the transmission system). DEP and the Customer have discussed potential solutions for meeting the power factor requirement. It has been determined that if the proposed 20 MVar Customer capacitor bank were increased to 23 MVar then the power factor requirement would be met.

**Estimate to Meet LGIP Power Factor Requirements**

The costs, if any, of meeting the LGIP Power Factor requirements will be associated with the design and installation of Customer owned equipment.

Since these costs will be incurred by the Customer, they are not included in this estimate.

**Short Circuit Analysis Results**

A short circuit evaluation was performed to assess the impact of the proposed generation addition on transmission system equipment capabilities. The evaluation indicates that no short circuit equipment capabilities will be exceeded as result of the proposed generation addition.

The results of the short circuit study are based on Customer provided generation equipment data and location. If the Customer provided technical data or interconnection points to the transmission system changes, the results of this analysis may need to be reevaluated.

**Interconnection of Customer’s Generation**

The point of interconnection for Queue #297 would be at a new DEP breaker station off the Havelock – Morehead Wildwood 230 kV Line, as shown in Figure 1. The new generation will be connected to the 230 kV point of interconnection via a Customer provided 230 kV line from the plant. The customer should verify that the MVA ratings of their lines are sufficient to accommodate delivering the total wind/solar farm MVA output to the point of interconnection at the required 0.95 power factor.
Estimate of Interconnection Cost
Total Interconnection Cost Estimate: $1,750,000 (total)

The estimate includes the assumption that DEP will acquire and use a portion of the property that the Customer will secure for the addition of the facility. The specifics of the property needed for the DEP facilities will be further identified in the Interconnection Agreement (IA).

Tap Line
Description: Tap DEP’s Havelock-Morehead Wildwood 230 kV Line and Construct Line to New Breaker Station adjacent to DEP ROW.
Estimated Cost: $300,000

New Breaker Station
Description: Construct new 1-230 kV breaker station at generation new connection point.
Estimated Cost: $700,000

Install Transfer Trip Scheme at New Breaker Station and Transmission Substations
Description: It will be necessary to separate this generation facility from the DEP system for faults on the Havelock-Morehead Wildwood 230 kV Line. Install protection system and transfer trip for coordination between DEP’s Havelock-Morehead Wildwood 230 kV Line and proposed generation facility.
Estimated Cost: $250,000

New Wave Traps on Tap Line to New P.O.I.
Description: Install Wave Trap at new Tap off of DEP’s Havelock-Morehead Wildwood 230 kV Line at new connection point.
Estimated Cost: $100,000

Line Switches in DEP’s Transmission Line to be Tapped for New P.O.I.
Description: Install required Line Switches on DEP’s Havelock-Morehead Wildwood 230 kV Line at New Tap Point.
Estimated Cost: $400,000

SUMMARY

Below is a summary of DEP’s estimated costs to interconnect the Customer’s generation and resolve the identified DEP transmission system impacts. Actual solutions, cost estimates and implementation schedules for Queue #297 will be finalized in the Customer’s Interconnection Facilities Study if requested. The results of the analysis indicate that the planned installation, as originally proposed, does not meet the power factor requirement but increasing the size of the Customer capacitor bank is a viable solution.

Current estimates are that the proposed upgrades can be completed to meet the Customer’s schedule. This is based on an assumption that DEP would have a firm commitment from the customer no later than 12 months prior to the In Service Date of the proposed generation.
The additional cost for telecommunications and metering can be estimated as a monthly charge of $3,000/month.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Power-flow</td>
<td>$0</td>
</tr>
<tr>
<td>Stability</td>
<td>$0</td>
</tr>
<tr>
<td>Short Circuit</td>
<td>$0</td>
</tr>
<tr>
<td>Interconnection</td>
<td>$1,750,000</td>
</tr>
<tr>
<td>Total Estimate</td>
<td>$1,750,000</td>
</tr>
</tbody>
</table>
INSTALL 230 KV CIRCUIT BREAKER AND ASSOCIATED EQUIPMENT INCLUDING PROTECTION SYSTEM AND TRANSFER TRIP FOR COORDINATION WITH HAVELock-MOREHEAD WILDWOOD 230 KV LINE AND INTERCONNECT THE FACILITY.