Large Generator Interconnection
Feasibility Study Report

Completed for
Interconnection Customer
Q0304

Proposed Interconnection
PacifiCorp’s Existing
115 kV Ponderosa substation

April 1, 2010
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1.0 DESCRIPTION OF THE GENERATING FACILITY

Interconnection Customer has proposed interconnecting a new 102.5 MW generating facility Project to PacifiCorp’s (“Transmission Provider”) existing facilities at the Ponderosa substation located in Lake County, Oregon. The proposed generation facility will consist of forty one (41) Fuhrländer FL 2500 2.5 MW wind turbine generators and will interconnect with the Ponderosa substation via a new 70 mile 115 kV transmission line.

The proposed commercial operation date is December 31, 2012.

Transmission Provider has assigned this project queue number Q0304.

2.0 SCOPE OF THE STUDY

The Interconnection feasibility study (“Study”) report (“Report”) shall provide the following information:

- preliminary identification of any circuit breaker short circuit capability limits exceeded as a result of the interconnection;
- preliminary identification of any thermal overload or voltage limit violations resulting from the interconnection; and
- preliminary description and non-binding estimated cost of facilities required to interconnect the large generating facility to the transmission system and to address the identified short circuit and power flow issues.

3.0 TYPE OF INTERCONNECTION SERVICE

The Interconnection Customer has selected Network Resource (NR) interconnection service, but has also elected to have the interconnection studied as an Energy Resource (ER). The Interconnection Customer will select NR or ER prior to the facilities study.

4.0 DESCRIPTION OF PROPOSED INTERCONNECTION

The major equipment required to interconnect the Q0304 generation Project to the Transmission Provider’s existing 115 kV facilities at the Ponderosa substation include two new circuit breakers, associated switches, metering and the extension of the Ponderosa 115 kV bus. Protection and control equipment and communication equipment will be required at the Interconnection Customer’s collector substation and at the Ponderosa substation. The Interconnection customer will be required to design, construct and own a approximately 70 mile 115 kV radial transmission line from the point of interconnection to the Q0304 generating facilities.
4.1 Other Options Considered (NERC Requirement)

The Interconnection Customer could construct a new point of interconnection substation to tap the existing Ponderosa – Prineville 115 kV transmission line but, this option would be more costly than interconnecting to the existing 115 kV facilities at the Ponderosa substation.

5.0 STUDY ASSUMPTIONS

- All active higher priority transmission service and/or generator interconnection requests will be considered in this study and are listed in Appendix 1. If any of these requests are withdrawn, the Transmission Provider reserves the right to restudy this request, and the results and conclusions could significantly change.

- For study purposes there are two separate queues:
  - Transmission Service Queue: to the extent practical, all network upgrades that are required to accommodate active transmission service requests and are expected to be in-service on or before the Interconnection Customer’s requested in-service date for the Project will be modeled in this study. Network upgrades assumed to be in-service at the requested Project in-service date include:
    - BPA Redmond second 230-115 kV transformer.
    - BPA Redmond - PAC Redmond 115 kV line re-conductor ed with 1272 ACSR.
    - New 69 kV, 20 MVAr capacitor bank at Transmission Provider’s Pilot Butte substation.
    - New 115 kV three breaker ring bus switching station looping through Transmission Provider’s Prineville – Powell Butte line.
  - Generation Interconnection Queue: when relevant, interconnection facilities associated with higher queue interconnection requests will be modeled in this study. However, network upgrades required to provide delivery will only be modeled for Projects which have requested network resource integration service or qualified facility status. No generation will be simulated from any higher queued project unless a commitment has been made to obtain transmission service.
• The Interconnection Customer’s request for energy or network resource interconnection service in and of itself does not convey transmission service. Only a network customer can make a request to designate a generating resource as a network resource. Since the queue of higher priority transmission services requests may be different when and if a network customer’s requests network resource designation for this generation facility, the available capacity or transmission modifications, if any, necessary to provide network resource interconnection service may be significantly different. Therefore, the Interconnection Customer should regard the results of this study as informational rather than final.

• This study assumes the Project will be integrated into the Transmission Provider’s system with a point of interconnection at the Transmission Provider’s existing facilities at the Ponderosa substation.

• The Interconnection Customer will construct and own all facilities required between the point of interconnection and the Project.

• Interconnecting Customer’s facilities are as specified in the feasibility study technical documentation received from the Interconnection Customer February 10, 2010 and as amended in subsequent technical data submissions received February 25, 2010.

• Interconnection Customer’s collector substation facilities are as shown on the Interconnection Customer supplied preliminary substation one-line diagram, dated November 12, 2009. Collector substation step-up transformer is specified as 115 kV-34.5 kV, 75/100/125 MVA with 10% impedance specified on a 75 MVA base and an X/R ratio of 30.

• The Fuhrländer FL 2500, 2.5 MW, turbines are specified as doubly-fed induction generators, with back-to-back IGBT converters and are capable of active and continuous voltage control within a power factor range of 0.95 lead to 0.95 lag.

• Each wind turbine generator will be stepped from 690 V to 34.5 kV via individual 2700 kVA transformers with 6.0% impedances on their nameplate base and an X/R ratio of 10.

• Interconnection Customer’s line parameter data for the 70 mile, 115 kV radial transmission line was specified as: \( R = 97 \, \Omega \), \( X_R = 52 \, \Omega \), \( X_C = 1290 \, \Omega \). The stated resistance of 1.39 \( \Omega \)/mi is similar to a #1 ACSR conductor. This resistance would cause real power losses of up to 48 MW at full project output. For the purposes of this study, the transmission line was modeled with 795 ACSR one single pole construction and phase spacing typical of Transmission Provider’s area 115 kV transmission lines.
• Generator tripping may be required for certain outages.

• All facilities will meet or exceed the minimum WECC, NERC, and the Transmission Provider’s performance and design standards

5.1 Energy Resource (ER) Interconnection Service

Energy resource interconnection service allows the Interconnection Customer to connect its generating facility to the Transmission Provider’s transmission system and to be eligible to deliver electric output using firm or nonfirm transmission capacity on an as available basis. Consistent with Section 38.2.2.2 of the Transmission Provider’s Open Access Transmission Tariff, the facility will be studied such that deliverability will be determined to the Transmission Provider’s aggregate network loads assuming some portion of existing network resources are displaced by the output of the Interconnection Customer’s large generating facility. Energy resource interconnection service in and of itself does not convey transmission service.

5.1.1 Discussion

For the purposes of this feasibility study, the forty-one Fuhrländer FL 2500 2.5 MW turbines were modeled as a single generator, having a real power output of 102.5 MW and a reactive range of 33.7 MVAr leading to 33.7 MVAr lagging (.95 pf). Based on information received from the Interconnecting Customer, the generating facility is capable of continuously varying the reactive power output of the machines to operate at a voltage set-point at the collector substation 34.5 kV bus. The line parameters submitted by the Interconnecting Customer do not appear to be realistic for the 70 mile 115 kV radial interconnection line. For the purposes of this study, the line was modeled with 795 ACSR on single pole transmission structures with spacing typical of the Transmission Provider’s local area transmission lines. At full Q0304 project output (102.5 MW), real power losses of approximately 7 MW were observed. A larger, lower resistance conductor may be preferred by the customer. In order to provide an accurate representation of the system, the Interconnecting Customer must specify the exact line parameters in the system impact study phase.

A power flow analysis was performed by adding the proposed Q0304 Project to a simulation of the power system. Power flows and voltages were evaluated with and without Q0304 connected to determine the impact on the transmission system during normal operation (N-0 configuration) and during outages of one transmission element at a time (N-1 configuration).

Normal transmission system operation for the local area transmission system is defined as the closed 115 kV transmission line connecting the energized buses at the Ponderosa substation and the BPA Redmond substation, and the Ponderosa 230 kV-115 kV transformer and the BPA Ponderosa 500kV-230kV transformer connected to energized 230 kV and 500 kV systems.
Power flow analysis was performed using system models at peak summer, peak winter and light loading conditions. Steady-state thermal and voltage violation screening, post-transient voltage deviation monitoring and a preliminary reactive margin analysis were performed to determine the feasibility of interconnection. A more detailed analysis, using a non-aggregate project model, will be performed in the system impact study.

5.1.2 Requirements

5.1.2.1 Generating Facility Modifications
Generator interconnections are required to operate under automatic voltage control with the voltage sensed electrically at the point of interconnection. This can be achieved using the reactive capabilities of the generators, by controlling shunt reactive support devices or some combination of both. The generating and interconnecting facility must have sufficient reactive capability to enable the delivery of 100 percent of the plant output to the point of interconnection at unity power factor measured at 1.0 per unit voltage under steady state conditions.

The 70 mile, 115 kV transmission line creates a significant amount of reactive loss. Using the Transmission Provider’s standard single pole transmission line construction, reactive losses of up to 30 MVar at full 102.5 MW generating output were observed. The collector substation step-up transformer, specified with relatively high 10% impedance, creates additional reactive power loss. To meet power factor requirements at the point of interconnection while maintaining acceptable collector system voltages, it is expected that the Interconnecting Customer will need to install switch shunt reactive support near the point of interconnection. Power flow simulations indicate that if the generators are set to control the collector substation 34.5 kV bus to 1.04 pu voltage, the generators will operate between 0.98 and 0.99 leading (producing VArS) under system normal conditions. Due to the reactive losses in the lines and transformers, an additional 30 MVar switched shunt reactive support is required to achieve unity power factor at the point of interconnection.

Per NERC standard VAR-001-1a, the Transmission Provider is required to specify voltage or reactive power schedule at the point of interconnection. Under normal conditions, the generation and interconnection facilities should be operated so as to maintain the voltage at the point of interconnection between 1.01 pu to 1.04 pu. Within this voltage range, the generating and interconnecting facilities should operate to minimize the reactive interchange between the generation/interconnection facilities and the Transmission Provider’s system (i.e operating at unity power factor at the point of interconnection). If the voltage is outside the upper or lower range, the voltage control scheme should operate to utilize the reactive capabilities of the generating and interconnecting facilities to maintain the voltage to a value within the control band. The control scheme should be designed so as to avoid hunting when switching between modes (i.e., effectively power factor control inside the band, voltage control outside the band).
The Interconnection Customer will be responsible for designing and setting the control systems to maintain the acceptable voltage range. Settings must be coordinated with the Transmission Provider prior to energization (or interconnection). The reactive compensation must be designed such that the discrete switching of any reactive device does not cause step voltage changes greater than +/-3% on the Transmission Provider’s system. Based on powerflow analysis, single-stage switching of a 115 kV, 30 MVAr capacitor bank near the Transmission Provider’s Ponderosa substation bus will not cause an excessive step voltage change.

Simulations were ran for system normal and contingency events during heavy summer, heavy winter and light loading conditions. No new post-transient voltage deviations exceeding NERC/WECC system performance criteria for Category B disturbances (greater than 5% deviation) were observed. However, during light loading conditions at full generating facility output (102.5 MW), a Ponderosa 230 kV-115 kV transformer trip will cause a new voltage deviation of up to 4.27% on the Ponderosa 115 kV bus and 3.26% on the load-serving Prineville 12.5 kV bus. Significant post-transient voltage deviations are listed in table 5.1.2.1.1 below:

<table>
<thead>
<tr>
<th>Contingency</th>
<th>Monitored Bus</th>
<th>Pre-Project</th>
<th>Post-Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy Summer, Ponderosa 500-230 kV</td>
<td>Prineville 12.5 kV</td>
<td>-10.33%</td>
<td>-7.00%</td>
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<tr>
<td>Transformer Trip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy Summer, Ponderosa 500-230 kV</td>
<td>Houston Lake 115 kV</td>
<td>-8.52%</td>
<td>-5.81%</td>
</tr>
<tr>
<td>Transformer Trip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy Winter, Ponderosa 500-230 kV</td>
<td>Prineville 12.5 kV</td>
<td>-15.06%</td>
<td>-8.16%</td>
</tr>
<tr>
<td>Transformer Trip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy Winter, Ponderosa 500-230 kV</td>
<td>Houston Lake 115 kV</td>
<td>-12.37%</td>
<td>-7.73%</td>
</tr>
<tr>
<td>Transformer Trip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy Winter, Ponderosa 500-230 kV</td>
<td>Redmond 12.5 kV</td>
<td>-10.59%</td>
<td>-6.45%</td>
</tr>
<tr>
<td>Transformer Trip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Load, Ponderosa 230-115 kV</td>
<td>Ponderosa 115 kV</td>
<td>1.18%</td>
<td>4.27%</td>
</tr>
<tr>
<td>Transformer Trip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Load, Ponderosa 230-115 kV</td>
<td>Prineville 12.5 kV</td>
<td>0.88%</td>
<td>3.26%</td>
</tr>
<tr>
<td>Transformer Trip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy Winter, Q0304 115 – 34.5 kV</td>
<td>Prineville 12.5 kV</td>
<td>N/A</td>
<td>2.72%</td>
</tr>
<tr>
<td>Transformer Trip</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy Winter, Q0304 115 kV, 30 MVAr Capacitor Trip</td>
<td>Prineville 12.5 kV</td>
<td>N/A</td>
<td>-1.26%</td>
</tr>
<tr>
<td>Light Load, Q0304 115 kV Point of Interconnection Circuit Breaker Trip</td>
<td>Prineville 12.5 kV</td>
<td>N/A</td>
<td>-1.65%</td>
</tr>
</tbody>
</table>

Table 5.1.2.1.1 – Post-transient Voltage Deviations
The voltage deviations listed above are preliminary, based on the modeling assumptions stated in section 5.0 on the previous page. Steady-state stability, steady-state voltage deviations and transient stability will be studied in detail for the System Impact Study using a complete, non-aggregate, project model and updated line parameters.

Preliminary reactive margin analysis indicates the project may have very limited margin at the Q0304 collector substation bus for the single contingency loss of the Ponderosa 500-230 kV transformer. This is likely due to the long radial interconnection of the project. Further analysis indicates that if the turbine type is changed to one that cannot actively control reactive power output, the project will be reactive margin deficient for either a Ponderosa 500 kV-230 kV or a Ponderosa 230 kV-115 kV transformer outage. A reactive margin deficiency indicates potential for voltage collapse during the post-transient period within approximately 3 minutes following a disturbance. Voltage collapse begins at the weakest bus in the system and propagates to other buses. Based on the preliminary analysis, if the generator type is changed to a fixed power factor machine, some form of dynamic reactive compensation device will likely be required to maintain steady-state stability.

All wind turbines must meet the Transmission Provider’s low voltage ride-through requirements as specified in the interconnection agreement. Low voltage ride-through capability will be evaluated in the system impact study.

5.1.2.2 Transmission Modifications
The proposed point of interconnection for Q0304 Project is on the Transmission Provider’s Ponderosa substation 115 kV bus. Interconnection will require completion of the 115kV ring bus, including two new 115 kV circuit breakers, associated switches and bus work. Unless otherwise specified in future studies, the Interconnection Customer will be responsible for the design, construction and ownership of all facilities between the point of interconnection and the Q304 generation facilities.
Figure I: System One Line Diagram
5.1.2.3 Existing Circuit Breaker Upgrades – Short Circuit
The increase in the fault duty on the system as a result of the addition of the generation facility with forty one Fuhrländer FL 2500 2.5MW wind turbine generators fed through one 75/125MVA step up transformer with 10% impedance will not push the fault duty above the interrupting rating of any of the existing fault interrupting equipment.

5.1.2.4 Protection Requirements
The installation of protective relays for line fault detection will be required at Ponderosa substation for the protection of the line to the Interconnection Customer’s collector substation. A current differential line protection system will be used for this line. The line relays will communicate over a high speed digital communication circuit which could be an optical fiber cable strung on the transmission line structures. The Transmission Provider will supply a relay panel to be installed in the Interconnection Customer’s collector substation. This panel will contain the equipment needed to function with the relays to be installed at Ponderosa substation to provide high speed protection for the 115 kV line.

In addition to the line protective relaying a relay used for under/over voltage and over/under frequency protection of the system will be installed at Ponderosa substation. If the voltage, magnitude or frequency, is outside of the normal operation range this relay will key transfer trip that will open all of the Interconnection Customer’s 34.5 kV line breakers at the collector substation.

5.1.2.5 Data (RTU) Requirements
Data for the operation of the power system will be needed from the Q0304 collector substation. This data will be acquired by installing a data concentrator at the collector station. The data concentrator will communicate with the RTU at Ponderosa substation. The data stream between the data concentrator and the RTU will use DNP 3.0 protocol and flow over the digital communication system between the substations.

In addition to the control and indication of the 115 kV breakers in the Ponderosa substation the following data will be acquired through the substation RTU. Also listed is the data that will be acquired from the collector station.
From the Ponderosa substation:

**Analogs:**
- Net Generation MW
- Net Generator MVAr

**Accumulator Pulses:**
- Interchange metering kWH

From the Collector Station:

**Analogs:**
- Real power flow through each of the 34.5 kV line feeder breakers
- Reactive power flow through each of the 34.5 kV line feeder breakers
- Reactive power flow from each of the shunt capacitor banks
- A phase 115 kV transmission voltage
- B phase 115 kV transmission voltage
- C phase 115 kV transmission voltage
- Wind speed

**Status:**
- All 34.5 and 115 kV breakers
- Line Relay Alarm

### 5.1.3 Cost Estimate

**Interconnection – Direct Assigned Facilities**
- Metering, relays, communications, protection & controls $2,000,000

**Subtotal – Direct Assigned Facilities** $2,000,000

**Interconnection – Network Upgrades**
- Engineering, procurement and construction costs to upgrade the Ponderosa substation with two new circuit breakers and associated switches, extension of the existing Ponderosa bus, protection and control and communications equipment.
- $5,000,000

**Subtotal – Network Upgrades** $5,000,000

**Total Cost – ER Interconnection Service – Interconnection Only** $7,000,000
5.1.4 Schedule
It will take approximately 18 months from the execution of a large generator interconnection request to engineer, procure, and construct the facilities necessary to interconnect the proposed Project.

5.1.5 Maximum Amount of Power that can be delivered into Network Load, with No Transmission Modifications (for informational purposes only).
See discussion in Section 5.2 Network Resource (NR) interconnection service.

5.1.6 Additional Transmission Modifications Required to Deliver 100% of the Power into Network Load (for informational purposes only)
See discussion in Section 5.2 Network Resource (NR) interconnection service.

5.2 Network Resource (NR) Interconnection Service
Network resource interconnection service allows the Interconnection Customer to integrate its large generating facility with the Transmission Provider’s transmission system in a manner comparable to that in which the Transmission Provider integrates its generating facilities to serve native load customers. The transmission system is studied at peak load, under a variety of severely stressed conditions. In order to determine the transmission modifications, if any, which are necessary in order to deliver the aggregate generation in the area of the point of interconnection to the Transmission Provider’s aggregate load, and assumes that some portion of existing network resources are displaced by the output of the Interconnection Customer’s large generating facility. Network resource interconnection service in and of itself does not convey transmission service.

5.2.1 Discussion
Transmission Provider’s local area network load is approximately 58 MW during light load periods. The Q0304 Project will result in a net power export from the area onto BPA’s transmission system during much of the year. The Interconnection Customer’s transmission agent will need to make arrangements with BPA for transmission service for the excess generation or construct approximately 120 miles of new 115 kV transmission line between the Q0304 collector substation and the Transmission Provider’s Klamath Falls (Chiloquin), Oregon load center.
5.2.2 Requirements

5.2.2.1 Generating Facility Modifications
See Section 5.1.2.1.

5.2.2.2 Transmission Modifications
No equipment thermal overloads or steady-state voltage violations were observed on the Transmission Provider’s local area transmission network as a result of network resource integration of Q0304.

5.2.3 Cost Estimate

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interconnection – ER Only</td>
<td>$7,000,000</td>
</tr>
<tr>
<td>NR Interconnection (Construction of 120 miles of 115 kV transmission line from the Q0304 collector substation to Chiloquin)</td>
<td>$120,000,000</td>
</tr>
</tbody>
</table>

Total Cost – NR Interconnection Service – Interconnection Only $127,000,000

5.2.4 Schedule
Provided Rights of Way and easements are readily available to construct 120 miles of 115 kV transmission line, it will take approximately 48 months from the execution of a large generator interconnection agreement to engineer, procure, and construct the facilities necessary to interconnect the proposed Project.

6.0 Participation by Affected Systems

Transmission Provider has identified the following as affected systems: Bonneville Power Administration. Copies of this report will be shared with each affected system.