SPP Southwest Power Pool

System Impact Study For Generation Interconnection Request GEN-2006-045

SPP Tariff Studies
(#GEN-2006-045)

October, 2007

Executive Summary

<OMITTED TEXT> (Customer) has requested a feasibility study for the purpose of interconnecting 240 MW of wind generation within the control area of Southwestern Public Service Company (SPS) in Randall County, Texas. The Customer has requested interconnection to the Potter County – Plant X 230 kV transmission line, which is owned by SPS. The proposed interconnection configuration in the Feasibility Study consisted of adding a fourth 230kV line terminal into the switching station proposed for interconnection request #GEN-2006-039. The proposed in-service date is December 31, 2008

Due to instability problems directly associated with the proposed interconnection method proposed in the Feasibility Study, an alternate method of interconnection was chosen during the Impact Study Phase. The newly proposed method of interconnection is to construct a new breaker-and-a-half switching station that will interconnect both the Potter County Interchange – Plant X Station 230 kV and the Bushland Interchange – Deaf Smith Interchange 230 kV transmission lines, as well as provide one terminal each for the previously proposed request (#GEN-2006-039) and this request (#GEN-2006-045). The proposed in-service date is December 31, 2008.

Power flow analysis has indicated that for the powerflow cases studied, it is possible to interconnect the 240 MW of generation with transmission system reinforcements within the local transmission system. In order to maintain acceptable reactive power compensation, the customer will be required to pay for the installation of a combined total of at least 60 Mvar of 34.5 kV capacitor bank(s) to be installed in the Customer's collector substation.

The requirement to interconnect the 240 MW of wind generation on the existing Potter County Interchange – Plant X Station 230 kV and the Bushland Interchange – Deaf Smith Interchange 230 kV transmission lines, owned by SPS, consists of constructing a new 230 kV nine-breaker, six-terminal ring-bus switching station. The Customer will be responsible for the incremental cost to build the station to this configuration from a three breaker ring bus. The new station will be constructed and maintained by SPS. The Customer did not propose a specific route for the 230 kV line extending to serve its 230/34.5 kV collection facilities. It is assumed that obtaining all necessary right-of-way for the new transmission line to serve its facilities will not be a significant expense.

The total minimum cost for building the required facilities for this 240 MW of generation is $10,900,000. These costs are shown in Tables 1 and 2. Network constraints in the American Electric Power West (AEPW), SPS, Sunflower Electric Power Corporation (SUNC), and West Plains (WEPL) transmission systems that were identified are shown in Table 4. These Network constraints will have to be verified with a Transmission Service Request (TSR) and associated studies. Network Constraints are in the local area of the new generation when this generation is sunk throughout the SPP footprint for the Energy Resource (ER) Interconnection request. With a defined source and sink in a Transmission Service Request, this list of Network Constraints will be refined and expanded to account for all Network Upgrade requirements. This cost does not include building the 230 kV line from the Customer 230/34.5 kV collector substation into the point of interconnection. This cost also does not include the Customer's 230/34.5 kV collector substation or the 34.5 kV, 60 Mvar capacitor bank(s).

In Table 5, a value of Available Transfer Capability (ATC) associated with each overloaded facility is included. These values may be used by the Customer for future analyses including the determination of lower generation capacity levels that may be installed. When transmission service associated with this interconnection is evaluated, the loading of the facilities listed in this table may be greater due to higher priority reservations. If the loading of a facility is higher, the level of ATC will be lower.

The stability study conducted by ABB indicates that with the required upgrades the generation will stay on line and not cause system instability due to interconnection. However, system instability was encountered for SPS system exports that were evaluated in the study. This is indicative of the lack of tie lines from SPS to the rest of SPP and the Eastern Interconnection. Therefore, the Customer cannot expect to export any generation from the Facilty outside of SPS until new tie lines are constructed.

There are several other proposed generation additions in the general area of the Customer's facility. It was assumed in this preliminary analysis that not all of these other projects within the SPS control area will be in service. Those previously queued projects that have advanced to nearly complete phases were included in this System Impact Study. In the event that another request for a generation interconnection with a higher priority withdraws, then this request may have to be re-evaluated to determine the local Network Constraints.

The required interconnection costs listed in Tables 1 and 2 and other upgrades associated with Network Constraints do not include all costs associated with the deliverability of the energy to final customers. These costs are determined by separate studies if the Customer submits a Transmission Service Request through Southwest Power Pool's OASIS.

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Introduction

<OMITTED TEXT> (Customer) has requested a feasibility study for the purpose of interconnecting 240 MW of wind generation within the control area of Southwestern Public Service Company (SPS) in Randall County, Texas. The Customer has requested interconnection to the Potter County – Plant X 230 kV transmission line, which is owned by SPS. The proposed interconnection configuration in the Feasibility Study consisted of adding a fourth 230kV line terminal into the switching station proposed for interconnection request #GEN-2006-039. The proposed in-service date is December 31, 2008

Interconnection Facilities

The primary objective of this study is to identify the system problems associated with connecting the plant to the area transmission system. The Feasibility, System Impact, and other subsequent Interconnection Studies are designed to identify attachment facilities, Network Upgrades and other Direct Assignment Facilities needed to accept power into the grid at the interconnection receipt point.

Due to voltage stability issues encountered during the stability analysis, the requirements for interconnection of the 240 MW have changed from the Feasibility Study. These issues are discussed in the stability section of this report that was conducted by ABB. The new interconnection facilities will consist of constructing a new 230 kV nine-breaker, six-terminal ring-bus switching station interconnecting both the Potter County Interchange – Plant X Station 230 kV and the Bushland Interchange – Deaf Smith Interchange 230 kV transmission lines, which are owned by SPS. This substation will be constructed and maintained by SPS. A preliminary one-line drawing of the interconnection facilities are shown in Figure 1. The Customer did not propose a specific route of its 230 kV line to serve its 230/34.5 kV collection system facilities. It is assumed that obtaining all necessary right-of-way for construction of the Customer 230 kV transmission line and the 230/34.5 kV collector substation will not be a significant expense.

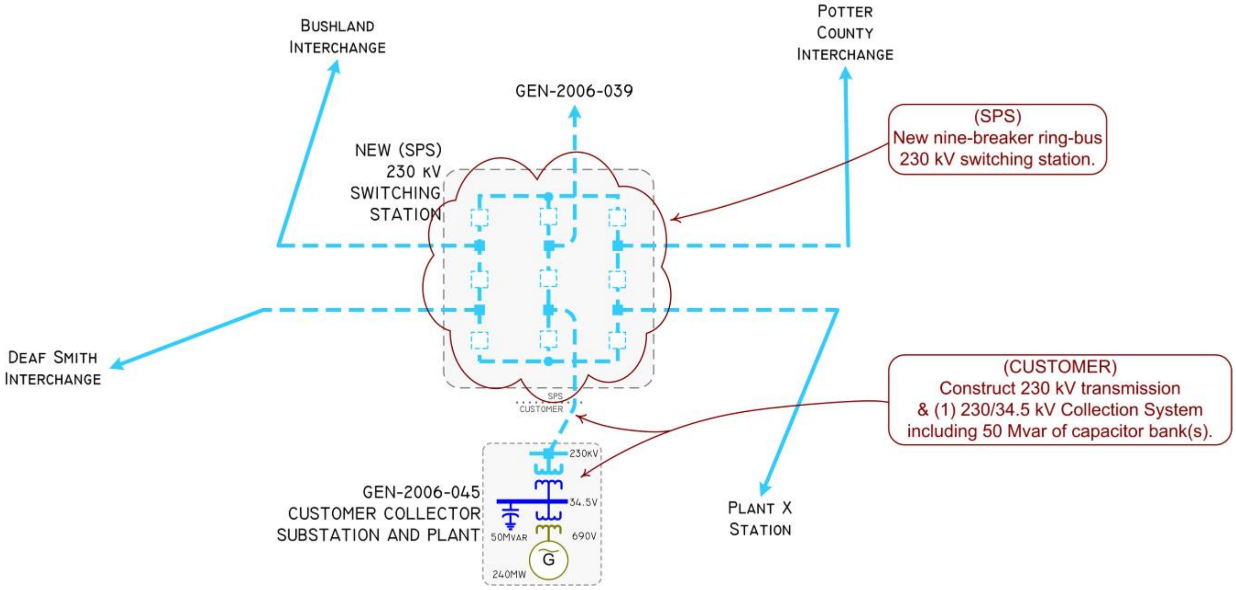

Figure 1: Proposed Method of Interconnection

(Final design to be determined)

Interconnection Estimated Costs

The minimum cost for constructing a new nine-breaker ring-bus switching station and terminating the transmission line serving GEN-2006-045 facilities is estimated at $10,900,000. These costs are listed in Tables 1 and 2. These estimates will be refined during the development of the System Impact Study based on the final designs. This cost does not include building the Customer's 230 kV transmission line extending from the point of interconnection to serve its 230/34.5 kV collection facilities. This cost also does not include the Customer's 230/34.5 kV collector substation or the 60 Mvar of capacitor bank(s), all of which should be determined by the Customer. The Customer is responsible for these 230 kV – 34.5 kV facilities up to the point of interconnection.

If the previous generation interconnection request #GEN-2006-039 withdraws from the queue, the Customer will be responsible for the cost of constructing the original three-breaker 230 kV ring-bus switching station located on the Potter County Interchange – Plant X Station 230 kV transmission line. The costs associated with this method of interconnection are listed in Table 3. As previously stated, this cost does not include the Customer's 230 kV transmission line, the 230/34.5 collector facilities or the 60 Mvar of 34.5 kV capacitor bank(s), all of which should be determined by the Customer. The Customer is responsible for these 230 kV – 34.5 kV facilities up to the point of interconnection.

The 60 Mvar of capacitor banks required to be installed by the Customer shall be staged banks such that voltage at the 230kV bus does not experience voltage swings not acceptable to SPS.

Other Network Constraints in the American Electric Power West (AEPW), SPS, Sunflower Electric Power Corporation (SUNC), and West Plains (WEPL) transmission systems that were identified are shown in Table 4.

These costs do not include any cost that might be associated with short circuit study results or dynamic stability study results. These costs will be determined when and if a System Facility Study is conducted.

Table 1: Direct Assignment Facilities

FACILITY	**ESTIMATED COST** (2007 DOLLARS)
CUSTOMER – (1) 230/34.5 kV Customer collector substation facilities.	*
CUSTOMER – (1) 230 kV transmission line from Customer collector substation to the Point of Interconnection.	*
CUSTOMER – 34.5 kV, 60 Mvar capacitor bank(s) to be installed in the Customer 230/34.5 kV collector substation.	*
CUSTOMER – Right-of-Way for all Customer facilities.	*
TOTAL	*****

* *Estimates of cost to be determined.*

Table 2: Required Interconnection Network Upgrade Facilities

FACILITY	ESTIMATED COST (2007 DOLLARS)
SPS – Additional cost to convert the 230kV three (3) breaker ring bus built for GEN-2006-039 to a 230 kV nine-breaker ring-bus switching station. Station to include breakers, switches, control relaying, high speed communications, metering and related equipment and all related structures.	$4,500,000
SPS – Additional 230 kV transmission to interconnect new station to the Potter County Interchange – Plant X Station 230 kV and the Bushland Interchange – Deaf Smith Interchange 230 kV transmission lines.	$5,200,000
SPS – Right-of-Way for all station and additional transmission facilities.	$1,200,000
TOTAL	**$10,900,000**

Table 3: Required Interconnection Facilities
IF Request (#GEN-2006-039) Withdraws

FACILITY	ESTIMATED COST (2007 DOLLARS)
SPS – (1) 230 kV three-breaker ring-bus switching station for GEN-2006-045 located on the Potter County Interchange – Plant X Station 230 kV transmission line. Station to include breakers, switches, control relaying, high speed communications, metering and related equipment and all related structures.	$3,000,000
TOTAL	**$3,000,000**

Powerflow Analysis

A powerflow analysis was conducted for the new configuration of the facility using modified versions of the 2008 winter peak model, the 2009 and 2012 summer and winter peak models, and the 2017 summer peak model. The output of the Customer's facility was offset in each model by a reduction in output of existing online SPP generation. This method allows the request to be studied as an Energy Resource (ER) Interconnection request. The proposed in-service date of the generation is December 31, 2008. The available seasonal models used were through the 2017 Summer Peak of which is the end of the current SPP planning horizon.

Following current practice, this analysis was conducted assuming that previous queued requests in the immediate area of this interconnect request were in service. The analysis of the Customer's project indicates that, given the requested generation level of 240 MW and location, additional criteria violations will occur on the existing AEPW, SPS, SUNC, and WEPL transmission systems under steady state and contingency conditions in the peak seasons. Table 4 lists these overloaded facilities.

In Table 5, a value of Available Transfer Capability (ATC) associated with each overloaded facility is included. These values may be used by the Customer to determine lower generation capacity levels that may be installed. When transmission service associated with this interconnection is evaluated, the loading of the facilities listed in this table may be greater due to higher priority reservations. When a facility is overloaded for more than one contingency, only the highest loading on the facility for each season is included in the table.

Voltage violations for load serving buses within the SPP footprint were also observed for some of the contingencies listed in Table 3. These voltage violations have not been listed in this report.

In order to maintain a zero reactive power flow exchanged at the point of interconnection, additional reactive compensation is required. The Customer will be required to install a combined total of 60 Mvar of capacitor bank(s) in the Customer's 230/34.5 kV collector substation on the 34.5 kV bus. Dynamic Stability studies performed as part of the System Impact Study have determined that with the new interconnection configuration, that all of this reactive compensation can be in the form of static capacitor banks. It was determined that with the new interconnection configuration that the Customer facility will comply with FERC Order 661A Low Voltage Ride-Through Provisions (LVRT) which went into effect January 1, 2006. FERC Order 661A orders that wind farms stay on-line for 3-phase faults at the point of interconnection even if that requires the installation of a SVC or STATCOM device.

There are several other proposed generation additions in the general area of the Customer's facility. Some of the local projects that were previously queued were assumed to be in service in this System Impact Study. Not all local projects that were previously queued and have advanced to nearly complete phases were included in this System Impact Study.

Powerflow Analysis Methodology

The Southwest Power Pool (SPP) criteria states that: "The transmission system of the SPP region shall be planned and constructed so that the contingencies as set forth in the Criteria will meet the applicable NERC Planning Standards for System Adequacy and Security – Transmission System Table I hereafter referred to as NERC Table I) and its applicable standards and measurements".

Using the created models and the ACCC function of PSS\E, single contingencies in portions or all of the modeled control areas of Sunflower Electric Power Corporation (SUNC), Missouri Public Service (MIPU), Westar Energy (WERE), Kansas City Power & Light (KCPL), West Plains (WEPL), Midwest Energy (MIDW), Oklahoma Gas and Electric OKGE, American Electric Power West (AEPW), Grand River Dam Authority (GRDA), Southwestern Public Service Company (SPS), Western Farmers Electric Cooperative (WFEC) and other control areas were applied and the resulting scenarios analyzed. This satisfies the 'more probable' contingency testing criteria mandated by NERC and the SPP criteria.

Powerflow Results

Table 4: Network Constraints

AREA	OVERLOADED ELEMENT
AEPW	CLINTON JUNCTION - ELK CITY 138KV CKT 1
AEPW	ELK CITY 230KV (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1
AEPW	SHAMROCK (SHAMRCK1) 115/69/14.4KV TRANSFORMER CKT 1
AEPW	SHAMROCK (SHAMRCK2) 138/69/14.4KV TRANSFORMER CKT 1
AEPW/SPS	ELK CITY 230KV - GRAPEVINE INTERCHANGE 230KV CKT 1
SPS	BUSHLAND INTERCHANGE 230/115KV TRANSFORMER CKT 1
SPS	CUNNINGHAM STATION 230/115KV TRANSFORMER CKT 1
SPS	DEAF SMITH COUNTY INTERCHANGE - HEREFORD INTERCHANGE 115KV CKT 1
SPS	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1
SPS	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 2
SPS	EAST PLANT INTERCHANGE 230/115KV TRANSFORMER CKT 1
SPS	EXELL TAP - FAIN SUB 115KV CKT 1
SPS	FAIN SUB - NICHOLS STATION 115KV CKT 1
SPS	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1
SPS	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2
SPS	HERRING TAP - RITA BLANCA REC-SNEED 115KV CKT 1
SPS	HERRING TAP - RIVERVIEW INTERCHANGE 115KV CKT 1
SPS	LUBBOCK POWER & LIGHT-HOLLY PLANT 230/69KV TRANSFORMER CKT 1
SPS	LUBBOCK POWER & LIGHT-SOUTHEAST 230/69KV TRANSFORMER CKT 1
SPS	LUBBOCK POWER & LIGHT-WADSWORTH 230/69KV TRANSFORMER CKT 1
SPS	MOORE COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1
SPS	MOORE COUNTY INTERCHANGE W. - DUMAS SUB 115KV CKT 1
SPS	MOORE COUNTY INTERCHANGE W. - RITA BLANCA REC-SNEED 115KV CKT 1
SPS	NORTHEAST HEREFORD INTERCHANGE 115/69KV TRANSFORMER CKT 1
SPS	PERRYTON INTERCHANGE - TRI COUNTY REC-COLE 115KV CKT 1
SPS	PRINGLE INTERCHANGE - SPEARMAN INTERCHANGE 115KV CKT 1
SPS	SPEARMAN INTERCHANGE - SPEARMAN SUB 115KV CKT 1
SUNC/WEPL	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1
AEPW	American Electric Power West
SPS	Southwestern Public Service
SUNC	Sunflower Electric Power Corporation
WEPL	West Plains

Table 5: Contingency Analysis

SEASON	OVERLOADED ELEMENT	RATING (MVA)	LOADING (%)	ATC (MW)	CONTINGENCY
08WP	ELK CITY 230KV (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1	287	121	0	OKLAUNION - TUCO INTERCHANGE 345KV CKT 1
08WP	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1	706	106	0	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2
08WP	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2	706	106	0	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1
08WP	ELK CITY 230KV - GRAPEVINE INTERCHANGE 230KV CKT 1	351	121	90	OKLAUNION - TUCO INTERCHANGE 345KV CKT 1
08WP	SHAMROCK (SHAMRCK1) 115/69/14.4KV TRANSFORMER CKT 1	69	105	156	ELK CITY 230KV (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1
08WP	SHAMROCK (SHAMRCK1) 115/69/14.4KV TRANSFORMER CKT 1	69	107	162	OKLAUNION - TUCO INTERCHANGE 345KV CKT 1
09SP	NORTHEAST HEREFORD INTERCHANGE 115/69KV TRANSFORMER CKT 1	84	124	0	DEAF SMITH COUNTY INTERCHANGE - HEREFORD INTERCHANGE 115KV CKT 1
09SP	LUBBOCK POWER & LIGHT-HOLLY PLANT 230/69KV TRANSFORMER CKT 1	100	121	0	LUBBOCK POWER & LIGHT-SOUTHEAST 230/69KV TRANSFORMER CKT 1
09SP	LUBBOCK POWER & LIGHT-SOUTHEAST 230/69KV TRANSFORMER CKT 1	100	119	0	JONES STATION - LUBBOCK POWER & LIGHT-HOLLY PLANT 230KV CKT 1
09SP	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1	635	110	0	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2
09SP	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2	635	110	0	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1
09SP	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1	172	118	55	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 2
09SP	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 2	172	118	55	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1
09SP	LUBBOCK POWER & LIGHT-WADSWORTH 230/69KV TRANSFORMER CKT 1	100	106	126	LUBBOCK POWER & LIGHT-SOUTHEAST 230/69KV TRANSFORMER CKT 1
09SP	BUSHLAND INTERCHANGE 230/115KV TRANSFORMER CKT 1	172	110	190	BUSHLAND INTERCHANGE - POTTER COUNTY INTERCHANGE 230KV CKT 1
09SP	DEAF SMITH COUNTY INTERCHANGE - HEREFORD INTERCHANGE 115KV CKT 1	161	104	193	NORTHEAST HEREFORD INTERCHANGE 115/69KV TRANSFORMER CKT 1
09SP	ELK CITY 230KV (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1	287	103	210	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
09WP	ELK CITY 230KV (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1	287	120	0	OKLAUNION - TUCO INTERCHANGE 345KV CKT 1
09WP	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1	706	107	0	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2
09WP	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2	706	106	0	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1
09WP	ELK CITY 230KV - GRAPEVINE INTERCHANGE 230KV CKT 1	351	120	100	OKLAUNION - TUCO INTERCHANGE 345KV CKT 1

TABLE 4: Contingency Analysis (continued)

SEASON	OVERLOADED ELEMENT	RATING (MVA)	LOADING (%)	ATC (MW)	CONTINGENCY
09WP	SHAMROCK (SHAMRCK1) 115/69/14.4KV TRANSFORMER CKT 1	69	111	112	OKLAUNION - TUCO INTERCHANGE 345KV CKT 1
09WP	CUNNINGHAM STATION 230/115KV TRANSFORMER CKT 1	168	103	149	LEA COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1
09WP	SHAMROCK (SHAMRCK2) 138/69/14.4KV TRANSFORMER CKT 1	69	100	237	OKLAUNION - TUCO INTERCHANGE 345KV CKT 1
12SP	NORTHEAST HEREFORD INTERCHANGE 115/69KV TRANSFORMER CKT 1	84	123	0	DEAF SMITH COUNTY INTERCHANGE - HEREFORD INTERCHANGE 115KV CKT 1
12SP	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1	172	118	51	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 2
12SP	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 2	172	118	51	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1
12SP	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1	635	107	54	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2
12SP	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2	635	107	60	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1
12SP	BUSHLAND INTERCHANGE 230/115KV TRANSFORMER CKT 1	172	115	163	BUSHLAND INTERCHANGE - POTTER COUNTY INTERCHANGE 230KV CKT 1
12SP	ELK CITY 230KV (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1	287	104	194	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
12SP	EAST PLANT INTERCHANGE 230/115KV TRANSFORMER CKT 1	252	101	225	MOORE COUNTY INTERCHANGE - POTTER COUNTY INTERCHANGE 230KV CKT 1
12SP	DEAF SMITH COUNTY INTERCHANGE - HEREFORD INTERCHANGE 115KV CKT 1	161	101	229	NORTHEAST HEREFORD INTERCHANGE 115/69KV TRANSFORMER CKT 1
12SP	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1	336	100	233	HOLCOMB - SETAB 345KV CKT 1
12WP	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1	706	110	0	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2
12WP	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2	706	110	0	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1
12WP	ELK CITY 230KV (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1	287	125	12	TUCO INTERCHANGE (TUCO XX4) 345/230/13.2KV TRANSFORMER CKT 1
12WP	ELK CITY 230KV - GRAPEVINE INTERCHANGE 230KV CKT 1	351	118	101	OKLAUNION - TUCO INTERCHANGE 345KV CKT 1
12WP	SHAMROCK (SHAMRCK1) 115/69/14.4KV TRANSFORMER CKT 1	69	110	106	ELK CITY 230KV (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1
12WP	CLINTON JUNCTION - ELK CITY 138KV CKT 1	143	103	215	OKLAUNION - TUCO INTERCHANGE 345KV CKT 1
17SP	NORTHEAST HEREFORD INTERCHANGE 115/69KV TRANSFORMER CKT 1	84	135	0	DEAF SMITH COUNTY INTERCHANGE - HEREFORD INTERCHANGE 115KV CKT 1
17SP	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1	172	127	0	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 2

TABLE 4: Contingency Analysis (continued)

SEASON	OVERLOADED ELEMENT	RATING (MVA)	LOADING (%)	ATC (MW)	CONTINGENCY
17SP	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 2	172	127	0	DEAF SMITH COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1
17SP	MOORE COUNTY INTERCHANGE W. - DUMAS SUB 115KV CKT 1	99	115	0	MOORE COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1
17SP	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1	635	109	0	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2
17SP	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2	635	108	0	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1
17SP	MOORE COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1	252	107	0	HERRING TAP - RIVERVIEW INTERCHANGE 115KV CKT 1
17SP	PRINGLE INTERCHANGE - SPEARMAN INTERCHANGE 115KV CKT 1	197	103	85	MOORE COUNTY INTERCHANGE E. - SHERMAN COUNTY TAP 115KV CKT 1
17SP	BUSHLAND INTERCHANGE 230/115KV TRANSFORMER CKT 1	172	126	95	BUSHLAND INTERCHANGE - POTTER COUNTY INTERCHANGE 230KV CKT 1
17SP	DEAF SMITH COUNTY INTERCHANGE - HEREFORD INTERCHANGE 115KV CKT 1	161	111	112	NORTHEAST HEREFORD INTERCHANGE 115/69KV TRANSFORMER CKT 1
17SP	SPEARMAN INTERCHANGE - SPEARMAN SUB 115KV CKT 1	161	108	146	HANSFORD 3 115.00 - SPEARMAN INTERCHANGE 115KV CKT 1
17SP	BUSHLAND INTERCHANGE 230/115KV TRANSFORMER CKT 1	150	105	187	BASE CASE
17SP	HERRING TAP - RIVERVIEW INTERCHANGE 115KV CKT 1	180	114	192	MOORE COUNTY INTERCHANGE - POTTER COUNTY INTERCHANGE 230KV CKT 1
17SP	ELK CITY 230KV (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1	287	103	205	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
17SP	HERRING TAP - RITA BLANCA REC-SNEED 115KV CKT 1	180	107	214	MOORE COUNTY INTERCHANGE - POTTER COUNTY INTERCHANGE 230KV CKT 1
17SP	FAIN SUB - NICHOLS STATION 115KV CKT 1	161	104	223	MOORE COUNTY INTERCHANGE - POTTER COUNTY INTERCHANGE 230KV CKT 1
17SP	PERRYTON INTERCHANGE - TRI COUNTY REC-COLE 115KV CKT 1	99	101	230	HANSFORD 3 115.00 - TEXAS COUNTY INTERCHANGE 115KV CKT 1
17SP	EXELL TAP - FAIN SUB 115KV CKT 1	161	102	233	MOORE COUNTY INTERCHANGE - POTTER COUNTY INTERCHANGE 230KV CKT 1
17SP	MOORE COUNTY INTERCHANGE W. - RITA BLANCA REC-SNEED 115KV CKT 1	180	101	236	MOORE COUNTY INTERCHANGE - POTTER COUNTY INTERCHANGE 230KV CKT 1

Note: When transmission service associated with this interconnection is evaluated, the loading of the facilities listed in this table may be greater due to higher priority reservations. If the loading of a facility is higher, the level of ATC will be lower.

Transient Stability Analysis

ABB T&D Consulting conducted the transient stability analysis for this request. The analysis indicated there were stability issues with the original interconnection configuration that was studied in the Feasibility Study. With the new interconnection configuration, the transmission system would remain stable for contingencies that do not involve SPS tie lines with the addition of the proposed generation.

Due to lack of tie lines from SPS, exports to systems outside of SPS will not be possible until new tie lines are constructed.

The entire stability analysis can be found in Attachment 1, found at the end of this study.

Conclusion

The minimum cost of interconnecting the Customer's interconnection request is estimated at $10,900,000 for Direct Assignment Facilities and Network Upgrades. At this time, the cost estimates for other Direct Assignment facilities including those in Tables 1 and 2 have not been defined by the Customer. In addition to the Customer's proposed interconnection facilities, the Customer will be responsible for installing a total of 60 Mvar of capacitor bank(s) in the Customer's substation for reactive support. As stated earlier, some but not all of the local projects that were previously queued are assumed to be in service in this System Impact Study. These costs exclude upgrades of other transmission facilities that were listed in Table 4 of which are Network Constraints.

In Table 5, a value of Available Transfer Capability (ATC) associated with each overloaded facility is included. These values may be used by the Customer to determine lower generation capacity levels that may be installed. When transmission service associated with this interconnection is evaluated, the loading of the facilities listed in this table may be greater due to higher priority reservations. When a facility is overloaded for more than one contingency, only the highest loading on the facility for each season is included in the table.

Transient stability analysis indicates that with the required upgrades, the generation and transmission system will be stable for outages that do not involve SPS tie lines. System instability will occur for loss of tie lines outside of SPS. Therefore, the Customer cannot expect to export any energy from the facility until new tie lines are constructed.

These interconnection costs do not include any cost that may be associated with short circuit analysis. These studies will be performed if the Customer signs a System Facility Study Agreement. At the time of the System Facility Study, a better determination of the interconnection facilities may be available.

The required interconnection costs listed in Tables 1 and 2 and other upgrades associated with Network Constraints do not include all costs associated with the deliverability of the energy to final customers. These costs are determined by separate studies if the Customer submits a Transmission Service Request through Southwest Power Pool's OASIS.

Appendix A: Point of Interconnection Area Map

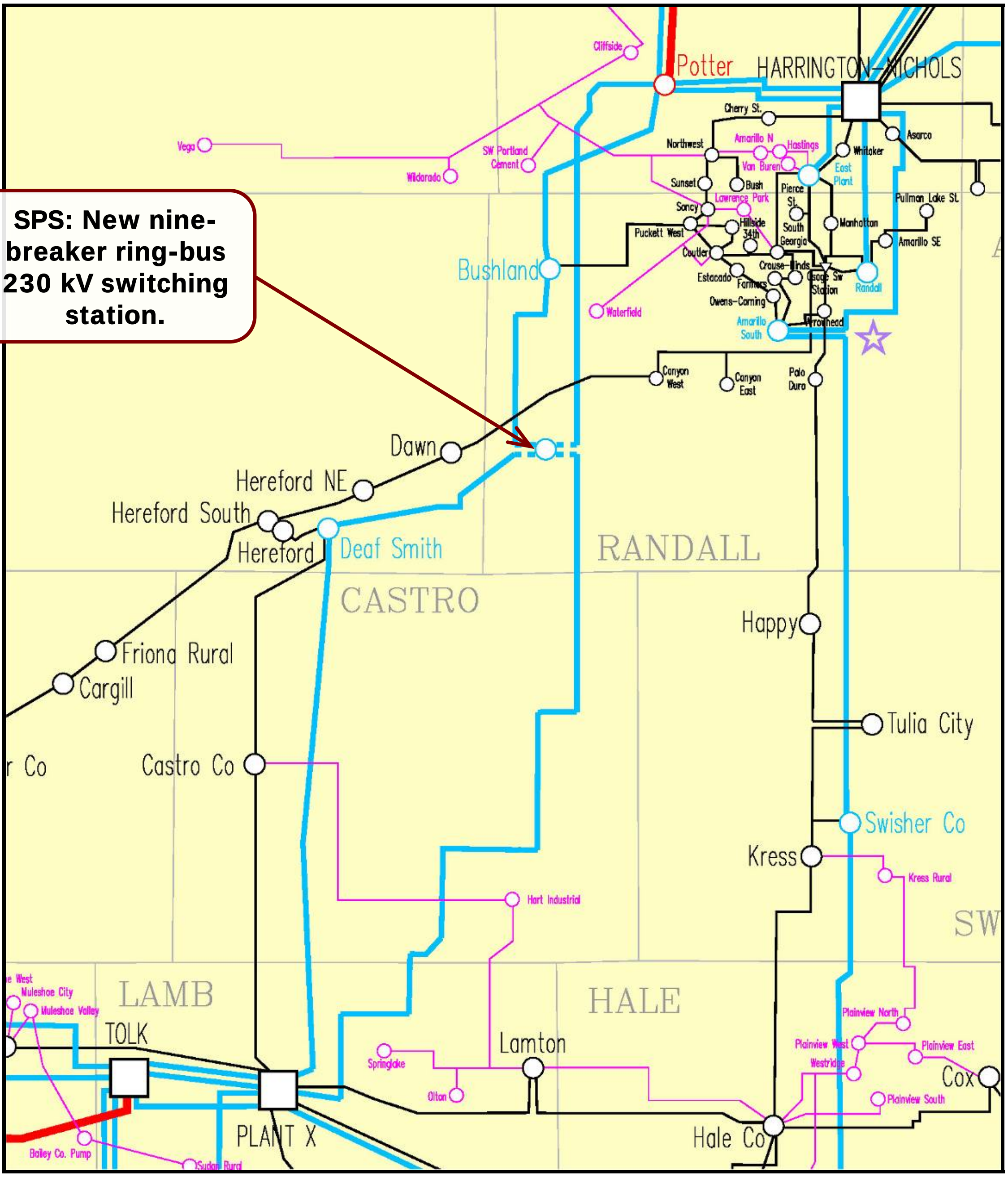
SPS: New nine-breaker ring-bus 230 kV switching station.

Figure 2: Point of Interconnection Area Map

Attachment 1: Stability Study

Stability Analysis
For
Generation Interconnection Request
GEN-2006-045

POWER SYSTEMS DIVISION
GRID SYSTEMS CONSULTING

IMPACT STUDY FOR GENERATION INTERCONNECTION REQUEST
GEN-2006-045

FINAL REPORT

REPORT NO.: 2007-11602-R0
Issued: November 5, 2007

ABB Inc.
Power Systems Division
Grid Systems Consulting
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Southwest Power Pool	**No.** 2007-11602-R0	
Impact Study for Generation Interconnection request GEN-2006-045	11/5/2007	# Pages 28

Author(s):	**Reviewed by:**	**Approved by:**
Sunil Verma	Bill Quaintance Amit Kekare	Willie Wong

Executive Summary

Southwest Power Pool (SPP) has a commissioned ABB Inc. to perform a generator interconnection study for a 230 kV interconnection of 240 MW wind farm in Randall County, Texas. This wind farm will be interconnected into the existing Potter – Plant X 230 kV transmission line. This line is owned by Southwestern Public Service (d/b/a Xcel Energy) (Xcel). This wind farm will interconnect into a proposed substation to be built for prior-queued project GEN-2006-039. As per the developer's request, the 240 MW of additional generation was studied assuming Suzlon 2.1 MW wind turbines. Several faults were simulated on the SPP system for Winter Peak 2008 and Summer Peak 2012 conditions.

The system was unstable following faults at the POI after interconnection of the proposed project. QV analysis showed that a reactive-power-only solution, such as an SVC or STATCOM, is not feasible to fix the instability problems. A fold-in of the Bushland – Deaf Smith 230 kV line to the POI station was studied and shown to be an acceptable solution, as long as 60 Mvar of shunt capacitors are also installed on the GEN-2006-045 substation 34.5 kV bus.

The faults involving loss of one of the major transmission outlets from the Texas Panhandle gave unstable results in both pre- and post-project system conditions. Stability problems with large power exports from the Texas Panhandle are already known to SPP. Hence, the mitigation of these problems was considered out of scope and not required for interconnection of the wind farm.

FERC Order 661A Compliance – With the Bushland – Deaf Smith 230 kV line fold-in and 60 Mvar of shunt capacitors, the GEN-2006-045 wind farm with Suzlon 2.1 MW turbines complies with the latest FERC order on low voltage ride through for wind farms. With this arrangement, the wind farm would not trip off line by voltage relay actuation for local faults near the POI.

Rev No.	Revision Description	Date	Authored by	Reviewed by	Approved by
0	Final Report	11/5/2007	Sunil Verma	Bill Quaintance	Willie Wong
DISTRIBUTION: Charles Hendrix – Southwest Power Pool					

The results of this analysis are based on available data and assumptions made at the time of conducting this study. If any of the data and/or assumptions made in developing the study model change, the results provided in this report may not apply.

TABLE OF CONTENTS

1 INTRODUCTION

SPP has commissioned ABB Inc. to perform an interconnection impact study for a 240 MW wind farm in Randall County, Texas. This wind farm will be interconnected into existing Potter – Plant X 230 kV transmission line. This line is owned by Southwestern Public Service (d/b/a Xcel Energy). The wind farm will interconnect into a proposed substation to be built for previous queued project GEN-2006-039. The feasibility (power flow) study was not performed as a part of this study.

The objective of the impact study is to evaluate the impact on system stability after connecting the additional 240 MW wind farm to the interconnection point and its effect on the nearby transmission system and generating stations. The study is performed on two system scenarios, 2008 Winter Peak and the 2012 Summer Peak, provided by SPP. Figure 1-1 shows the location of the proposed 240 MW wind farm interconnecting station and Figure 1-2 shows a one-line of the proposed interconnection with the existing network.

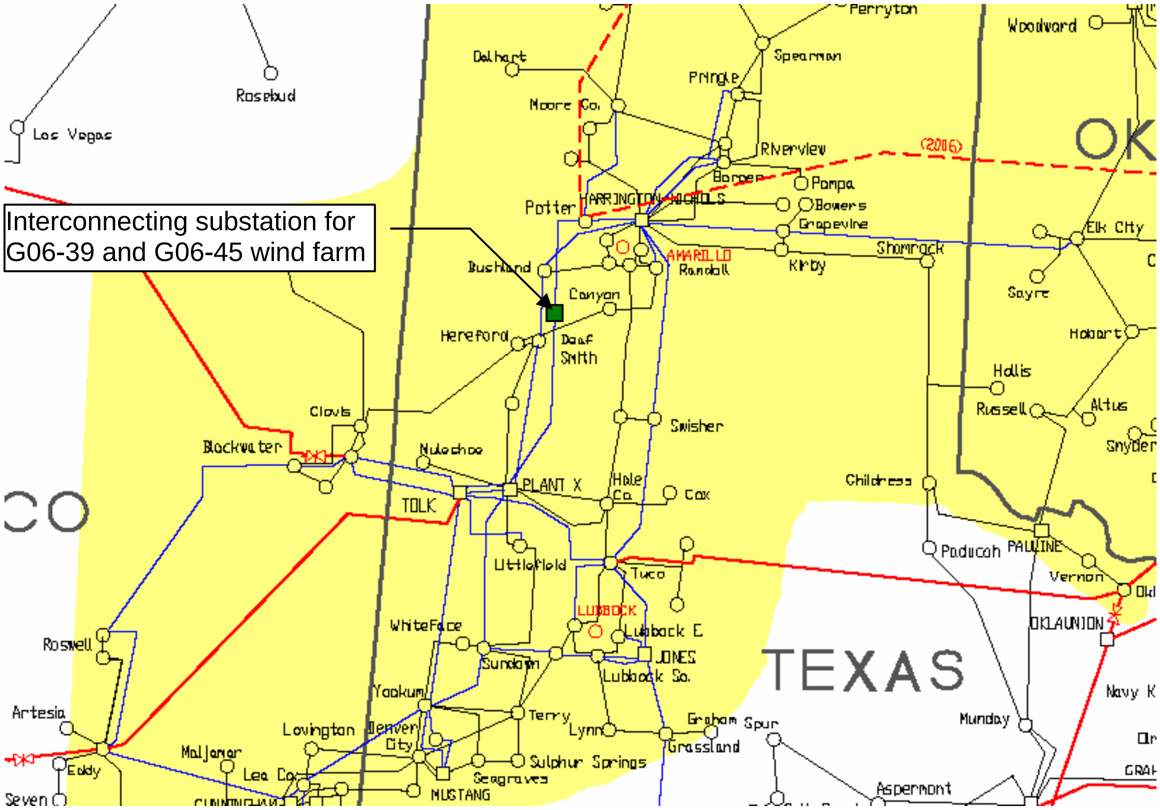
Interconnecting substation for G06-39 and G06-45 wind farm

Figure 1-1 Wind farm (G06-39 and G06-45) interconnecting substation

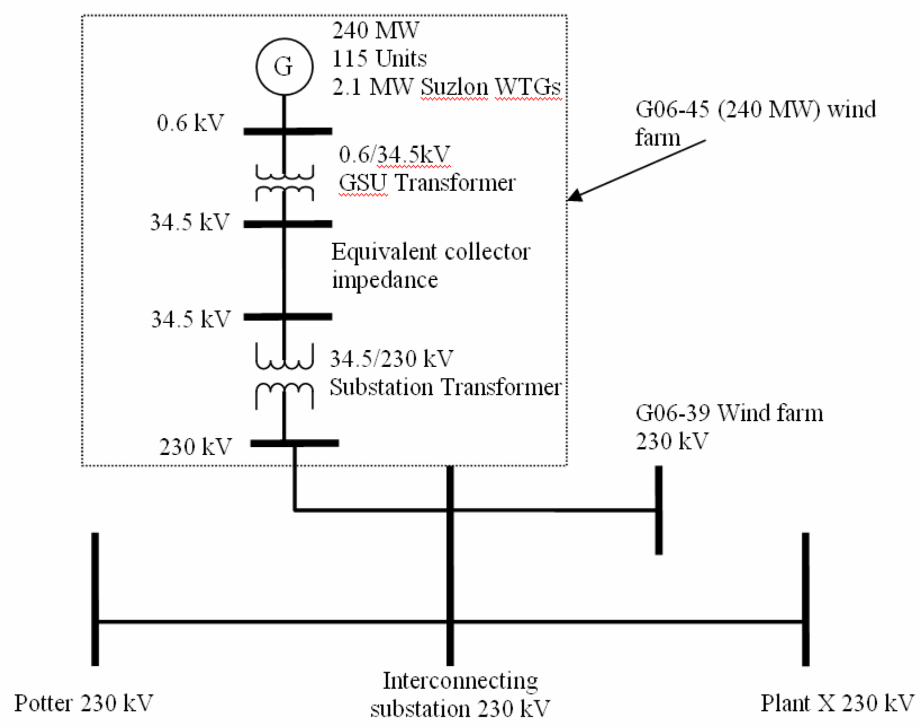

Figure 1-2 Proposed 240 MW wind farm interconnection

2 STABILITY ANALYSIS

In this stability study, ABB investigated the stability of the system for a series of faults specified by SPP, which are in the vicinity of the proposed plant. Three-phase and Single-line-to-ground (SLG) faults with reclosing in the vicinity of the proposed project were considered.

2.1 STABILITY ANALYSIS METHODOLOGY

Using Planning Standards approved by NERC, the following stability definition was applied in the Transient Stability Analysis:

"Power system stability is defined as that condition in which the differences of the angular positions of synchronous machine rotors become constant following an aperiodic system disturbance."

In addition, new wind generators (which are usually asynchronous) are required to stay on-line following normally cleared faults at the Point of Interconnection (POI).

Stability analysis was performed using Siemens-PTI's PSS/E^{TM} dynamics program V30.2.1. Three-phase and single-phase line faults were simulated for the specified durations, including re-closing, and the synchronous machine rotor angles were monitored to make sure they maintained synchronism following the fault removal. Stability of asynchronous machines was monitored as well.

Single-phase line faults were simulated with the standard method of applying fault impedance to the positive sequence network 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 fault location of approximately 60% of pre-fault voltage, which is a typical value.

The ability of the wind generators to stay connected to the grid during the disturbances and during the fault recovery was monitored. This is primarily determined by their low-voltage ride-through capabilities, or lack thereof, as represented in the models by low-voltage trip settings.

2.2 STUDY MODEL DEVELOPMENT

The study model consists of power flow cases and dynamics databases, developed as follows.

Power Flow Case

SPP provided two (2) Pre-project PSS/E power flow cases called "*gen-2006-045_08wp.sav*" representing the 2008 Winter Peak conditions and the "*gen-2006-045_12sp.sav*" representing the 2012 Summer Peak conditions.

Figure 2-1 and Figure 2-2 show the power flow diagrams for the local area without the proposed project for 2008 Winter Peak and 2012 Summer Peak respectively.

The proposed GEN-2006-045 project is comprised of 115 Suzlon 2.1 MW wind turbine generators. The plant will be connected to the interconnection substation bus (#560109) at the Potter – Plant X 230 kV transmission line with 230/34.5 kV transformer. The proposed project was added to the Pre-project cases and the generation was dispatched by scaling down generation in areas 502, 524, 525, 536, 540, 541, 544. Table 2-1 shows the details for the same. Thus two power flow cases with GEN-2006-045 were established:

- WP08-GEN-06-045.SAV – a 2008 winter peak case
- SP12-GEN-06-045.SAV – a 2012 summer peak case

Table 2-1: GEN-2006-045 project details

System condition	MW	Location	Point of Interconnection	Sink
Winter Peak	240	Randall County, Texas	Substation at Potter – Plant X 230kV line (#560109)	Areas 502, 524, 525, 536, 540, 541, 544
Summer Peak	240	Randall County, Texas	Substation at Potter – Plant X 230kV line (#560109)	Areas 502, 524, 525, 536, 540, 541, 544

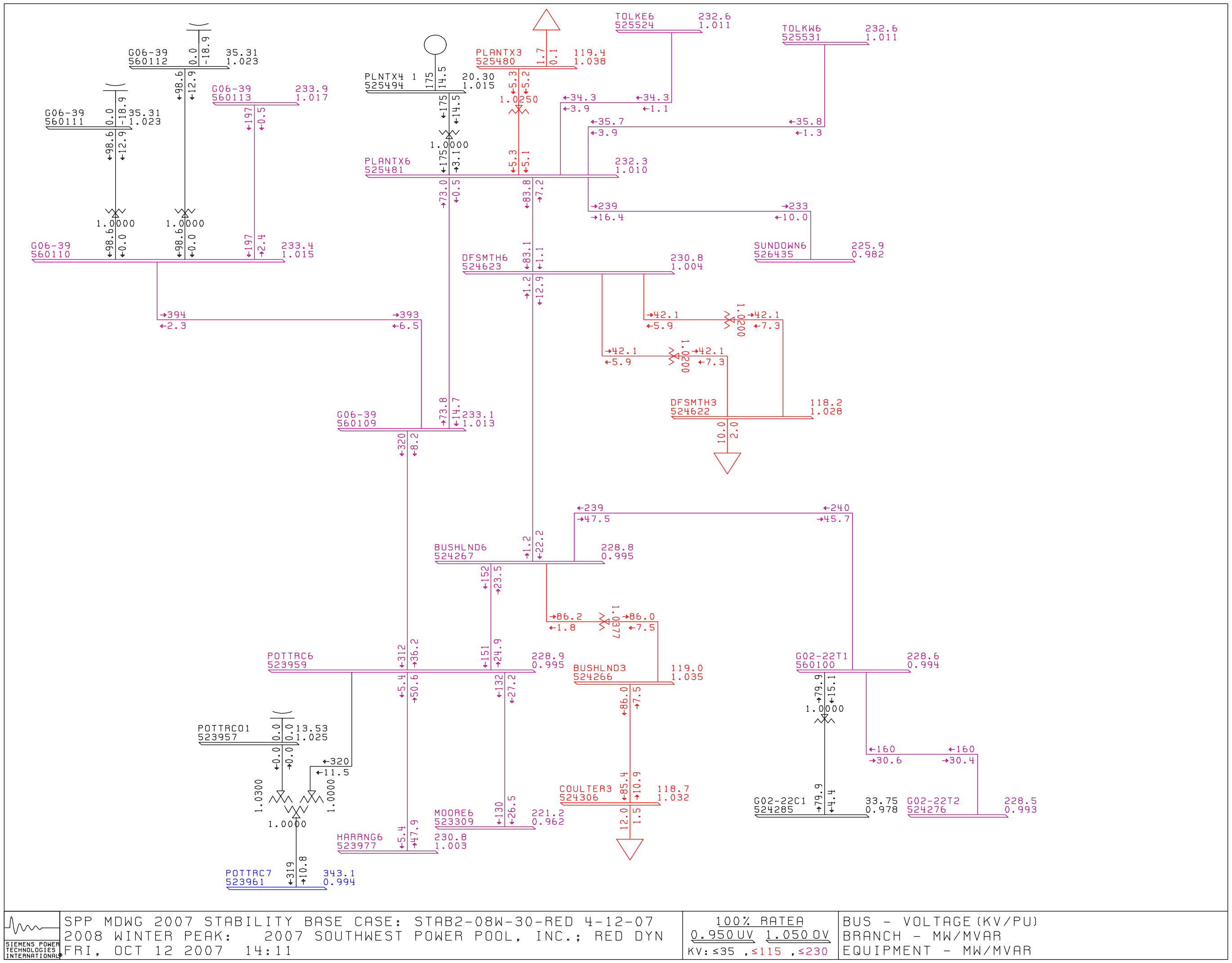

Figure 2-1 Winter Peak Flows and Voltages without GEN-2006-045

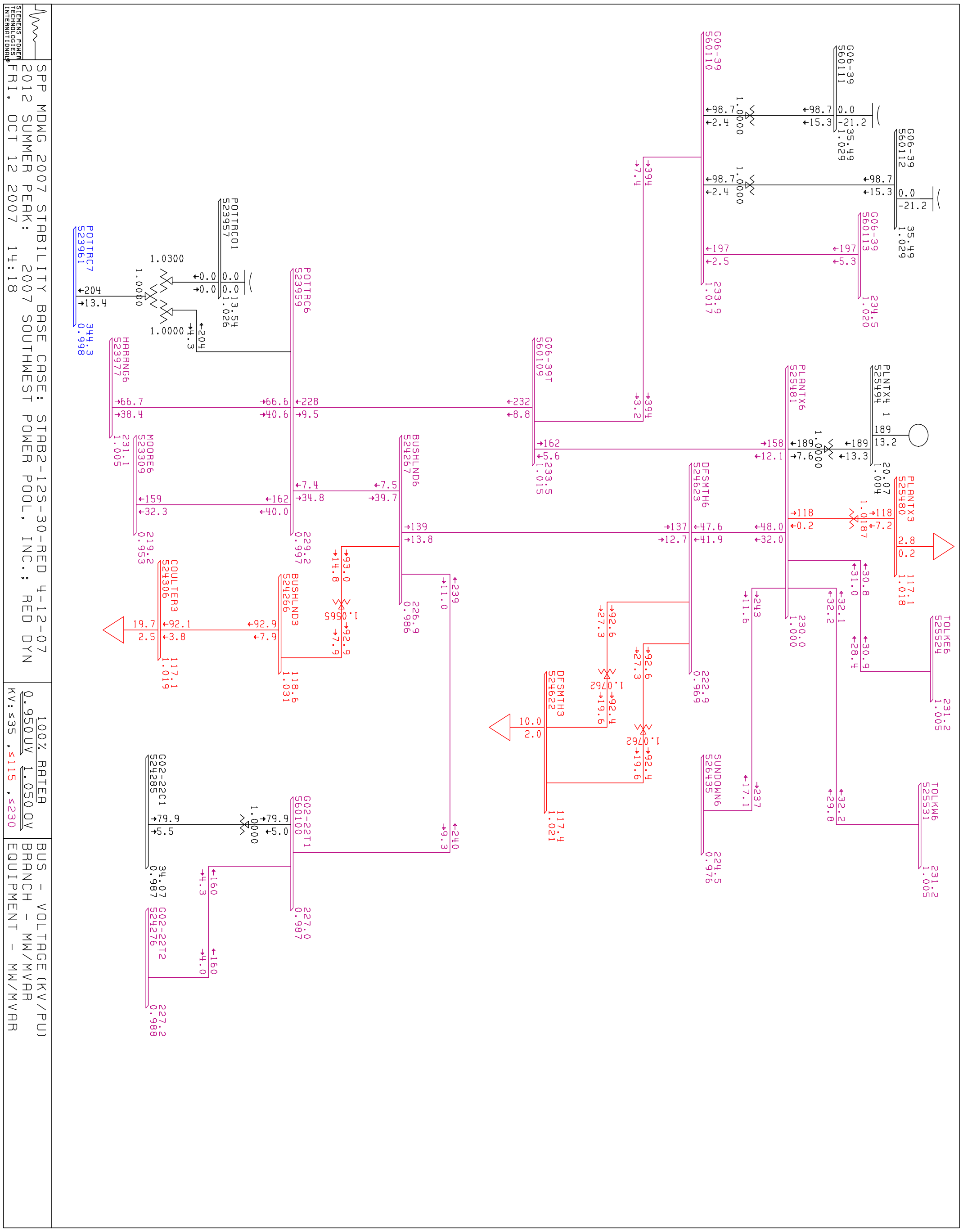

Figure 2-2 Summer Peak Flows and Voltages without GEN-2006-045

Wind Farm Power Flow Model

A single equivalent of the 115 Suzlon 2.1 MW wind turbine generators was modeled. The equivalent generator is then connected to an equivalent collector system through a single equivalent generator step-up transformer (0.60/34.5 kV). The wind farm collector system is then connected to the POI through a step-up transformer (34.5/230 kV) and a 230 kV line (see Figure 2-3). The detailed process of wind farm model development is described in Appendix A. In order to maintain a unity p.f. at the Point Of Interconnection (POI) a 60 Mvar shunt capacitor was added in Winter Peak 2008 and 45 Mvar shunt capacitor was added in 2012 Summer Peak cases.

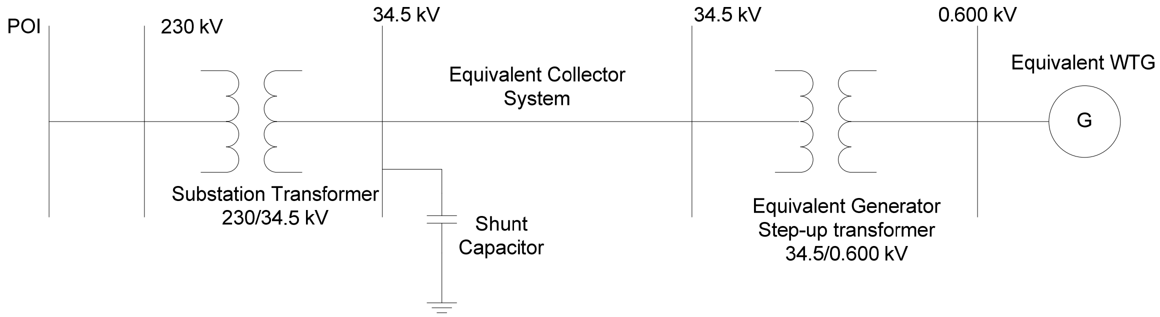

Figure 2-3: Wind farm modeling for the stability analysis

Figure 2-4 and Figure 2-5 show the one-line diagrams for the local area with the wind farm for 2008 Winter Peak and 2012 Summer Peak respectively.

Stability Database

SPP provided the stability database in the form of PSS/E dynamic data files, "*gen-2006-045_08wp.dyr*" to model the 2008 Winter Peak configuration, and "*gen-2006-045_12sp.dyr*" to model the 2012 Summer Peak configuration. Command files were also provided to compile and link user-written models. These files are compatible with PSS/E version 30.2.1.

The stability data for GEN-2006-045 was appended to the Pre-project data. The stability model incorporates the ride-through capability that allows wind turbine generator operation below 90% terminal voltage for up to 60.0 seconds and fast tripping (80 ms) for terminal voltages below 15%. The voltage trip settings are hard-coded in the model's FLECS code and cannot be adjusted by the PSS/E user.

The power flow and stability model representations for GEN-2006-045 are included in Appendix B.

Table 2-2 lists the faults simulated for stability analysis.

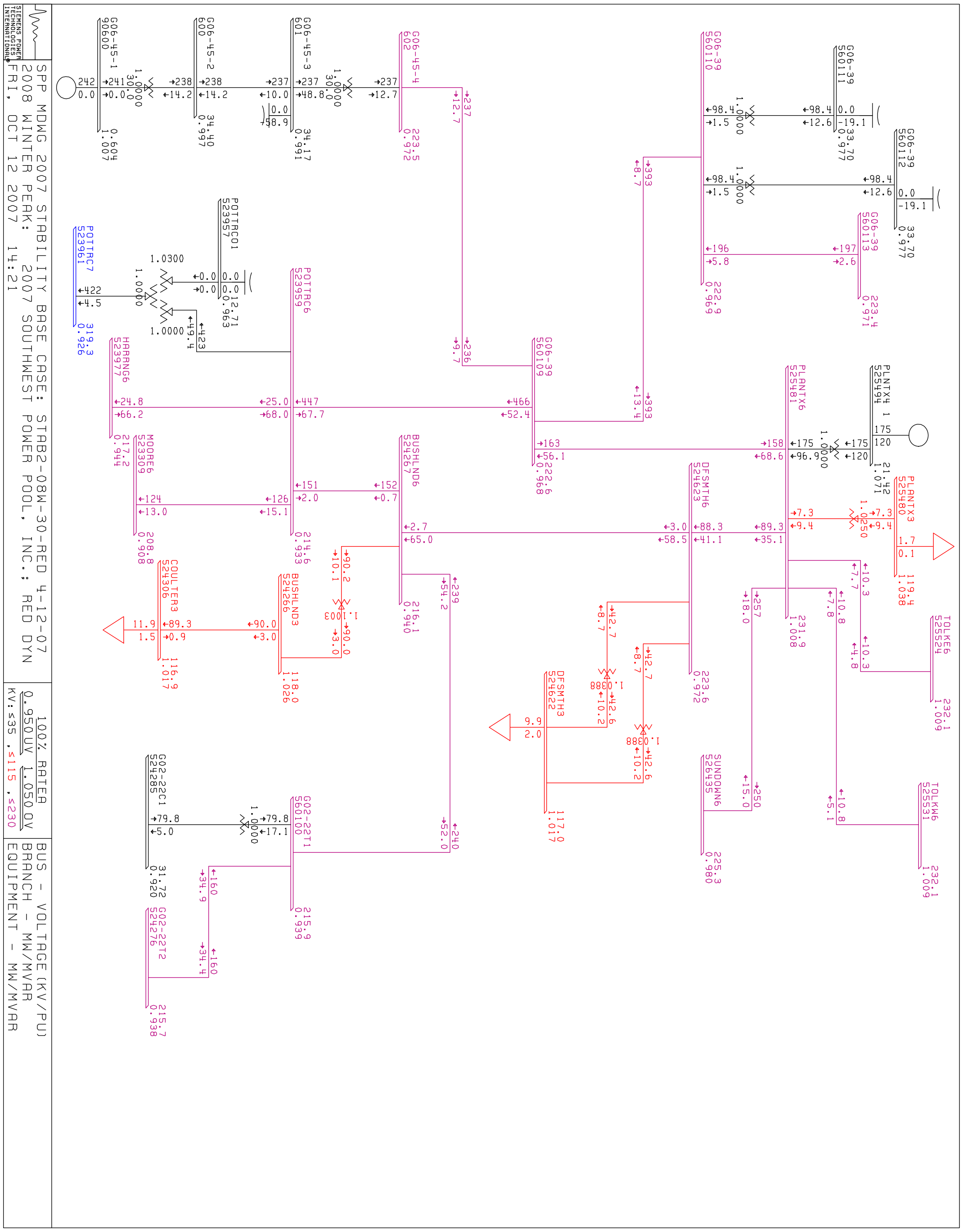

Figure 2-4 Winter Peak Flows and Voltages with GEN-2006-045

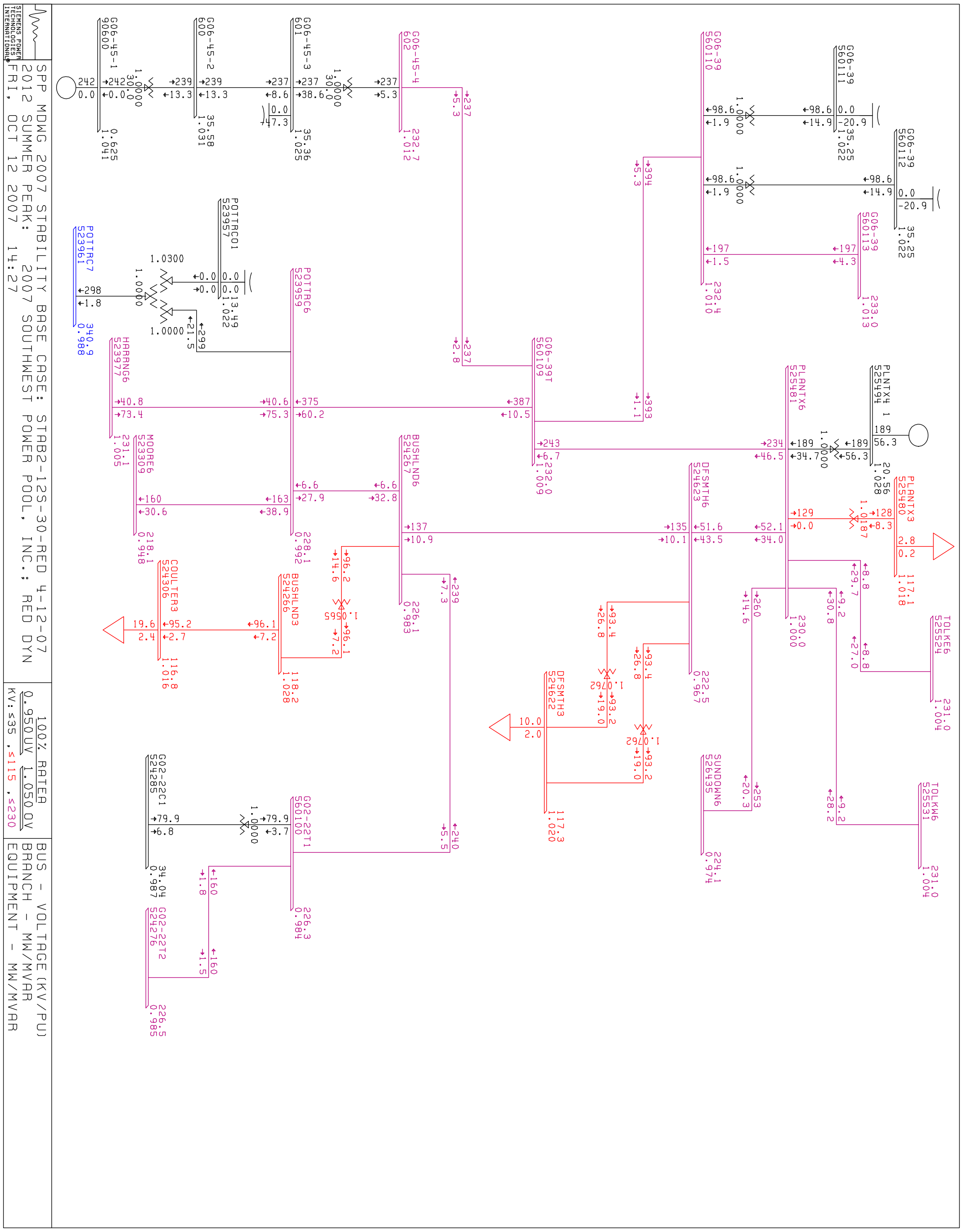

Figure 2-5 Summer Peak Flows and Voltages with GEN-2006-045

Table 2-2 List of Faults for Stability Analysis

Fault Name	***Description***
FLT_1_3PH	Three phase fault on the Wind Farm (560109) to Potter (523959) 230 kV line, near the Wind Farm. a) Apply fault at the Wind Farm 230kV bus. b) Clear fault after 5 cycles by tripping the line from the Wind Farm-Potter. 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.
FLT_2_1PH	Single phase fault on the Wind Farm (560109) to Potter (523959) 230 kV line, near the Wind Farm. a) Apply fault at the Wind Farm 230kV bus. b) Clear fault after 5 cycles by tripping the line from the Wind Farm-Potter. 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.
FLT_3_3PH	Three phase fault on the Wind Farm (560109) to Plant X (525481) 230 kV line, near the Wind Farm. a) Apply fault at the Wind Farm 230kV bus. b) Clear fault after 5 cycles by tripping the line from the Wind Farm-Plant X. 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.
FLT_4_1PH	Single phase fault on the Wind Farm (560109) to Plant X (525481) 230 kV line, near the Wind Farm. a) Apply fault at the Wind Farm 230kV bus. b) Clear fault after 5 cycles by tripping the line from the Wind Farm-Plant X. 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.
FLT_5_3PH	Three phase fault on the Bushland (524267) – Deaf Smith (524623) 230kV line, near Deaf Smith. a) Apply fault at the Deaf Smith 230kV bus. b) Clear fault after 5 cycles by tripping the line from Bushland – Deaf Smith 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.
FLT_6_1PH	Single phase fault on the Bushland (524267) – Deaf Smith (524623) 230kV line, near Deaf Smith. a) Apply fault at the Deaf Smith 230kV bus. b) Clear fault after 5 cycles by tripping the line from Bushland – Deaf Smith 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.
FLT_7_3PH	Three phase fault on the Potter (523961) – Finney (523853) 345kV line, near Potter. a) Apply fault at the Potter 345kV bus. b) Clear fault after 4 cycles by tripping the line from the Potter – Finney

Fault Name	***Description***
FLT_8_1PH	Single phase fault on the Potter (523961) – Finney (523853) 345kV line, near Potter. a) Apply fault at the Potter 345kV bus. b) Clear fault after 4 cycles by tripping the line from the Potter – Finney
FLT_9_3PH	Three phase fault on the GEN-2005-015 (560040) – Oklaunion (511456) 345kV line, near Oklaunion. a) Apply fault at the Oklaunion 345kV bus. b) Clear fault after 5 cycles by tripping the line from the Oklaunion – Gen-2005-015
FLT_10_1PH	Single phase fault on the GEN-2005-015 (560040) – Oklaunion (511456) 345kV line, near Oklaunion. a) Apply fault at the Oklaunion 345kV bus. b) Clear fault after 5 cycles by tripping the line from the Oklaunion – Gen-2005-015
FLT_11_3PH	Three phase fault on the Potter (523959) – Moore (523309) 230kV line near Moore. a) Apply fault at the Moore bus. b) Clear fault after 5 cycles by tripping the line Potter - Moore 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.
FLT_12_1PH	Single phase fault on the Potter (523959) – Moore (523309) 230kV line near Moore. a) Apply fault at the Moore bus. b) Clear fault after 5 cycles by tripping the line Potter - Moore 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.
FLT_13_3PH	Three phase fault on the Potter – Harrington 230kV line near Potter a) Apply fault at the Potter 230kV bus. b) Clear fault after 5 cycles by tripping the line c) No recluse
FLT_14_1PH	Single phase fault on the Potter – Harrington 230kV line near Potter a) Apply fault at the Potter 230kV bus. b) Clear fault after 5 cycles by tripping the line c) No recluse
FLT_15_3PH	Three phase fault on the Conway (524079)-Kirby 115kV line near Kirby a) Apply fault at the Kirby bus. b) Clear fault after 5 cycles by tripping the line Conway-Kirby 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
FLT_16_1PH	Single phase fault on the Conway (524079)-Kirby 115kV line near Kirby a) Apply fault at the Kirby bus. b) Clear fault after 5 cycles by tripping the line Conway-Kirby 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

Fault Name	***Description***
FLT_17_3PH	Three phase fault on the Nichols (524044)-Grapevine (523771) 230kV line near Grapevine a) Apply fault at the Grapevine bus. b) Clear fault after 5 cycles by tripping the line Nichols - Grapevine 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
FLT_18_1PH	Single phase fault on the Nichols (524044)-Grapevine (523771) 230kV line near Grapevine a) Apply fault at the Grapevine bus. b) Clear fault after 5 cycles by tripping the line Nichols - Grapevine 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
FLT_19_3PH	Three phase fault on the Tolk (525549)-Eddy (527802) 345kV line near Tolk a) Apply fault at the Tolk bus. b) Clear fault after 5 cycles by tripping the line Tolk - Eddy 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
FLT_20_1PH	Single phase fault on the Tolk (525549)-Eddy (527802) 345kV line near Tolk a) Apply fault at the Tolk bus. b) Clear fault after 5 cycles by tripping the line Tolk - Eddy 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
FLT_21_3PH	Three phase fault on the Plant X (525481)- Deaf Smith (524623) 230kV line near Deaf Smith a) Apply fault at the Deaf Smith bus. b) Clear fault after 5 cycles by tripping the Deaf Smith – Plant X 230kV line
FLT_22_1PH	Single phase fault on the Plant X (525481)- Deaf Smith (524623) 230kV line near Deaf Smith c) Apply fault at the Deaf Smith bus. d) Clear fault after 5 cycles by tripping the Deaf Smith – Plant X 230kV line
FLT_23_3PH	Three phase fault on the Wind Farm (560109) to Bushland (524267) 230 kV line, near the Wind Farm. a) Apply fault at the Wind Farm 230kV bus. b) Clear fault after 5 cycles by tripping the line from the Wind Farm- Bushland. 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.
FLT_24_1PH	Single phase fault on the Wind Farm (560109) to Bushland (524267) 230 kV line, near the Wind Farm. a) Apply fault at the Wind Farm 230kV bus. b) Clear fault after 5 cycles by tripping the line from the Wind Farm- Bushland. 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.

Fault Name	***Description***
FLT_25_3PH	Three phase fault on the Wind Farm (560109) to Deaf smith (524623) 230 kV line, near the Wind Farm. a) Apply fault at the Wind Farm 230kV bus. b) Clear fault after 5 cycles by tripping the line from the Wind Farm- Deaf smith. 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.
FLT_26_1PH	Three phase fault on the Wind Farm (560109) to Deaf smith (524623) 230 kV line, near the Wind Farm. a) Apply fault at the Wind Farm 230kV bus. b) Clear fault after 5 cycles by tripping the line from the Wind Farm- Deaf smith. 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.

2.3 STUDY RESULTS

The results for the simulated disturbances are summarized in Table 2-3. The plots showing the simulation results are included in Appendix C.

The initial results showed instability and wind farm tripping after numerous faults in the post-project cases. The unstable faults can be separated into two groups: local instability problems and regional instability problems.

Faults 7, 8, 9, 10, 17, and 18 make up the regionally unstable faults. These all involve loss of one of the three major interconnections between the Texas Panhandle and the eastern part of Southwest Power Pool:

- Potter – Finney 345 kV line
- Tuco – Oklaunion 345 kV line
- Nichols – Grapevine 230 kV line

These faults were repeated in the pre-project cases, and some of them were unstable in the pre-project scenario as well.

Due to the proposed addition of so much wind generation in the Texas Panhandle, the ability of these lines to reliably export power to the north and east is reaching a limit. However, these problems are considered to be a function of the chosen dispatch after adding GEN-2006-045 and not a result of the interconnection itself. Fixing these unstable faults is not considered to be required for interconnection, and these faults were not studied further. However, these results indicate that dispatching restrictions may be imposed on GEN-2006-045 under high Texas Panhandle export conditions.

Faults 1, 2, 3, and 4 are the locally unstable faults. They are stable in the pre-project cases. These problems are directly due to the addition of the GEN-2006-045 wind farm and are discussed further below.

Steady-state Voltage Stability – QV Analysis

To determine if a reactive power source such as SVC or STATCOM could fix the local instabilities, QV analysis was performed following local contingencies. The outage of the POI to Potter 230 kV line in the 2008 winter peak case is the worst local outage, so QV analysis was focused on this outage. Figure 2-6 shows the QV results of the pre- and post-project cases with the critical contingency already in effect. The minimum point indicates the reactive power margin (if $Q<0$) or deficit (if $Q>0$). For each curve, the points to the left of the minimum are the unstable region (increasing Mvar injection causes lower voltage). The PSS/E power flow program can solve in the unstable region, but this is not considered to be an acceptable operating region.

The pre-project case shows a reactive power ***margin*** of approximately 15 Mvar occurring at 0.86 pu voltage. The post-project case has a reactive power ***deficit*** of approximately 101 Mvar at 1.03 pu voltage. This shows that, even if large amounts of reactive power are added (i.e. >= 101 Mvar), voltages below 1.03 pu are unstable in the post-project case. As a result, simply adding a reactive power source such as an SVC or STATCOM is not an adequate solution.

SPP indicated that folding in the Bushland – Deaf Smith 230 kV line to the POI of GEN-2006-039 and -045 is a possible solution. A schematic of this upgrade is shown in Figure 2-7, with PSS/E one-lines of 08wp and 12sp shown in Figure 2-8 and Figure 2-9, respectively.

QV analysis of the critical contingency was performed after modeling this 230 kV line fold-in, with the results shown as the “With Fold-in” curve in Figure 2-6. As can be seen, the reactive power ***margin*** is greatly improved to 50 Mvar. Also, the more vertical slope is an indication of a stronger system, since voltage varies only a small amount with large variations in Mvar injection. The voltage at the 0 Mvar level is the steady-state post-contingency voltage with no reactive power addition.

With the improved voltages due to the fold-in, only 45 Mvar are required to maintain 1.0 power factor at the POI.

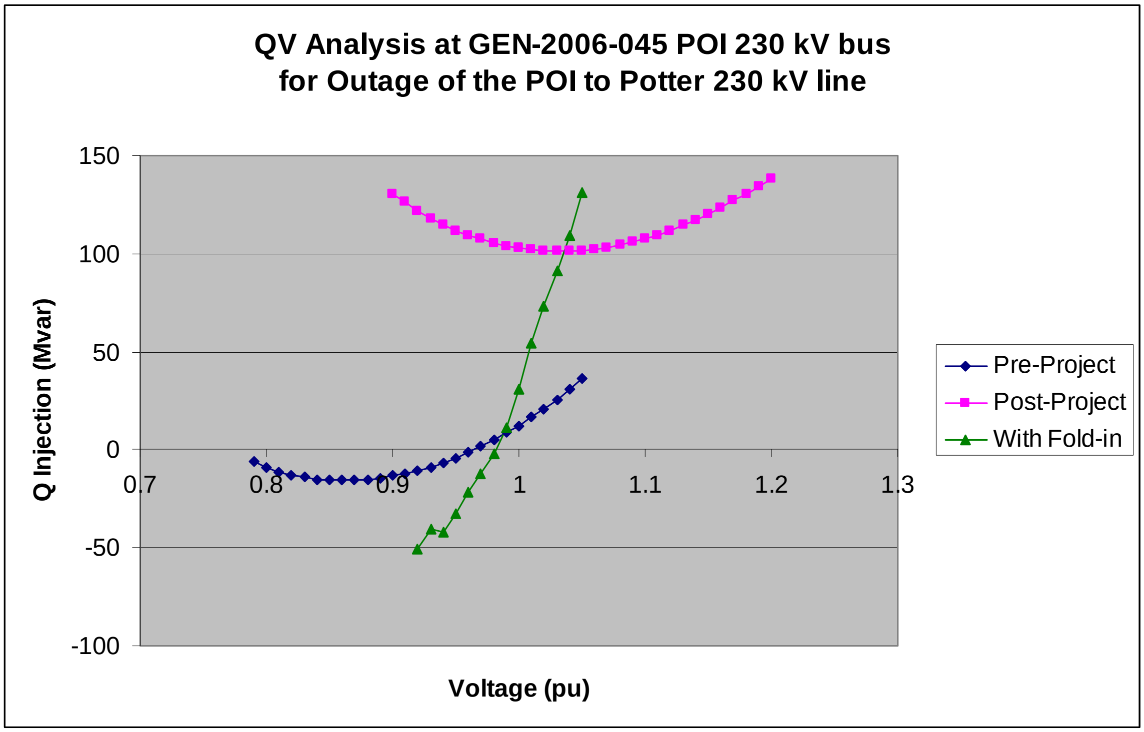

Figure 2-6 QV Curves

Dynamic Stability Analysis

The fold-in of the Bushland – Deaf Smith 230 kV line was also tested in dynamic simulations. Faults 1, 2, 3, and 4 are all stable with this solution, with no wind farm tripping occurring. This transmission upgrade required the addition of Faults 23, 24, 25, and 26 at the POI, replacing Faults 5 and 6. Fault 25 crashed due to instability. However, if the capacitors at GEN-2006-045 are increased to 60 Mvar, Fault 25 becomes stable.

The regional faults 7, 8, 9, 10, 17, and 18 are not fixed by this line fold-in. However, as indicated previously, this is a known regional problem due to high exports from of the Texas Panhandle.

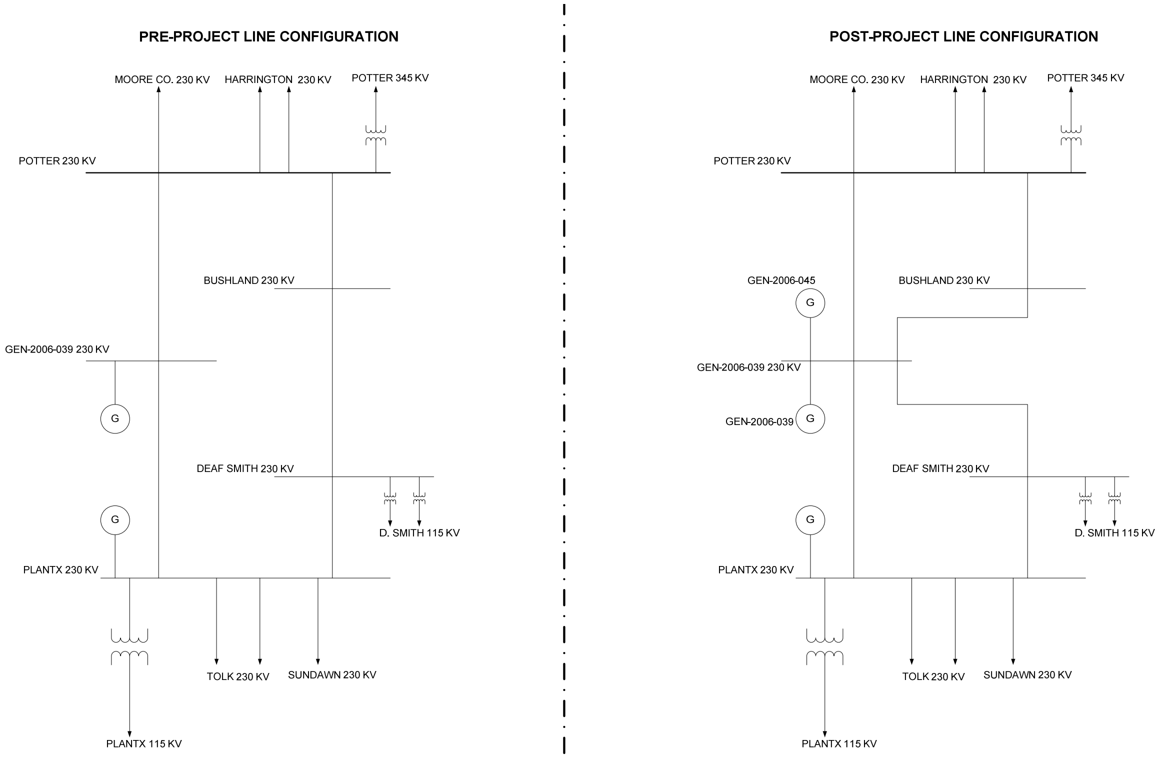

Figure 2-7 Bushland – Deaf Smith 230 kV fold-in (before and after)

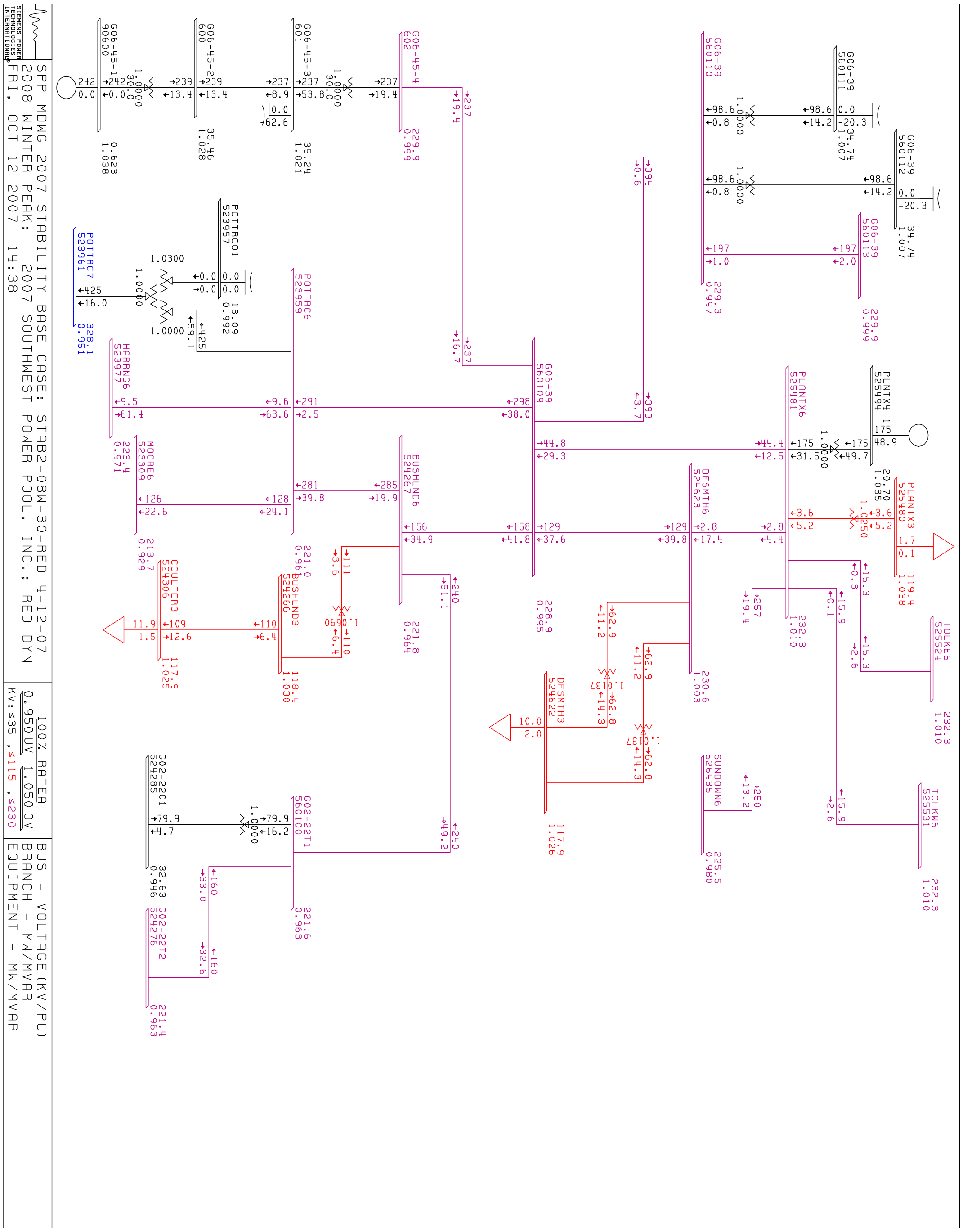

Figure 2-8 Winter Peak Flows and Voltages with GEN-2006-045 and Line tap

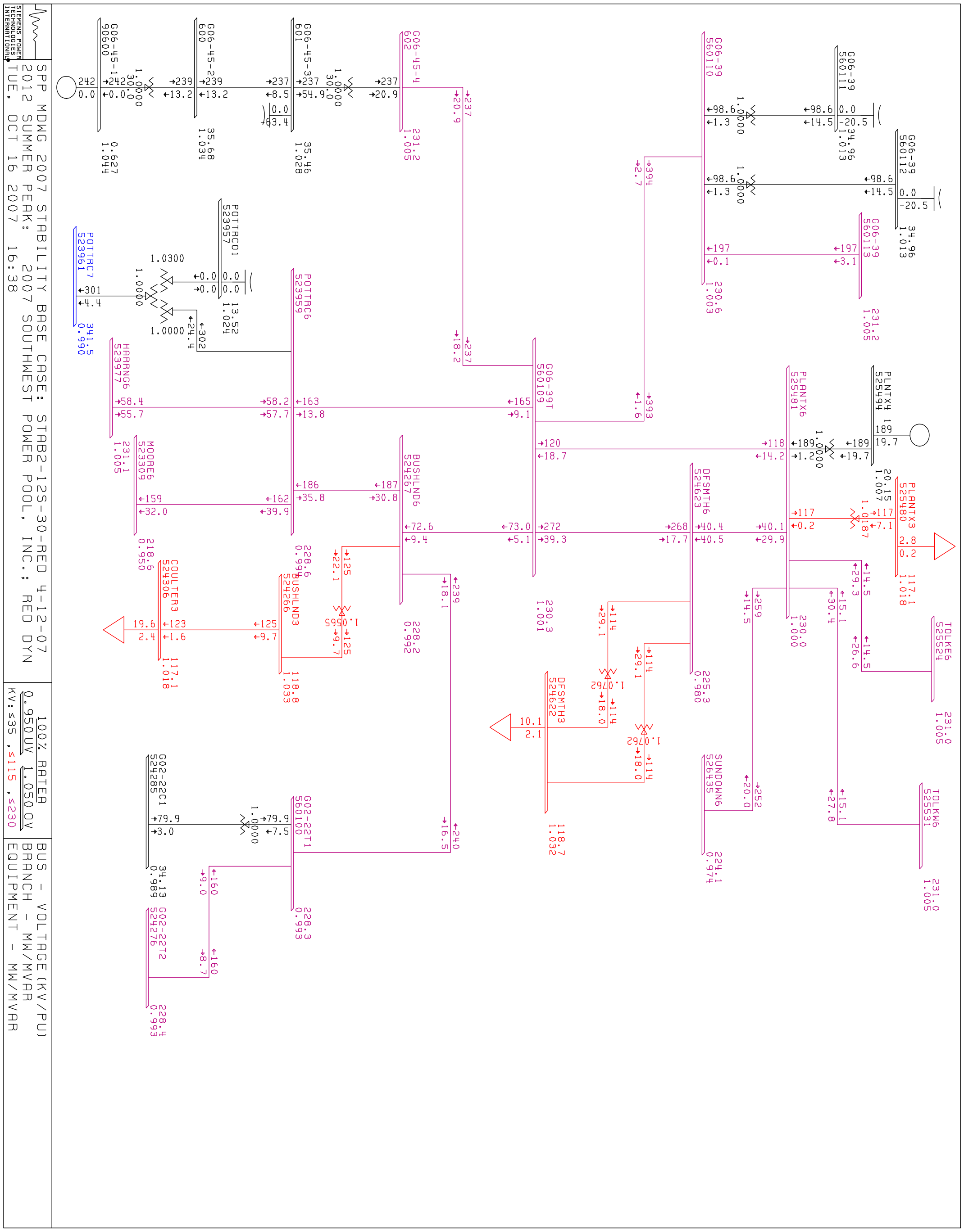

Figure 2-9 Summer Peak Flows and Voltages with GEN-2006-045 and Line tap

Table 2-3: Results of Stability Simulations

	2008 Winter Peak			**2012 Summer Peak**		
FAULT	**Pre-project**	**Post-project**	**Post-project With Line tap**	**Pre-project**	**Post-project**	**Post-project With Line tap**
FLT_1_3PH	STABLE	UNSTABLE	STABLE	---	UNSTABLE	STABLE
FLT_2_1PH	STABLE	UNSTABLE	STABLE	---	UNSTABLE	STABLE
FLT_3_3PH	STABLE	UNSTABLE	STABLE	---	UNSTABLE	STABLE
FLT_4_1PH	STABLE	UNSTABLE	STABLE	---	UNSTABLE	STABLE
FLT_5_3PH[1]	---	STABLE	---	---	STABLE	---
FLT_6_1PH[1]	---	STABLE	---	---	STABLE	---
FLT_7_3PH	UNSTABLE	UNSTABLE	UNSTABLE	STABLE	UNSTABLE	UNSTABLE
FLT_8_1PH	UNSTABLE	UNSTABLE	UNSTABLE	STABLE	UNSTABLE	UNSTABLE
FLT_9_3PH	UNSTABLE	UNSTABLE	UNSTABLE	STABLE	UNSTABLE	UNSTABLE
FLT_10_1PH	UNSTABLE	UNSTABLE	UNSTABLE	STABLE	UNSTABLE	UNSTABLE
FLT_11_3PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_12_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_13_3PH	---	STABLE	UNSTABLE	---	STABLE	STABLE
FLT_14_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_15_3PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_16_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_17_3PH	STABLE	UNSTABLE	UNSTABLE	---	STABLE	STABLE
FLT_18_1PH	STABLE	UNSTABLE	UNSTABLE	---	STABLE	STABLE
FLT_19_3PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_20_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_21_3PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_22_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_23_3PH[2]	---	---	STABLE	---	---	STABLE
FLT_24_1PH[2]	---	---	STABLE	---	---	STABLE
FLT_25_3PH[2]	---	---	UNSTABLE[3]	---	---	STABLE
FLT_26_1PH[2]	---	---	STABLE	---	---	STABLE

Notes:

[1] These faults are not applicable after fold-in of the Bushland – Deaf Smith 230 kV line

[2] These faults are only applicable after fold-in of the Bushland – Deaf Smith 230 kV line

[3] Fixed by increasing capacitor size to 60 Mvar at GEN-2006-045

[4] The speeds of the Siemens wind turbines at GEN-2002-022 show instability both pre-project and post-project for a number of faults, reaching extremes of +300% and -100%. However, the active and reactive power outputs look fine. Since speeds of this magnitude are not realistic, the SMK203 model must be inaccurate, and it is ignored.

3 CONCLUSIONS

The objective of this study is to evaluate the impact of the proposed GEN-2006-045 wind farm on the stability of SPP system. The study is performed for two system scenarios: the 2008 Winter Peak and the 2012 Summer Peak.

The system was unstable following faults at the POI after interconnection of the proposed project. QV analysis showed that a reactive-power-only solution, such as an SVC or STATCOM, is not feasible to fix the instability problems. A fold-in of the Bushland – Deaf Smith 230 kV line to the POI station was studied and shown to be an acceptable solution, as long as 60 Mvar of shunt capacitors are also installed on the GEN-2006-045 substation 34.5 kV bus.

The faults involving loss of one of the major transmission outlets from the Texas Panhandle gave unstable results in both pre- and post-project system conditions. Stability problems with large power exports from the Texas Panhandle are already known to SPP. Hence, the mitigation of these problems was considered out of scope and not required for interconnection of the wind farm.

FERC Order 661A Compliance – With the Bushland – Deaf Smith 230 kV line fold-in and 60 Mvar of shunt capacitors, the GEN-2006-045 wind farm with Suzlon 2.1 MW turbines complies with the latest FERC order on low voltage ride through for wind farms. With this arrangement, the wind farm would not trip off line by voltage relay actuation for local faults near the POI.

The results of this analysis are based on available data and assumptions made at the time of conducting this study. If any of the data and/or assumptions made in developing the study model change, the results provided in this report may not apply.

APPENDIX A - Wind Farm Model Development

APPENDIX B - Load Flow and Stability Data

APPENDIX C - Plots for Stability Simulations