Southwest Power Pool

Facility Study
For
Generation Interconnection
Request
GEN-2005-015

SPP Tariff Studies

(#GEN-2005-015)

March, 2007

Summary

Pursuant to the tariff and at the request of the Southwest Power Pool (SPP), Xcel Energy performed the following Facility Study to satisfy the Facility Study Agreement executed by the requesting customer and SPP for SPP Generation Interconnection request Gen-2005-015. The request for interconnection was placed with SPP in accordance SPP's Open Access Transmission Tariff, which covers new generation interconnections on SPP's transmission system.

Impact Re-Study

The Facility Study conducted by Xcel included a switching surge study using an electromagnetic transients program (EMTP) to determine if transmission line reactors were required for the generation interconnection request, and if so, to size the reactors.

The EMTP study determined that a 25Mvar line reactor is required at the wind farm switching station 345kV line terminal to Tuco and a 50Mvar line reactor is required at the wind farm switching station 345kV line terminal to Oklaunion. These values are larger than the estimated line reactor sizes studied in the original impact study. Therefore, the impact study was conducted again using the same contingencies on a summer peak model and a winter peak model and including the newly sized line reactors.

The Customer's original requested turbine type (Games G87 2.0 MW) was utilized for the restudy using the turbine layout submitted for the original study.

Due to the addition of the line reactors, the Customer will now be required to install 21Mvar of 34.5kV capacitor bank(s) in the Customer substation in order to maintain a unity power factor at the point of interconnection.

Stability Study results show that the transmission system remains stable for all simulated contingencies studied. Further Stability study results shows that for the wind farm using the Gamesa wind turbines will meet the provisions of FERC Order #661A's Low Voltage Ride Through (LVRT) provisions as long as the wind turbines operate in a power factor range of 0.97-0.98 lagging (producing vars).

Nothing in this study should be construed as a guarantee of transmission service. If the customer wishes to sell power from the facility, a separate request for transmission service shall be requested on Southwest Power Pool's OASIS by the Customer.

The entire Impact Re-Study can be found as Attachment 1 following the Facility Study in this document.

Facilities Study For
[Omitted Text]

150 MW Wind-Generated Energy Facilities
Motley County, Texas
SPP #GEN-2005-015

March 15, 2007

Xcel Energy Services, Inc.
Transmission Planning

Executive Summary

[Omitted Text] ("Interconnection Customer") has requested the connection of a wind energy facility to the Southwestern Public Service Company (SPS) (d/b/a Xcel Energy, Inc.) 345 kV transmission line. This facility is a new wind energy generation facility located approximately 46 miles east of TUCO Interchange and will be interconnecting to the 345 kV transmission circuit between TUCO and Oklaunion. The Southwest Power Pool (SPP) evaluated the request to connect this wind energy facility to the SPS transmission system in a System Impact Study completed in April 2006. This connection request was studied using seventy-five (75) individual Gamesa G87 2.0 MW wind turbines for a total of 150 MW. The Interconnection Customer's requested in-service date is December 20, 2007 for commercial operation.

Xcel Energy will require the Interconnection Customer to construct the Connection Facilities in compliance with the latest revision of the Xcel Energy Interconnection Guidelines for Transmission Interconnection Producer-Owned Generation Greater than 20 MW, Version 2.0 dated Jan. 20, 2004, and is available at http://www.xcelenergy.com/XLWEB/CDA/0,3080,1-1-1_16699_24407-1428-0_0_0-0,00.html. This document describes the requirements for connecting new generation to the Xcel Energy operating company transmission systems including technical, protection, commissioning, operation, and maintenance. Xcel Energy will also require that the Interconnection Customer be in compliance with all applicable criteria, guidelines, standards, requirements, regulations, and procedures issued by the North American Electric Reliability Council, (NERC), Southwest Power Pool (SPP), and Federal Energy Regulatory Commission (FERC) or their successor organizations.

The Interconnection Customer is responsible for the cost of the Interconnection Facilities and any Direct Assigned Interconnection Facilities; inclusive of all construction required for the 345 kV transmission line from the Interconnection Customer's substation to the switching station.

It is anticipated that the construction of the new switching station, for the acceptance of wind generated electric energy from the Interconnection Customer's Wind Farm, will require approximately 15 months for completion from the day an interconnection agreement is signed and after all internal approvals, unless prior arrangements have been made. The requested in-service date was December 2006, which is not feasible. The cost of these upgrades, inclusive of the Interconnection Customer's cost for the Interconnection Facilities required for the connection of this new wind energy generation facility, is shown below. See Table 2 for a detail description of all the costs.

Upgrade	Cost
Stand-alone Network Upgrade:	$ 9,620,988
Network Upgrade:	$ 535,000
Interconnection Facilities [1]:	$ 238,204
Total:	$ 10,394,192

These costs were estimated using 2007 costs (2007 dollars) with no AFUDC[2] added with an estimated accuracy is ± 20%.

[1] Direct Assigned Cost To Requester for the interconnection facilities
[2] AFUDC - Allowance for Funds Used During Construction.

An EMTP[3] study (at the Interconnection Customer's expense) was completed to determine the size of the line reactors as part of this facilities study.

[3] Electromagnetic Transient Program

Discussion

A new 345 kV switching station is required for the Interconnection of the Customer's wind-generated energy facility and it will be located adjacent to the existing 345 kV transmission line and the Cedar Cap Substation. The new switching station will consist of three 345 kV breakers in a ring bus configuration. The existing transmission line will be routed in and out of the new switching station. A 345 kV bus will be built from the Cedar Cap Substation to the 345 kV switching station. The Interconnection Customer will connect their 345 kV transmission bus from the Wind Farm's Substation to SPS's Cedar Cap Switching Station.

General Description of Modifications and New SPS[4] Facilities

1. **Construction of the New Switching Station:** See Figure A-2 in Appendix A for one-line diagram and Figure A-3 for a plan view of the station.

   1.1. **Location:** The new 345 kV switching station is located adjacent to J-01 on the north side and adjacent to the Customer's Cedar Cap Substation. These facilities are located approximately 46 miles east of the TUCO Interchange in the H & G N Railroad Survey, Block 1, and West half of Section 9, Floyd County, Texas.

   1.2. See Figure A-1 for a map of the local transmission system.

   1.3. **Bus Design:**

      1.3.1. The new 345 kV switching station will be built to accommodate the output from the wind energy facility. The new bus design will be a 3-breaker ring with 3 terminals expandable to a breaker and one half design. The terminals will be: One for the tap to the wind farm connection from their substation; a second one for the 345 kV line from the TUCO Interchange; and a third one for the 345 kV line to Oklaunion Interchange. The new breaker design that is proposed is shown in Figure A-2 in Appendix A.

   1.4. **Control House:** The control house will be utilized to house the new metering, protective relaying and control devices, terminal cabinets, and any fiber-optic cable terminations, etc. for the new 345 kV switching station.

   1.5. **Line Reactors:** Switchable line reactors will be installed at the new switching station to control high voltage. The reactors will be connected to the 345kV lines toward TUCO Interchange (25 MVAr) and toward Oklaunion Interchange (50 MVAr). These reactors were determined through an EMTP study.

   1.6. **Security Fence:** The switching station will have a 7-foot chain-link fence with steel posts set in concrete, with 1-foot of barbed wire on the top in a "V" configuration. The enclosed area will be approximately 800' by 800', with a rock yard surface.

[4] All modifications to SPS facilities will be owned, maintained and operated by SPS.

1.7. **Ground Grid:** A complete ground-grid will be installed per ANSI/IEEE STD 80-2000, with our standard 4/0 copper ground mesh on 40-foot centers with ground rods and 20-foot centers in the corners and the loop outside of the fence.

1.8. **Site Grading:** Company contractor, per company specifications, will perform initial site grading and erosion control of the new switching station. Soil compaction shall be not less than 95% of laboratory density as determined by ASTM-D-698.

1.9. **Station Power:** A 199 kV/120-240 volt transformer tapped off of the 345 kV bus will provide station power. A backup station power source will be taken from local distribution. Additionally, an automatic throw over switch to automatically transfer the station power will be installed.

1.10. **Relay and Protection Scheme**: The 345 kV transmission line between the new switching station to the TUCO Interchange will have two pilot schemes. The first will be a directional comparison-unblocking scheme with transfer trip (send and receive) using a SEL 321-1 relay and a Pulsar TCF-10B, 3-frequency carrier with amplification. The second scheme is a directional comparison-unblocking scheme with transfer trip (send and receive) using a SEL 421 relay and a Pulsar TCF-10B, 3-frequency carrier with amplification. Re-closing will utilize logic built into SEL-421 line relay. Breaker failure relaying is also required.

The 345 kV transmission line between the new switching station to the Oklaunion Interchange will have two pilot schemes. The first will be a directional comparison-unblocking scheme with transfer trip (send and receive) using a SEL 321-1 relay and a Pulsar TCF-10B, 3- frequency carrier with amplification. The second scheme is a directional comparison-unblocking scheme with transfer trip (send and receive) using a SEL 421 relay and a Pulsar TCF-10B, 3-frequency carrier with amplification. Re-closing will utilize logic built into SEL-421 line relay. Breaker failure relaying is also required.

Two sets of 345 kV PTs will be installed on the west and east buses with disconnect switches. There will be a provision made for an automatic throw-over of the PTs. A manual transfer switch will be available for maintenance purposes.

On both the TUCO Interchange and Oklaunion Interchange lines, there will be CCVT's for line conditions with phase-to-phase coupling. Line tuning units and wave traps will also be installed for the power line carrier communications.

Line arresters will be installed at each line termination on the dead-end towers.

1.11. **Revenue Metering:** On the 345 kV line to the Interconnection Customer's substation, a billing meter will be installed along with an ION 8400 meter unit, ANSI C12.1 accuracy class 0.2 (3 PTs IEEE C57.13 accuracy class 0.3 and 3 CTs IEEE C57.13 accuracy class 0.15) for full 3 phase 4-wire metering. The metering unit will have 1000/600:1 PTs and 200/400:5 CTs. There will be two meters; one will be primary and the other will be back up, and each will have full 4 quadrant metering. Pulses out of the primary billing meter will be sent via SCADA to the Amarillo Control Center.

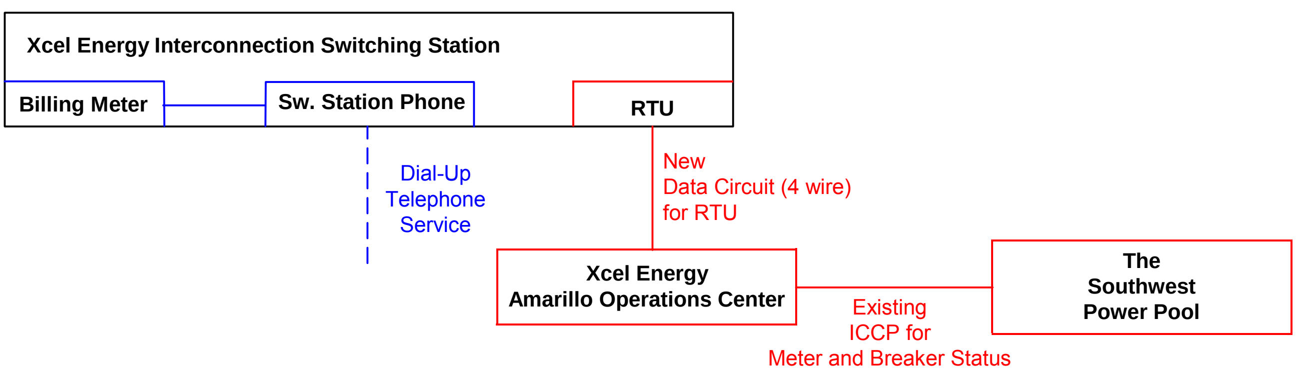
Metering at this new switching station will be installed to comply with present SPP market protocols.

1.12. **Disturbance Monitoring Device:** Disturbance-monitoring equipment, capable of recording faults, swings, and long term trending, will be installed to monitor and record conditions in the switching station and on the transmission lines. This equipment will have communication capability with a dedicated communication circuit. The disturbance equipment will have its own dedicated dial-up communications telephone circuit. The disturbance equipment shall also be equipped with a GPS time synching clock.

1.13. **Remote Terminal Unit (RTU):** A new RTU will be utilized with communications. An SEL 2020 will be installed for relay communication and other functions as required.

1.14. **Communications:** Communications from the new switching station to the Amarillo Control Center will consist of a 4-wire telephone and data circuit. **It is the Interconnection Customer's responsibility to make arrangements with the local phone company to provide both the four-wire data circuit and both telephone circuits to the new switching station. Prior to any construction, the Interconnection Customer is required to contact the Xcel Energy substation-engineering department for all details.**

A schematic outlining the proposed communications is provided below:



2. **Transmission Line:**

The Interconnection Customer will construct, own, operate, and maintain the new customer owned 345 kV transmission line/bus from the Interconnection Customer's 345/34.5 kV substation to the new SPS switching station. Figure A-4 shows the Point of Connection and Change of Ownership. ***The Xcel Energy transmission design group will require an engineering review of the Interconnection Customer's transmission line design prior to any construction by the Interconnection Customer or its contractor on the customer owned 345 kV transmission line or doing work in close proximity to any SPS transmission line, will require an engineering review in a timely manner before construction of the 345 kV transmission line begins. If the review has not been made or the design at any of the aforementioned locations is deemed inadequate, the crossing(s) and or termination into the new switching station will be delayed until the matters are resolved. Xcel Energy will not be held responsible for these delays.***

2.1. **345 kV Termination Structure:** The existing Xcel Energy overhead 345 kV transmission line (J-01) will be terminated in and out of the new switching station. The transmission termination structures will be constructed on the south side of the switching station. The existing 345 kV line between the TUCO Interchange and the Oklaunion Interchange will be re-terminated such that power flows in and out of the proposed switching station. The location of the switching station will be in the H & G N Railroad Survey, Block 1, and West half of Section 9, Floyd County, Texas.

2.2. The third 345 kV transmission termination will be on the north side of the switching station for the Cedar Cap Wind Farm. All circuits will be dead-ending on 345 kV terminals within the new switching station. See Figure A-2.

3. **Right-Of-Way:**

3.1. **New 345 kV Transmission Line Taps**: See Figure A-3 for location of the line taps relative to the switching station site.

3.2. **Permitting**: Permitting for the construction of the new switching station is not required from the Public Utility Commission in the State of Texas.

3.3. **Switching Station Location:** The new switching station will be constructed adjacent to the existing 345 kV transmission circuit J-01. SPS will provide the Interconnection Customer with easement detailing the metes and bounds description for the required real estate. The Interconnection Customer will obtain all necessary signatures from landowner(s) for the easement needed on the land where the new SPS switching station will be built.

4. **Construction Power and Distribution Service:** Both Construction and Station power, in addition to any distribution service required for the Interconnection Customer's wind-generated energy facility, are the sole responsibility of the Interconnection Customer. **Xcel Energy, Inc. cannot provide station power (retail distribution service) for the Interconnection Customer's substation if the location of the Interconnection Customer's substation lies outside of the Xcel Energy service area.**

5. **Project and Operating Concerns:** Close work between the Transmission group, the Interconnection Customer's Personnel, and local operating groups will be imperative to have this project in service on the scheduled date.

6. **Short Circuit Study Results: Approximately 46 miles east of TUCO.**

The Short Circuit Analysis was performed internally by Xcel Energy Services to determine the available fault current at the 345 kV bus on J-01 for the new switching station. These values may be used as a starting point for the determination of the available fault currents and interrupting capability of their facilities. The results are shown in Table 1, and the impedances are in per-unit at the specified voltage.

Table 1: Short Circuit Information				
Fault Location	Fault Current (A)		Impedance (p.u Ω)[5]	
	Line-to-Ground	3–Phase	Z^+	Z^0
New Switching Facility 345 kV Bus	2,950	3,875	0.0038 + j0.0431	0.01705 + j0.0818

Estimated Construction Costs:

The projects required for the interconnection of the 150 MW wind energy generating facility consist of the projects summarized in Table 2 shown below:

Table 2: Required Interconnection Projects		
Project	**Description**	**Estimated Cost**
	Stand-alone Network Upgrade	
1	345 kV 3-breakers ring configuration, 25 & 50 MVAr line reactors	$ 9,545,988
2	Right-of-Way Cost (station land, surveying, etc.)	$ 75,000
	Subtotal:	**$ 9,620,988**
	Network Upgrade	
3	Relay Modifications at TUCO and Oklaunion Interchange	$ 120,000
4	345 kV Transmission Line Work	$ 415,000
	Subtotal:	**$ 535,000**
	Interconnection Facilities (at the Interconnection Customer's Expense)	
5	Communications[6]	$ See footnote
6	Remote Terminal Unit (RTU)	$ 54,120
7	Revenue metering	$ 95,084
8	345 kV Arresters	$ 89,000
	Subtotal:	**$ 238,204**
	Total Cost:	**$ 10,394,192**

The Interconnection Facilities cost does not include the construction of customer's facilities required to connect with SPS's switching station.

These costs were estimated using 2007 costs (2007 dollars) with no AFUDC[7] added with an estimated accuracy is ± 20%.

[5] Z^+ – Positive Sequence Impedance in p.u on a 100 MVA base
Z^0 – Zero Sequence Impedance in p.u on a 100 MVA base

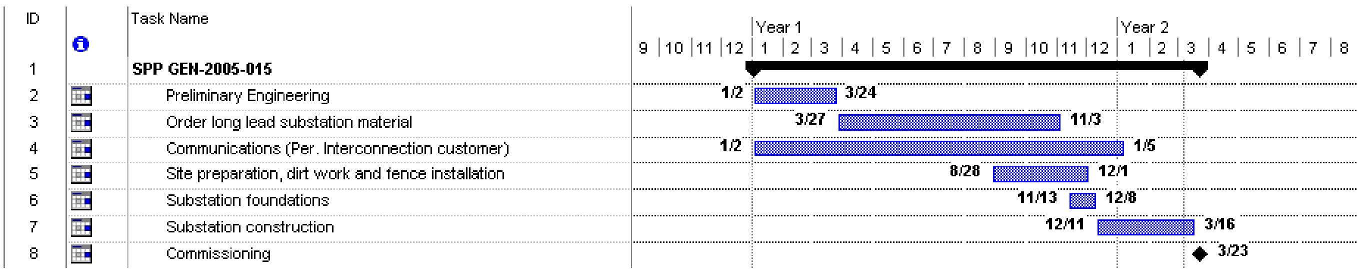
[6] It is the Requester's responsibility to provide both the data circuit and both dial-up telephone circuits, see Section 1.13.

[7] AFUDC - Allowance for Funds Used During Construction.

Capital budget approval has not been sought for this project as of the date of this report. The required approval process may impact the projected in-service date requested by the Interconnection Customer.

7. **Engineering and Construction Schedule:**

It is anticipated that the switching station and all associated components will be constructed and ready to receive power from the Interconnection Customer's wind farm approximately 15 months from the day an interconnection agreement is signed and after all internal approvals, unless prior arrangements have been made. A proposed construction schedule is shown below.



Appendix A

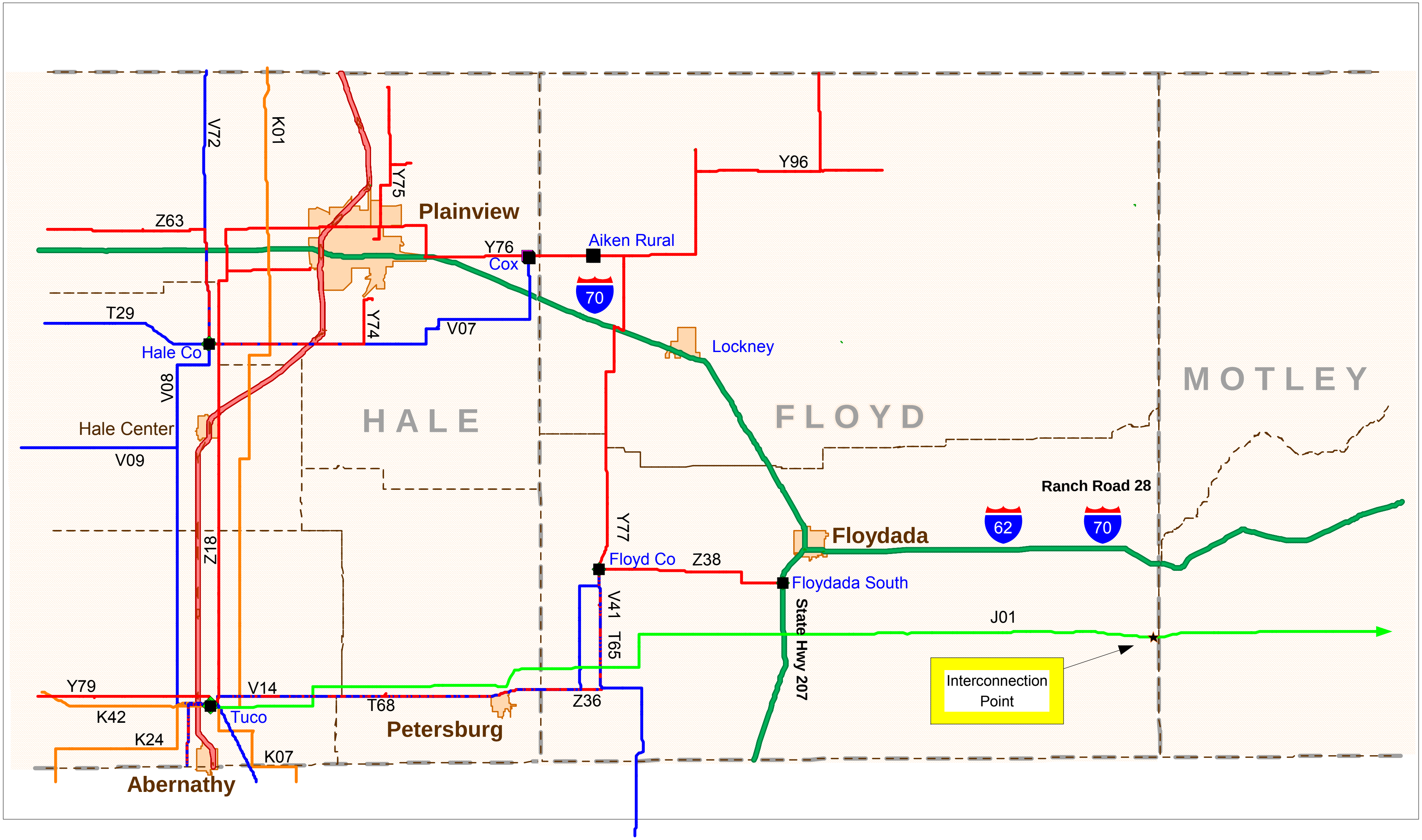


Figure A-1. Proposed Interception Point to the Xcel Energy 345 kV Circuit J-01.

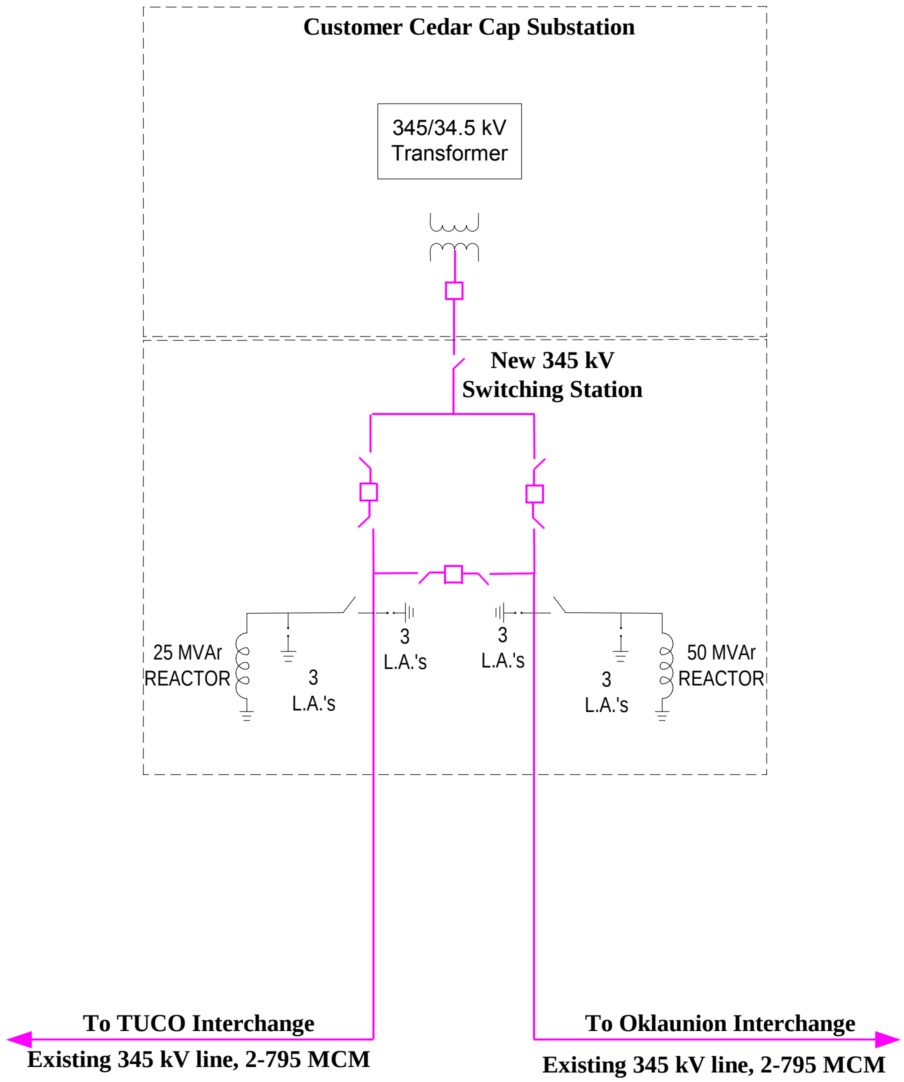


Figure A - 2. This is a one-line diagram for Cedar Cap Wind and a new 345 kV Switching Station in Floyd County.

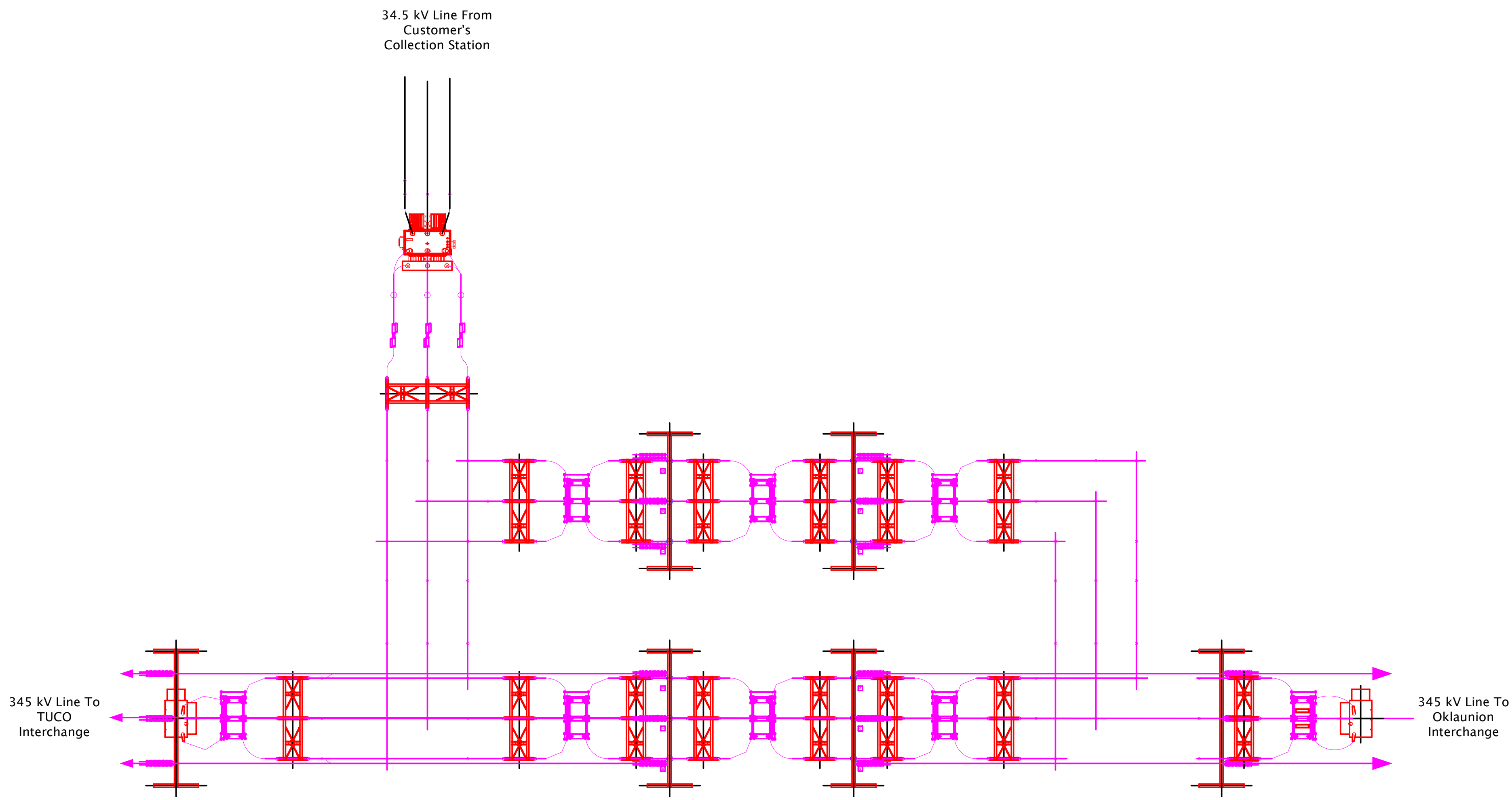


Figure A-3. This is a site Layout for 345 kV Cedar Cap Switching Station.

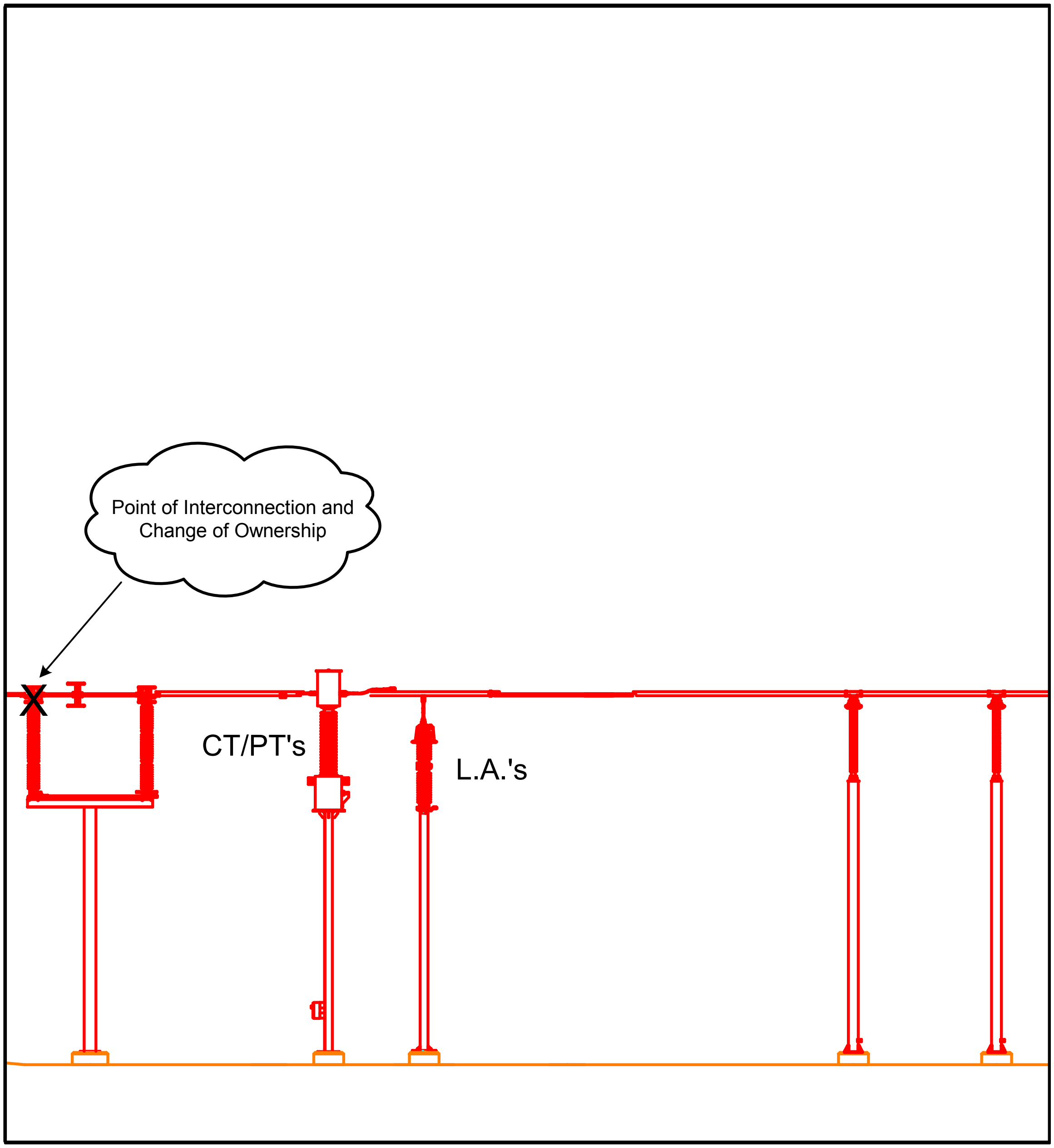


Figure A-4. This shows the Point of Interconnection & Change of Ownership.

ATTACHMENT 1.

IMPACT RE-STUDY

IMPACT RESTUDY

1.0 Introduction

This Impact Re-Study was conducted due to the change in transmission system topography that was determined to be needed by the Facility Study. As part of the Facility Study, Xcel Energy contracted a switching surge study, also known as an EMTP study, to determine the need for transmission line reactors on the Tuco-Oklaunion 345kV line caused by splitting the line into two segements. The Customer is requesting interconnection of a 150 MW wind powered generation facility in Motley County, Texas to the transmission system of Xcel Energy (Xcel). The wind farm configuration used Gamesa 2.0 MW wind turbines and was comprised of seventy-five (75) individual 2.0 MW Gamesa G87 wind turbines.

The original requested in-service date for the 150 MW facility was December 31, 2006. The wind powered generation facility will interconnect into the existing Tuco-Oklaunion 345kV transmission line. This study will address the stability and reactive compensation issues associated with the Gamesa turbines as a result of adding the 75Mvar of line reactors to the Tuco-Oklaunion 345kV line.

Nothing in this System Impact Study constitutes a request for transmission service or confers upon the Interconnection Customer any right to receive transmission service.

2.0 Purpose

The purpose of the Interconnection System Impact Study is to evaluate the impact of the proposed interconnection on the reliability of the Transmission System. The Impact Study considers the Base Case as well as all Generating Facilities (and with respect to (iii) below, any identified Network Upgrades associated with such higher queued interconnection) that, on the date the Interconnection System Impact Study is commenced: (i) are directly interconnected to the Transmission System; (ii) are interconnected to Affected Systems and may have an impact on the Interconnection Request; (iii) have a pending higher queued Interconnection Request to interconnect to the Transmission System; and (iv) have no Queue Position but have executed an LGIA or requested that an unexecuted LGIA be filed with FERC.

There are two previously queued projects in the immediate area ahead of this request in the SPP Generation Interconnection queue. It was assumed for purposes of this study that those projects would be in-service if this project is built. Any changes to this assumption, i.e. one or more of the previously queued projects not included in the study signing an interconnection agreement, may require a re-study of this request at the expense of the customer. Other wind farms which have higher queue priority than this request, were modeled in this case.

Nothing in this System Impact Study constitutes a request for transmission service or confers upon the Interconnection Customer any right to receive transmission service.

3.0 Facilities

3.1 Generating Facility

The facility was studied using the Gamesa G87 2.0 MW wind turbines. The nameplate rating of each turbine is 2000kW with a machine base of 2030kVA. The turbine output voltage is 690V. The Gamesa turbines utilize a doubly fed induction-generator. The generator synchronous speed is 1800 rpm, and a variable frequency power converter tied to the generator rotor allows the generator to operate at speeds ranging from 1020 rpm to 2340 rpm. Nominal speed at 2.0MW power output is 2015 rpm. The power converter allows the generator to produce power at a power factor of 0.95 lagging (producing vars) to 0.9 leading (absorbing vars). The power factor is settable at each WTG or by the Plant SCADA system.

3.2 Interconnection Facility

For detailed discussion of the interconnection facilities, see the Facility Study section of this document.

Analysis of the reactive compensation requirements of the wind farm determined that 21Mvars of 34.5kV capacitors will be required by the Customer to be installed in the Customer 345/34.5kV substation. These capacitors are necessary for reactive compensation of the wind farm as well as reactive compensation for the transmission line reactors in the interconnection substation.

The Impact Stability Study has determined that for the wind farm to meet FERC Order #661A Low Voltage Ride through (LVRT) provisions, the Customer will be required to install run the wind turbines in a var producing mode at a power factor around 0.97 – 0.98.

Descriptions of the facilities to be provided by the Customer are listed in Table 1.

A preliminary one-line diagram of the generating facility and Customer's interconnection facility using the Gamesa G87 2.0MW wind turbines is shown in Figure 1.

Table 1: Direct Assignment Facilities

Facility	ESTIMATED COST (2007 DOLLARS)
Customer – 345-34.5 kV Substation facilities.	*
Customer – 34.5kV 21Mvar capacitor bank in the Customer 345/34.5kV substation	*
Customer - 345kV line between Customer substation and new SPS 345kV switching station.	*
Customer - Right-of-Way for Customer Substation & Line.	*

Note: *Estimates of cost to be determined by Customer.

Table 2: Required Interconnection Network Upgrade Facilities

Facility	ESTIMATED COST (2007 DOLLARS)
See Facility Study	
Total	

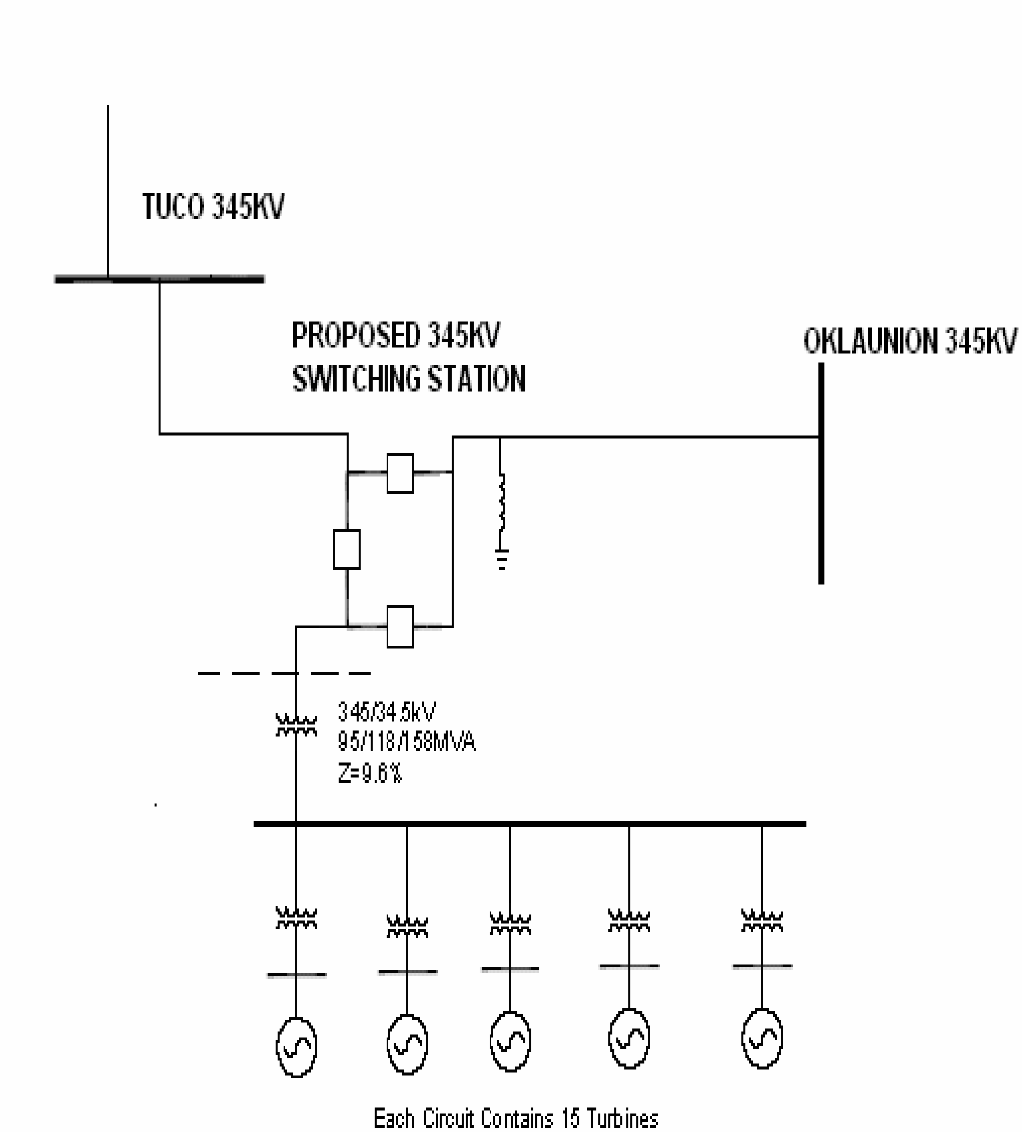


Figure 1: Proposed Interconnection Configuration
With Gamesa G87 wind turbines
(Final substation design to be determined)

4.0 Stability Analysis

4.1 Objective

The objective of the stability study is to determine the impact on system stability of connecting the proposed GEN-2005-015 wind farm to SPP's 345 kV transmission system.

4.2 Equivalent Modeling of the Wind Generating Facility

The rated output of the generation facility is 150MW, comprised of 75 Gamesa 2.0MW wind turbines. The base voltage of the Gamesa turbine is 690 V, and a generator step up transformer (GSU) of 2500kVA connects each unit to the high side of 34.5kV. The rated power output of each turbine is 2.0 MW while the actual power output depends on the wind.

In conducting the system impact study, the wind farm generation from the study customer and previously queued customers is dispatched into the SPP footprint.

The generating facility 345/34.5 substation will consist of (1) 345/34.5kV transformer with an impedence of 9.6% on a 95 MVA OA Base with a top rating of 158MVA. From the one-lines received from the customer, on the 34.5kV side of the transformer, 5 feeder circuits each will extend from the Customer's 345/34.5kV substation. The feeders will consist of 15 turbines on each circuit as shown in Figure 1.

4.3 Modeling of the Wind Turbines in the Power Flow

In order to simplify the model of the wind farm while capturing the effect of the different impedances of cables (due to change of the conductor size and length), the wind turbines connected to the same 34.5kV feeder end points were aggregated into one equivalent unit. An equivalent impedance of that feeder is represented in the load flow database by taking the equivalent series impedances of the different feeders connecting the wind turbines. Using this approach, the wind farm was modeled with equivalent units as indicated in Table 3. For the 2.0 MW turbines, each circuit contained 15 turbines connected in series and has identical cabling characteristics.

Wind Turbine	Circuit	Collector buses	Number of Turbines Aggregated
2.0 MW	1-5	10	1,1,1,1,1,1,1,1,1,6

Table 3. Equivalent Generators

4.4 Modeling of the Wind Turbines for the Stability Simulation

4.4.1 Machine Dynamics Data for Gamesa G87 turbines

The Gamesa G87 generators have a nameplate rating of 2.0 MW with a machine base of 2030kVA. The turbine output voltage is 690V. The Gamesa turbines utilize a doubly fed induction-generator. The generator synchronous speed is 1800 rpm, and a variable frequency power converter tied to the generator rotor allows the generator to operate at speeds ranging from 1020 rpm to 2340 rpm. Nominal speed at 2.0MW power output is 2015 rpm. The power converter allows the generator to produce power at a power factor of 0.95 lagging (producing vars) to 0.9 leading (absorbing vars). The power factor is settable at each WTG or by the Plant SCADA system.

The wind turbine manufacturer provided a wind turbine model package for use on PTI's PSS/E simulation software. This package was used exclusively in modeling this wind farm. The model package used is version 5.3 received from the Customer.

The Gamesa model package consists of an IPLAN that creates modeling data in the PSSE loadflow as well as creating a dynamic record that can be read into the program. Also included are several object code files that were linked into the dynamic libraries already being used for the transmission network.

The wind farm was dispatched directly by the user to the level specified (100% rated power for most runs). One set of simulations was run at 20% rated power. Default protection schemes were used for the turbines.

4.4.2 Turbine Protection Schemes

The Gamesa turbines have an under-voltage/over-voltage protection scheme and an under-frequency/over-frequency protection scheme. The various protection schemes are designed to protect the wind turbines in the case of system disturbances that can cause damage to the mechanical systems or power electronics on board the turbine. Generally, the protection schemes will disconnect the generator from the electric grid if the sampled frequency or voltage is outside of a specified band for a specified amount of time.

FERC Order #661A places specific requirements on wind farms through its Low Voltage Ride Through (LVRT) provisions. For Agreements signed after December 31, 2006, wind farms shall stay on line for faults at the POI that draws the voltage down at the POI to 0.0 pu.

The voltage protection scheme provided by Gamesa is outlined in Table 4.

Voltage	Time Limit
1.1pu +	3.6 cycles (0.06s)
0.90pu-1.1pu	Continuous Operation
0.75pu – 0.90pu	2.55 seconds
0.60pu – 0.75pu	2.05 seconds
0.45pu – 0.60pu	1.575 seconds
0.30pu – 0.45 pu	1.1 seconds
0.15pu - 0.30pu	0.625 seconds
< 0.15pu	2.4 cycles (0.04s)

Table 4: Gamesa Turbine Voltage Protection

The frequency protection scheme provided by Gamesa is outlined in Table 5 below:

Frequency	Time Limit
57-62 HZ	Continuous Operation
Below 57Hz	3 cycles (0.05 s)
Above 62 Hz	3 cycles (0.05 s)

Table 5: Gamesa Turbine Frequency Protection

4.5 Contingencies Simulated

Fifteen (15) contingencies were considered for the transient stability simulations which included three phase faults, as well as single phase line faults, at the locations defined by SPP. Single-phase line faults were simulated by applying a fault impedance to the positive sequence network at the fault location to represent the effect of the negative and zero sequence networks on the positive sequence network. The fault impedance was computed to give a positive sequence voltage at the specified fault location of approximately 60% of pre-fault voltage. This method is in agreement with SPP current practice.

The faults that were defined and simulated are listed in Table 6.

Table 6. Contingencies Evaluated

Cont. No.	*Cont. Name*	*Description*
1	*FLT13PH*	Three phase fault on the Oklaunion to the Wind Farm Switching Station 345kV line, near the Wind Farm. a. Apply fault at the Wind Farm Switching Station 345kV bus. b. Clear Fault after 4 cycles by removing the 345kV line from the Wind Farm to Oklaunion and removing the line reactor from service. c. Wait 30 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 4 cycles, then trip the line in (b) and remove fault.
2	FLT21PH	*Single phase fault and sequence like Cont. No. 1*
3	FLT33PH	Three phase fault on the Wind Farm Switching Station to Tuco 345 kV line, near Tuco. a. Apply fault at the Tuco 345kV bus. b. Clear fault after 5 cycles by removing the 345kV line from Tuco to the Wind Farm Switching Station and the Tuco 345/230kV autotransformer. c. Wait 30 cycles, and then re-close the line and autotransformer in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line and autotransformer in (b) and remove fault.
4	FLT41PH	*Single phase fault and sequence like Cont. No. 3*
5	FLT53PH	Three phase fault on the Oklaunion to Lawton Eastside 345V line, near Lawton East Side. a. Apply Fault at the Lawton East Side bus. b. Trip the line after 2.5 cycles by removing the line from Oklaunion to Lawton ES and the Oklaunion HVDC tie, and remove the fault. c. Wait 30 cycles, and then re-close the line in (b) into the fault. d. Leave fault on for 2.5 cycles, then trip the line in (b) and remove fault.
6	FLT61PH	*Single phase fault and sequence like Cont. No. 5*
7	FLT73PH	Three phase fault on the Tuco to Tolk 230kV line near Tolk. a. Apply fault at the Tolk 230 kV bus. b. Clear fault after 5 cycles by tripping the 230kV line from Tolk to Tuco. (No reclose on power plant bus).
8	FLT81PH	*Single phase fault and sequence like Cont. No. 7*
9	FLT93PH	Three phase fault on the Tuco to Swisher 230kV line, near Swisher. a. Apply fault at the Swisher 230kV bus. b. Clear fault after 5 cycles by tripping the 230kV line from Swisher to Tuco. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
10	FLT101PH	*Single phase fault and sequence like Cont. No. 9*
11	FLT113PH	Three phase fault on the Tuco to Jones 230kV line near Tuco. a. Apply fault at the Tuco 230kV bus. b. Clear fault after 5 cycles by tripping the 230kV line from Tuco to Jones (no relose on power plant bus)
12	FLT121PH	*Single phase fault and sequence like Cont. No. 11*
13	FLT133PH	Three phase fault on the Grapevine to Elk City 230kV line near Grapevine. a. Apply fault at the Grapevine 230kV bus. b. Clear fault after 5 cycles by tripping the 230kV line from Grapevine to Elk

Cont. No.	*Cont. Name*	*Description*
		City. c. Wait 20 cycles, and then re-close line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
14	FLT141PH	*Single phase fault and sequence like Cont. No. 13*
15	FLT153PH	Three phase fault on the Finney to GEN-2003-013 Wind Farm 345kV line near Finney a. Apply fault at the Finney 345kV bus. b. Clear fault after 3.5 cycles by removing the line from GEN-2003-013 Wind Farm to Finney (no reclose).

4.6 Further Model Preparation

The contingencies were simulated for the following scenarios

- 2007 Winter Peak Loading (SPP MDWG Case) (Turbines running at 100%)
- 2011 Summer Peak Loading (SPP MDWG Case)
  - Case #1 (All contingencies)
    - Turbines running at 100% production
    - Turbines running at 1.0 PF
  - Case #2 (All contingencies)
    - Turbines running at 20% production
    - Turbines operating at 1.0 PF

4.7 <u>Results</u>

Results are summarized in Table 7. The results indicate that for all contingencies, the transmission system remains stable.

An additional run was made with the turbines running at 20% production. This reduced output from the turbines was chosen to closer simulate actual conditions during the summer peak. The transmission system remained stable for this run also.

<u>FERC Order #661A Compliance</u> – Contingency FLT13PH AND FLT33PH were simulated for determining compliance with FERC Order #661A. The FERC order dictates that wind farms stay on line for three phase faults at the point of-interconnection. For this study, a three phase fault was simulated at the 345kV bus on the Tuco-Oklaunion 345kV line.

The wind farm was found to tripp off-line under certain circumstances during simulations for FERC Order #661A compliance. Due to the non-dynamic nature of the var production of the Gamesa turbines, issues arise depending on the power factor that the turbines are programmed to operate at. If the wind turbines are operating near unity power factor at 100% of nameplate, the wind farm will stay on line. However, for the reduced production cases (20% nameplate), the wind farm will trip off-line for the wind farm operating at unity power factor. If the wind turbines are operating at 95% lagging power factor at 20% nameplate, the wind farm will stay on line. However, if the wind farm is operating at 100% nameplate and operating at 95% lagging power factor, the wind farm may trip off under certain conditions for high voltage. It was determined the Gamesa turbines should be programmed to operate in the power factor range of about 0.97-0.98 lagging. This setting would keep the wind turbines on-line for all contingencies and scenarios studied.

FAULT	FAULT DEFINITION	2011 SP Case 1	2011 SP Case 2	2007 WP
FLT13PH	Three phase fault on the Wind Farm to Oklaunion 345kV line near the Wind Farm.	STABLE	STABLE – Wind Farm trips off-line	STABLE
FLT13PH w/turbine at 97%PF	Three phase fault on the Wind Farm to Oklaunion 345kV line near the Wind Farm.	STABLE	STABLE	STABLE
FLT21PH	Single phase fault same as above	STABLE	STABLE	STABLE
FLT33PH	Three phase fault on the Wind Farm to Tuco 345kV line near Tuco.	STABLE	STABLE – Wind Farm trips off-line	STABLE
FLT33PH with turbines at 97% PF	Three phase fault on the Wind Farm to Tuco 345kV line near Tuco.	STABLE	STABLE	STABLE
FLT41PH	Single phase fault same as above	STABLE	STABLE	STABLE
FLT53PH	Three phase fault on the Oklaunion to Lawton Eastside 345kV line near Lawton Eastside	STABLE	STABLE	STABLE
FLT61PH	Single phase fault same as above	STABLE	STABLE	STABLE
FLT73PH	Three phase fault on the Tuco-Tolk 230kV line near Tolk	STABLE	STABLE	STABLE
FLT81PH	Single phase fault same as above	STABLE	STABLE	STABLE
FLT93PH	Three phase fault on the Tuco-Swisher 230kV line near Swisher	STABLE	STABLE	STABLE
FLT101PH	Single phase fault same as above	STABLE	STABLE	STABLE
FLT113PH	Three phase fault on the Tuco-Jones 230kV line near Tuco	STABLE	STABLE	STABLE
FLT121PH	Single phase fault same as above	STABLE	STABLE	STABLE
FLT133PH	Three phase fault on the Grapevine to Elk City 230kV line near Grapevine.	STABLE	STABLE	STABLE
FLT141PH	Single phase fault same as above	STABLE	STABLE	STABLE
FLT153PH	Three phase fault on the Finney-GEN-2003-013 Wind Farm 345kV line near Finney	STABLE	STABLE	STABLE

* If a full 3 phase fault that draws the voltage to 0.0 pu, the turbines will trip off line

Table 7. SUMMARY OF FAULT SIMULATION RESULTS (Using Gamesa 2.0 MW Turbines)

5.0 Conclusion

This study analyzed the system stability for the interconnection of the GEN-2005-015 generation request. The Customer has requested to interconnect seventy-five (75) Gamesa G87 2.0 wind turbines. The transmission system remains stable for all contingencies studied. The Gamesa turbines should be programmed to operate in a manner in which they are producing vars with a power factor of around 0.97-0.98.

Due to the addition of the 345kV line reactors needed for switching surge applications, the Customer will also be required to install 21Mvars of 34.5kV capacitor banks in the Customer 345/34.5kV substation.