Impact Study for Generation Interconnection Request GEN–2006–044

SPP Tariff Studies
(#GEN-2006-044)

February 8, 2008

Executive Summary

<OMITTED TEXT> (Customer) has requested a Impact Study for the purpose of interconnecting 400 MW of wind generation within the control area of Southwestern Public Service (SPS) primarily located in Texas County, Oklahoma and partially located in Hansford County, Texas. The proposed point of interconnection the 345kV substation proposed to be built for prior queued generation interconnection request GEN-2002-008 on the Potter – Finney 345kV transmission line owned by Southwestern Public Service (SPS). The proposed in-service date is October 1, 2010. This request is behind a prior queued request to interconnect into the same point. The prior queued request, GEN-2002-008, is for 240 MW.

This study has determined the requirements to interconnect the 400MW of generation is to add a new 345kV ring bus terminal to the switching station to be built for GEN-2002-008. In addition, a new 345kV line to either the Western Farmers Electric Cooperative (WFEC) Mooreland substation or the Oklahoma Gas and Electric (OKGE) Woodward substation will be required for the interconnection of this wind farm. The Customer will be required to install 107 Mvar of capacitors within their interconnection facilities.

A stability study was conducted by ABB Consulting and is included in Attachment 1. The stability study showed that, due to large amount of prior queued generation on the Potter – Finney 345kV line and in the Texas Panhandle on the 115kV and 230kV system, the interconnection could not be accommodated without the addition of the 345kV line to Mooreland/Woodward. The powerflow analysis was performed again with the 345kV line to Mooreland in service. The results are part of this report.

The total minimum costs for interconnection are estimated at $120,000,000. These costs are listed in Table 2.

The required interconnection costs listed in Table 2 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 requests transmission service through Southwest Power Pool's OASIS.

Introduction

<OMITTED TEXT> (Customer) has requested a Impact Study for the purpose of interconnecting 400 MW of wind generation within the control area of Southwestern Public Service (SPS) primarily located in Texas County, Oklahoma and partially located in Hansford County, Texas. The proposed point of interconnection the 345kV substation proposed to be built for prior queued generation interconnection request GEN-2002-008 on the Potter – Finney 345kV transmission line owned by Southwestern Public Service (SPS). The proposed in-service date is October 1, 2010. This request is behind a prior queued request to interconnect into the same point. The prior queued request, GEN-2002-008, is for 240 MW.

Interconnection Facilities

The Customer has requested interconnecting a 400 MW wind farm within the control area of Southwestern Public Service Company (d/b/a Xcel Energy) (SPS). The plant site is located in Hansford County, Texas to be interconnected into the proposed 345kV substation to be built for interconnection request GEN-2002-008. This substation is to be located along the Potter – Finney 345kV transmission line. The proposed method of interconnection is to add a new 345kV terminal into this substation.

The Impact study has determined that adding a fourth 345kV terminal to the proposed GEN-2002-008 substation will not be adequate for interconnecting the 400 MW of wind generation. Generator and voltage instability are encountered for certain contingencies that were studied in the analysis. Initially, the interconnection request was studied with prior queued projects and the existing transmission network for the Texas panhandle area. The SPP Transmission Expansion Plan and SPS have now identified a transmission project in the Texas panhandle to add a 345/230/115kV step down station near the GEN-2002-008 switching station. This station is to be named Hitchland. This expansion plan project was then added to the model and the analysis was run again. The results showed that even with the Hitchland project, GEN-2006-044 will still experience generator and voltage instability issues.

These results indicate that panhandle area of Texas cannot accommodate any more generation without sufficient outlets to the rest of the SPP transmission system. Therefore, the interconnection of GEN-2006-044 will require the addition of a 345kV transmission line to the east. For this study, a 345kV transmission line from GEN-2002-008 (Hitchland) to the Western Farmers Electric Cooperative (WFEC) Mooreland substation was analyzed. The analysis has indicated that stability issues will be alleviated with the addition of this 345kV transmission line. Therefore, GEN-2006-044 interconnection Customer is responsible for the addition of this transmission line.

The proposed Hitchland-Mooreland 345kV transmission line is not a definitive project at this time. The Oklahoma terminus point may be changed at a later date to possibly the Oklahoma Gas & Electric (OKGE) Woodward substation. The approximate distance from Hitchland to Mooreland is estimated at 120 miles. With necessary substation construction, the line and substation work is estimated to cost approximately $120,000,000. This estimate will be refined during the course of a Facility Study if the Customer wishes to execute the Facility Study Agreement.

The Impact Study has determined the reactive compensation requirements of the GEN-2006-044 wind farm. With the Customer requested Suzlon S88 2.1 MW wind turbines, the wind farm will be required to install four (4) capacitor banks with a total of 107 Mvar.

The banks will include three (3) 34.5kV kV capacitor banks on the low side of the Customer 115/34.5kV transformers sized at 10 Mvar, 22 Mvar, and 31 Mvar. The fourth banks will be a 115kV, 45 Mvar bank to be located on the low side of the Customer's 345/115kV transformer.

The Impact Study has also determined that with the Suzlon wind turbines, the required capacitor banks, and the 345kV transmission line to Mooreland in service, GEN-2006-044 will meet FERC Order #661A low voltage requirements for low voltage ride through.

Table 1. Interconnection Facilities

FACILITY	ESTIMATED COST (2007 DOLLARS)
CUSTOMER – (3) 115/34.5 kV collector substation facilities.	*
CUSTOMER – (3) 115 kV transmission facilities between the three Customer 115/34.5 kV collector substation facilities and the Customer 345/115 kV switching station.	*
CUSTOMER – (2) 345/115 kV transformers and all related 345/115 kV switching equipment located at the Customer 345/115 kV switching station.	*
CUSTOMER – (1) 345 kV tie between Customer 345/115 kV switching station and the point of interconnection.	*
CUSTOMER – Right-of-Way for Customer facilities.	*
CUSTOMER – Four (4) capacitors banks – Three (3) 34.5 kV banks sized at 10Mvar, 22 Mvar, and 31Mvar. One (1) 115kV, 45 Mvar in three Customer substations.	*
TOTAL	*

* Determined by Customer

Table 2. Network Upgrades

FACILITY	ESTIMATED COST (2007 DOLLARS)
Various Transmission Owners - Add (2) 345 kV terminals to Hitchland substation; build 120 miles of 345kV line to WFEC Mooreland substation (or OKGE Woodward), and build 345kV switchyard and autotransformer at the Oklahoma terminal point.	**$120,000,000**
TOTAL	**$120,000,000**

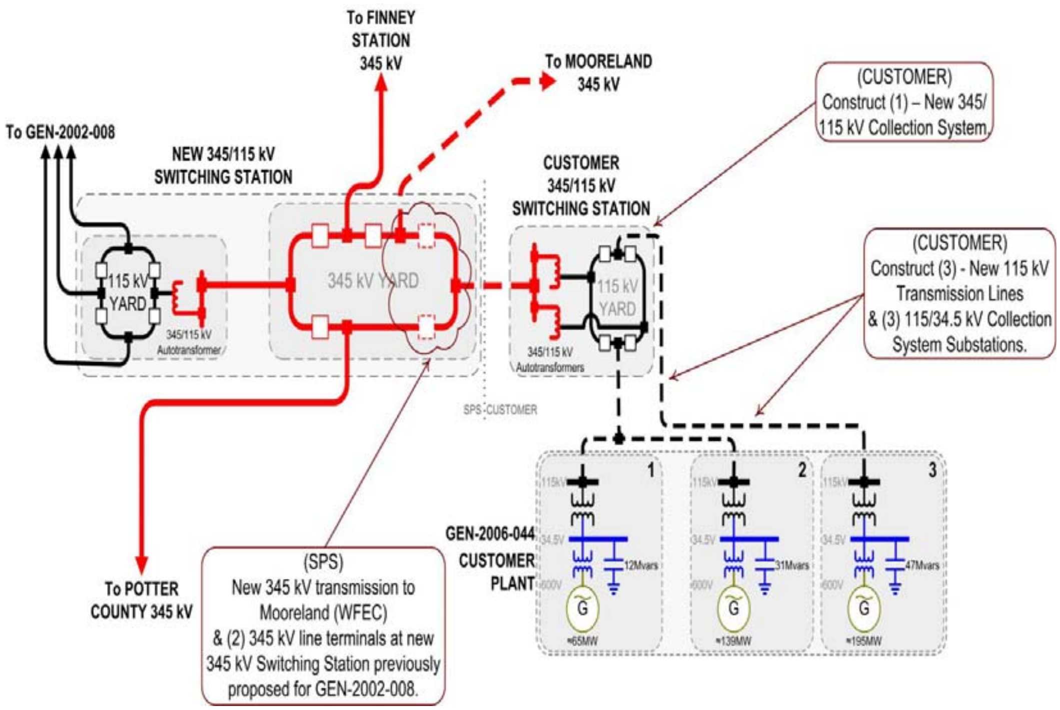

Figure 1. Proposed Interconnection Configuration (Final designs to be determined)

Powerflow Analysis

A powerflow analysis was conducted for the facility using modified versions of the 2009 and 2012 summer and winter peak, and 2017 summer peak models. 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 October 1, 2010. The available seasonal models used were through the 2017 Summer Peak of which is the end of the current SPP planning horizon.

The analysis of the Customer's project indicates that, given the requested generation level of 400 MW and location, additional criteria violations will occur on the existing AEPW, MIDW, SPS, SUNC, and WEPL transmission systems under steady state and contingency conditions in the peak seasons. These network constraints are shown in Table 3.

In Table 4, 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.

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 Feasibility Study. Those local projects that were previously queued and have advanced to nearly complete phases were included in this Feasibility 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 (WESTAR), 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 (SPS), Western Farmers Electric Cooperative (WFEC), Western Resources (WERE), 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.

Table 3: Network Constraints

AREA	OVERLOADED ELEMENT
AEPW	ELK CITY (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1
AEPW	JERICHO (JERIC2WT) 115/69/14.4KV TRANSFORMER CKT 1
AEPW	OKLAUNION - OKLAUN 345KV 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 - GRAPEVINE INTERCHANGE 230KV CKT 1
MIDW	ALEXANDER - NEKOMA 115KV CKT 1
MIDW	ALEXANDER - NESS CITY 115KV CKT 1
MIDW	COLBY - HOXIE 115KV CKT 1
MIDW	HEIZER 115/69KV TRANSFORMER CKT 2
SPS	CANYON EAST SUB - CANYON WEST SUB 115KV CKT 1
SPS	CANYON EAST SUB - OSAGE SWITCHING STATION 115KV CKT 1
SPS	CUNNINGHAM STATION 230/115KV TRANSFORMER CKT 1
SPS	HAPPY INTERCHANGE - PALO DURO SUB 115KV CKT 1
SPS	HAPPY INTERCHANGE - TULIA TAP 115KV CKT 1
SPS	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1
SPS	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2
SPS	HITCHLAND 345.00 345/115KV TRANSFORMER CKT 1
SPS	HITCHLAND 345.00 345/115KV TRANSFORMER CKT 2
SPS	HITCHLAND (HITCHLN7) 345/230/13.2KV TRANSFORMER CKT 1
SPS	KRESS INTERCHANGE - TULIA TAP 115KV CKT 1
SPS	LEA COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1
SPS	MCCLELLAN SUB - KIRBY SWITCHING STATION 115KV CKT 1
SPS	PALO DURO SUB - RANDALL COUNTY INTERCHANGE 115KV CKT 1
SPS	RANDALL COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1
SUNC	BEELER - DIGHTON TAP 115KV CKT 1
SUNC	DIGHTON TAP - MANNING TAP 115KV CKT 1
WEPL	GREENSBURG - JUDSON LARGE 115KV CKT 1
WEPL	MULLERGREN - SPEARVILLE 230KV CKT 1
WEPL	SEWARD - ST JOHN 115KV CKT 1
WEPL/MIDW	MULLERGREN - S HAYS6 230.00 230KV CKT 1
WEPL/SUNC	CIMARRON RIVER PLANT - NORTH CIMARRON 115KV CKT 1
WEPL/SUNC	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1
WERE	CIRCLE - RENO COUNTY 115KV CKT 2
AEPW	American Electric Power West
MIDW	Midwest Energy
SPS	Southwestern Public Service Company
SUNC	Sunflower Electric Power Corporation
WELP	West Plains

Table 4: Contingency Analysis

SEASON	OVERLOADED ELEMENT	RATING (MVA)	LOADING (%)	ATC (MW)	CONTINGENCY
09SP	PALO DURO SUB - RANDALL COUNTY INTERCHANGE 115KV CKT 1	99	127	0	AMARILLO SOUTH INTERCHANGE - SWISHER COUNTY INTERCHANGE 230KV CKT 1
09SP	HAPPY INTERCHANGE - PALO DURO SUB 115KV CKT 1	99	126	0	AMARILLO SOUTH INTERCHANGE - SWISHER COUNTY INTERCHANGE 230KV CKT 1
09SP	SEWARD - ST JOHN 115KV CKT 1	80	118	0	GREENSBURG - JUDSON LARGE 115KV CKT 1
09SP	CANYON EAST SUB - OSAGE SWITCHING STATION 115KV CKT 1	99	118	0	BUSHLAND INTERCHANGE - DEAF SMITH COUNTY INTERCHANGE 230KV CKT 1
09SP	HEIZER 115/69KV TRANSFORMER CKT 2	24	170	1	BASE CASE
09SP	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1	336	118	66	HOLCOMB - SETAB 345KV CKT 1
09SP	CIRCLE - RENO COUNTY 115KV CKT 2	92	121	75	CIRCLE - RENO COUNTY 115KV CKT 1
09SP	CIMARRON RIVER PLANT - NORTH CIMARRON 115KV CKT 1	143	117	89	HOLCOMB - SPEARVILLE 345KV CKT 1
09SP	ELK CITY (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1	287	119	159	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
09SP	RANDALL COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1	259	104	164	AMARILLO SOUTH INTERCHANGE - NICHOLS STATION 230KV CKT 1
09SP	DIGHTON TAP - MANNING TAP 115KV CKT 1	98	111	186	HOLCOMB - SPEARVILLE 345KV CKT 1
09SP	ELK CITY - GRAPEVINE INTERCHANGE 230KV CKT 1	351	120	192	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
09SP	ALEXANDER - NESS CITY 115KV CKT 1	101	111	215	HOLCOMB - SPEARVILLE 345KV CKT 1
09SP	HAPPY INTERCHANGE - TULIA TAP 115KV CKT 1	99	109	223	AMARILLO SOUTH INTERCHANGE - SWISHER COUNTY INTERCHANGE 230KV CKT 1
09SP	SHAMROCK (SHAMRCK1) 115/69/14.4KV TRANSFORMER CKT 1	69	110	258	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
09SP	KRESS INTERCHANGE - TULIA TAP 115KV CKT 1	99	104	319	AMARILLO SOUTH INTERCHANGE - SWISHER COUNTY INTERCHANGE 230KV CKT 1
09SP	CANYON EAST SUB - CANYON WEST SUB 115KV CKT 1	99	103	320	BUSHLAND INTERCHANGE - DEAF SMITH COUNTY INTERCHANGE 230KV CKT 1
09SP	BEELER - DIGHTON TAP 115KV CKT 1	98	104	331	HOLCOMB - SPEARVILLE 345KV CKT 1
09SP	ALEXANDER - NEKOMA 115KV CKT 1	101	104	333	HOLCOMB - SPEARVILLE 345KV CKT 1
09SP	MULLERGREN - SPEARVILLE 230KV CKT 1	355	105	335	HOLCOMB - SETAB 345KV CKT 1
09SP	COLBY - HOXIE 115KV CKT 1	101	101	376	MULLERGREN - SPEARVILLE 230KV CKT 1
09SP	GREENSBURG - JUDSON LARGE 115KV CKT 1	130	101	378	MULLERGREN - SPEARVILLE 230KV CKT 1
09SP	HITCHLAND (HITCHLN7) 345/230/13.2KV TRANSFORMER CKT 1	560	101	393	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1

SEASON	OVERLOADED ELEMENT	RATING (MVA)	LOADING (%)	ATC (MW)	CONTINGENCY
09WP	CUNNINGHAM STATION 230/115KV TRANSFORMER CKT 1	168	115	0	LEA COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1
09WP	ELK CITY (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1	287	123	82	2003-13 - FINNEY SWITCHING STATION 345KV CKT 1
09WP	LEA COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1	168	117	93	CUNNINGHAM STATION 230/115KV TRANSFORMER CKT 1
09WP	ELK CITY - GRAPEVINE INTERCHANGE 230KV CKT 1	351	136	103	2003-13 - FINNEY SWITCHING STATION 345KV CKT 1
09WP	CIMARRON RIVER PLANT - NORTH CIMARRON 115KV CKT 1	143	113	134	HOLCOMB - SPEARVILLE 345KV CKT 1
09WP	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1	336	112	173	OKLAUNION - TUCO INTERCHANGE 345KV CKT 1
09WP	OKLAUNION - OKLAUN 345KV CKT 1	250	103	174	2003-13 - FINNEY SWITCHING STATION 345KV CKT 1
09WP	SHAMROCK (SHAMRCK1) 115/69/14.4KV TRANSFORMER CKT 1	69	118	182	2003-13 - FINNEY SWITCHING STATION 345KV CKT 1
09WP	ALEXANDER - NESS CITY 115KV CKT 1	101	110	233	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1
09WP	SHAMROCK (SHAMRCK2) 138/69/14.4KV TRANSFORMER CKT 1	69	107	319	2003-13 - FINNEY SWITCHING STATION 345KV CKT 1
09WP	ALEXANDER - NEKOMA 115KV CKT 1	101	104	336	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1
09WP	DIGHTON TAP - MANNING TAP 115KV CKT 1	98	103	350	HOLCOMB - SPEARVILLE 345KV CKT 1
12SP	PALO DURO SUB - RANDALL COUNTY INTERCHANGE 115KV CKT 1	99	123	0	AMARILLO SOUTH INTERCHANGE - SWISHER COUNTY INTERCHANGE 230KV CKT 1
12SP	HAPPY INTERCHANGE - PALO DURO SUB 115KV CKT 1	99	122	0	AMARILLO SOUTH INTERCHANGE - SWISHER COUNTY INTERCHANGE 230KV CKT 1
12SP	RANDALL COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1	259	106	0	AMARILLO SOUTH INTERCHANGE - NICHOLS STATION 230KV CKT 1
12SP	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1	336	117	54	CIMARRON RIVER PLANT - NORTH CIMARRON 115KV CKT 1
12SP	ELK CITY (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1	287	121	123	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
12SP	ELK CITY - GRAPEVINE INTERCHANGE 230KV CKT 1	351	124	155	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
12SP	HEIZER 115/69KV TRANSFORMER CKT 2	32	127	156	BASE CASE
12SP	SHAMROCK (SHAMRCK1) 115/69/14.4KV TRANSFORMER CKT 1	69	115	183	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
12SP	DIGHTON TAP - MANNING TAP 115KV CKT 1	98	111	185	MULLERGREN - SPEARVILLE 230KV CKT 1
12SP	HITCHLAND 345.00 345/115KV TRANSFORMER CKT 2	250	159	197	HITCHLAND 345.00 345/115KV TRANSFORMER CKT 1
12SP	MULLERGREN - SPEARVILLE 230KV CKT 1	355	115	200	HOLCOMB - SETAB 345KV CKT 1

SEASON	OVERLOADED ELEMENT	RATING (MVA)	LOADING (%)	ATC (MW)	CONTINGENCY
12SP	CIMARRON RIVER PLANT - NORTH CIMARRON 115KV CKT 1	143	111	202	HOLCOMB - SPEARVILLE 345KV CKT 1
12SP	ALEXANDER - NESS CITY 115KV CKT 1	101	109	238	HOLCOMB - SPEARVILLE 345KV CKT 1
12SP	HAPPY INTERCHANGE - TULIA TAP 115KV CKT 1	99	105	266	AMARILLO SOUTH INTERCHANGE - SWISHER COUNTY INTERCHANGE 230KV CKT 1
12SP	BEELER - DIGHTON TAP 115KV CKT 1	98	104	329	HOLCOMB - SPEARVILLE 345KV CKT 1
12SP	MULLERGREN - S HAYS6 230.00 230KV CKT 1	147	103	357	CIRCLE - MULLERGREN 230KV CKT 1
12SP	ALEXANDER - NEKOMA 115KV CKT 1	101	102	363	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1
12SP	GREENSBURG - JUDSON LARGE 115KV CKT 1	130	101	376	MULLERGREN - SPEARVILLE 230KV CKT 1
12SP	HITCHLAND (HITCHLN7) 345/230/13.2KV TRANSFORMER CKT 1	560	102	381	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
12SP	JERICHO (JERIC2WT) 115/69/14.4KV TRANSFORMER CKT 1	46	106	398	MCCLELLAN SUB - MCLEAN RURAL SUB 115KV CKT 1
12WP	ELK CITY (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1	287	123	73	2003-13 - FINNEY SWITCHING STATION 345KV CKT 1
12WP	ELK CITY - GRAPEVINE INTERCHANGE 230KV CKT 1	351	136	99	2003-13 - FINNEY SWITCHING STATION 345KV CKT 1
12WP	CIMARRON RIVER PLANT - NORTH CIMARRON 115KV CKT 1	143	113	137	HOLCOMB - SPEARVILLE 345KV CKT 1
12WP	OKLAUNION - OKLAUN 345KV CKT 1	250	103	144	2003-13 - FINNEY SWITCHING STATION 345KV CKT 1
12WP	SHAMROCK (SHAMRCK1) 115/69/14.4KV TRANSFORMER CKT 1	69	120	169	2003-13 - FINNEY SWITCHING STATION 345KV CKT 1
12WP	CUNNINGHAM STATION 230/115KV TRANSFORMER CKT 1	168	104	253	LEA COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1
12WP	ALEXANDER - NESS CITY 115KV CKT 1	101	108	260	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1
12WP	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1	336	104	329	GEN542962 2
12WP	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1	706	102	329	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2
12WP	SHAMROCK (SHAMRCK2) 138/69/14.4KV TRANSFORMER CKT 1	69	105	333	2003-13 - FINNEY SWITCHING STATION 345KV CKT 1
12WP	HARRNG_MID6 230.00 - NICHOLS STATION 230KV CKT 2	706	102	336	HARRINGTON STATION - NICHOLS STATION 230KV CKT 1
12WP	DIGHTON TAP - MANNING TAP 115KV CKT 1	98	103	353	HOLCOMB - SPEARVILLE 345KV CKT 1
12WP	ALEXANDER - NEKOMA 115KV CKT 1	101	102	364	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1
17SP	RANDALL COUNTY INTERCHANGE 230/115KV TRANSFORMER CKT 1	259	112	0	AMARILLO SOUTH INTERCHANGE - NICHOLS STATION 230KV CKT 1

SEASON	OVERLOADED ELEMENT	RATING (MVA)	LOADING (%)	ATC (MW)	CONTINGENCY
17SP	SPEARVILLE (SPEARVL) 345/230/13.8KV TRANSFORMER CKT 1	336	126	27	HOLCOMB - SETAB 345KV CKT 1
17SP	PALO DURO SUB - RANDALL COUNTY INTERCHANGE 115KV CKT 1	99	115	84	AMARILLO SOUTH INTERCHANGE - SWISHER COUNTY INTERCHANGE 230KV CKT 1
17SP	HAPPY INTERCHANGE - PALO DURO SUB 115KV CKT 1	99	114	109	AMARILLO SOUTH INTERCHANGE - SWISHER COUNTY INTERCHANGE 230KV CKT 1
17SP	ELK CITY (ELKCTY-6) 230/138/13.8KV TRANSFORMER CKT 1	287	120	143	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
17SP	ELK CITY - GRAPEVINE INTERCHANGE 230KV CKT 1	351	124	165	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
17SP	SHAMROCK (SHAMRCK1) 115/69/14.4KV TRANSFORMER CKT 1	69	114	199	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
17SP	MULLERGREN - SPEARVILLE 230KV CKT 1	355	111	265	MINGO - SETAB 345KV CKT 1
17SP	MULLERGREN - S HAYS6 230.00 230KV CKT 1	147	109	292	MINGO - SETAB 345KV CKT 1
17SP	DIGHTON TAP - MANNING TAP 115KV CKT 1	98	104	338	MINGO - SETAB 345KV CKT 1
17SP	HITCHLAND (HITCHLN7) 345/230/13.2KV TRANSFORMER CKT 1	560	106	345	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
17SP	MCCLELLAN SUB - KIRBY SWITCHING STATION 115KV CKT 1	90	101	388	FINNEY SWITCHING STATION - HOLCOMB 345KV CKT 1
17SP	JERICHO (JERIC2WT) 115/69/14.4KV TRANSFORMER CKT 1	46	107	398	KIRBY SWITCHING STATION - MCCLELLAN SUB 115KV 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.

IMPACT STUDY FOR GENERATION INTERCONNECTION REQUEST GEN-2006-044

FINAL REPORT

REPORT NO.: 2007-11628-R1
Issued: February 8, 2008

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Legal Notice

ABB Inc – Grid Systems Consulting

Technical Report

Southwest Power Pool	**No.** 2007-11628-R1	
Impact Study for Generation Interconnection request GEN-2006-044	2/8/2008	# Pages 64

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Executive Summary

Southwest Power Pool (SPP) has a commissioned ABB Inc. to perform a generator interconnection study for a 345 kV interconnection of a 400 MW wind farm in Hansford County, Texas. This wind farm will be interconnected into a proposed 345 kV switching station on the Potter – Finney 345 kV line. The proposed station is to be built for prior-queued generation interconnection request GEN-2002-008. This transmission line is owned by Southwestern Public Service (d/b/a Xcel Energy). Per the developer's request, the 400 MW of additional generation was studied assuming Suzlon S88 2.1 MW wind turbines. Faults were simulated on the SPP system for Winter Peak 2008 and Summer Peak 2012 conditions.

The system was unstable following faults at or near the POI after interconnection of the proposed project with the original base cases. The same faults were stable in the pre-project cases. QV analysis showed that a shunt reactive power addition, such as an SVC or STATCOM, is not feasible to fix the stability problems. An upgrade featuring a new 345 kV line to Mooreland was studied, but the GEN-2006-044 plant still had unacceptable post-contingency oscillations.

A new base case was created with the planned Hitchland 345/230/115 kV tie, but there were still stability problems with GEN-2006-044 on-line. Finally, adding the 345 kV line to Mooreland, and still including the Hitchland 345/230/115 kV tie, made all stability problems go away with GEN-2006-044. This is the final recommended solution.

The final shunt capacitor requirements for GEN-2006-044, assuming installation of the Hitchland 345/230/115 kV tie and the new 345 kV line to Mooreland, are 10, 22, and 31 Mvar at Substation-1, Substation-2 and Substation-3 respectively, as well as 45 Mvar on the low side of the wind farm 345/115 kV transformers. The exact distribution of these Mvar can be adjusted among these locations by the wind project developer, but the total must result in 1.0 power factor at the POI.

FERC Order 661A Compliance – With the new 345 kV line from GEN-2002-008 station to Mooreland and the already-planned Hitchland 345/230/115 kV tie, the GEN-2006-044 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.

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1 INTRODUCTION

SPP has commissioned ABB Inc. to perform an interconnection impact study for a 400 MW wind farm in Hansford County, Texas. This wind farm will be interconnected into a proposed 345 kV switching station on the Potter – Finney 345 kV line. The proposed station is to be built for prior-queued generation interconnection request GEN-2002-008. This transmission line is owned Southwestern Public Service (d/b/a Xcel Energy). 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 400 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 400 MW wind farm interconnecting station and Figure 1-2 shows a one-line of the proposed interconnection with the existing network.

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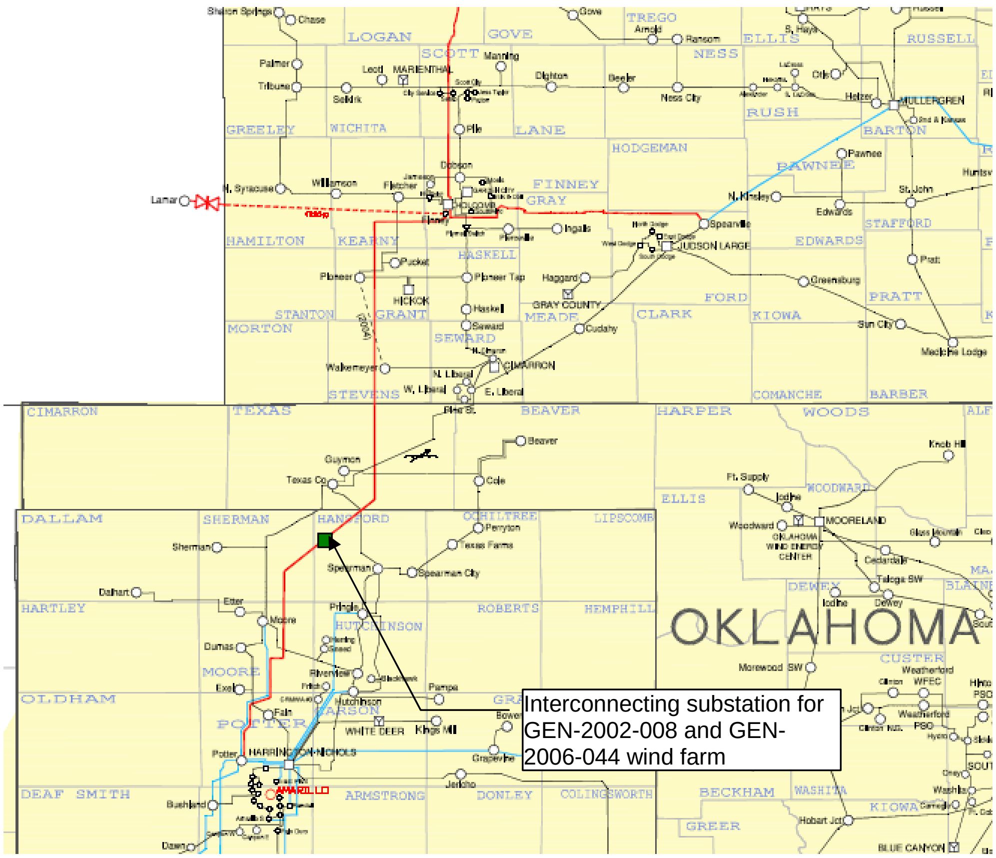

Figure 1-1 Wind farm GEN-2002-008 and GEN-2006-044 interconnecting substation

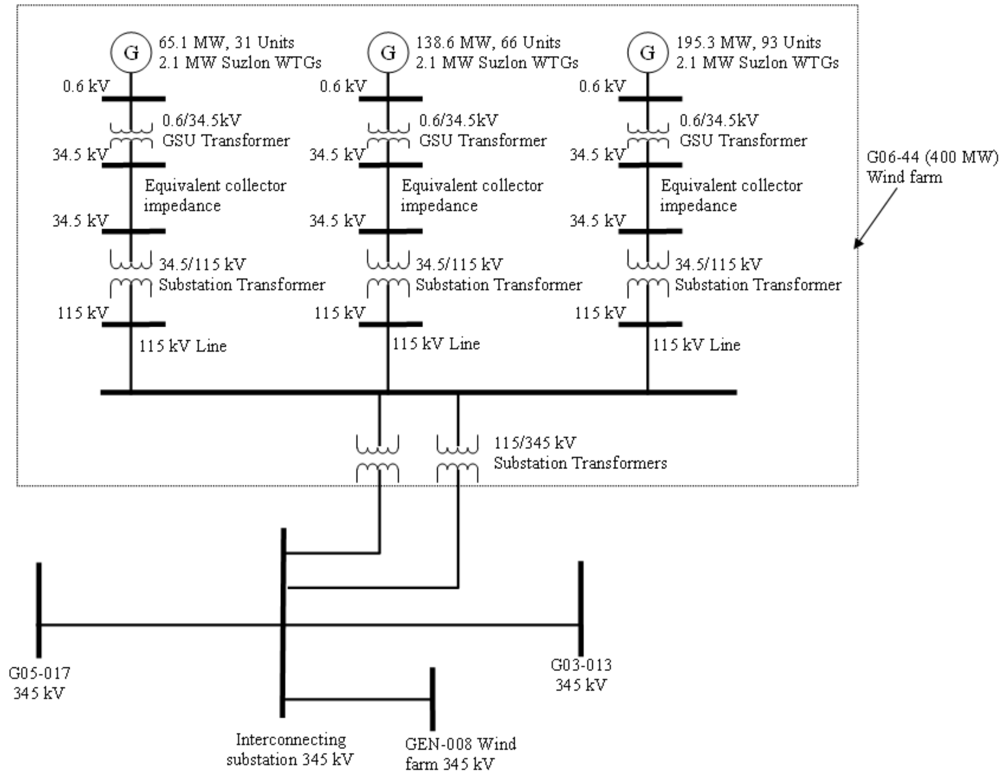

Figure 1-2 Proposed 400 MW wind farm interconnection

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.

When stability analysis was performed on the original base cases (Pass 1) problems were found with the addition of the GEN-2006-044 project. SPP then created a second set of base cases that includes a proposed 345/230/115 kV tie station called Hitchland that is proposed near the POI of GEN-2006-044. The stability analysis of these new base cases is called Pass 2.

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™ 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 – PASS 1

The Pass 1 study model consists of power flow cases and dynamics databases, developed as follows.

Pre-Project Power Flow Case

SPP provided two (2) Pre-project PSS/E power flow cases called "*gen-2006-044_08wp.sav*" representing the 2008 Winter Peak conditions and the "*gen-2006-044_12sp.sav*" representing the 2012 Summer Peak conditions.

These cases were modified before connecting GEN-2006-044 by shifting of the existing 50 Mvar SVC at bus #21 to bus #5170 (at GEN-2005-017), as well as a few other fixes. PSS/E one-line diagrams of the final Pass 1 pre-project power flow cases are shown in Figure 2-1 and Figure 2-2. These cases are named:

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- *gen-2006-044_08wp_mod.sav* – a 2008 winter peak case
- *gen-2006-044_12sp_mod.sav* – a 2012 summer peak case

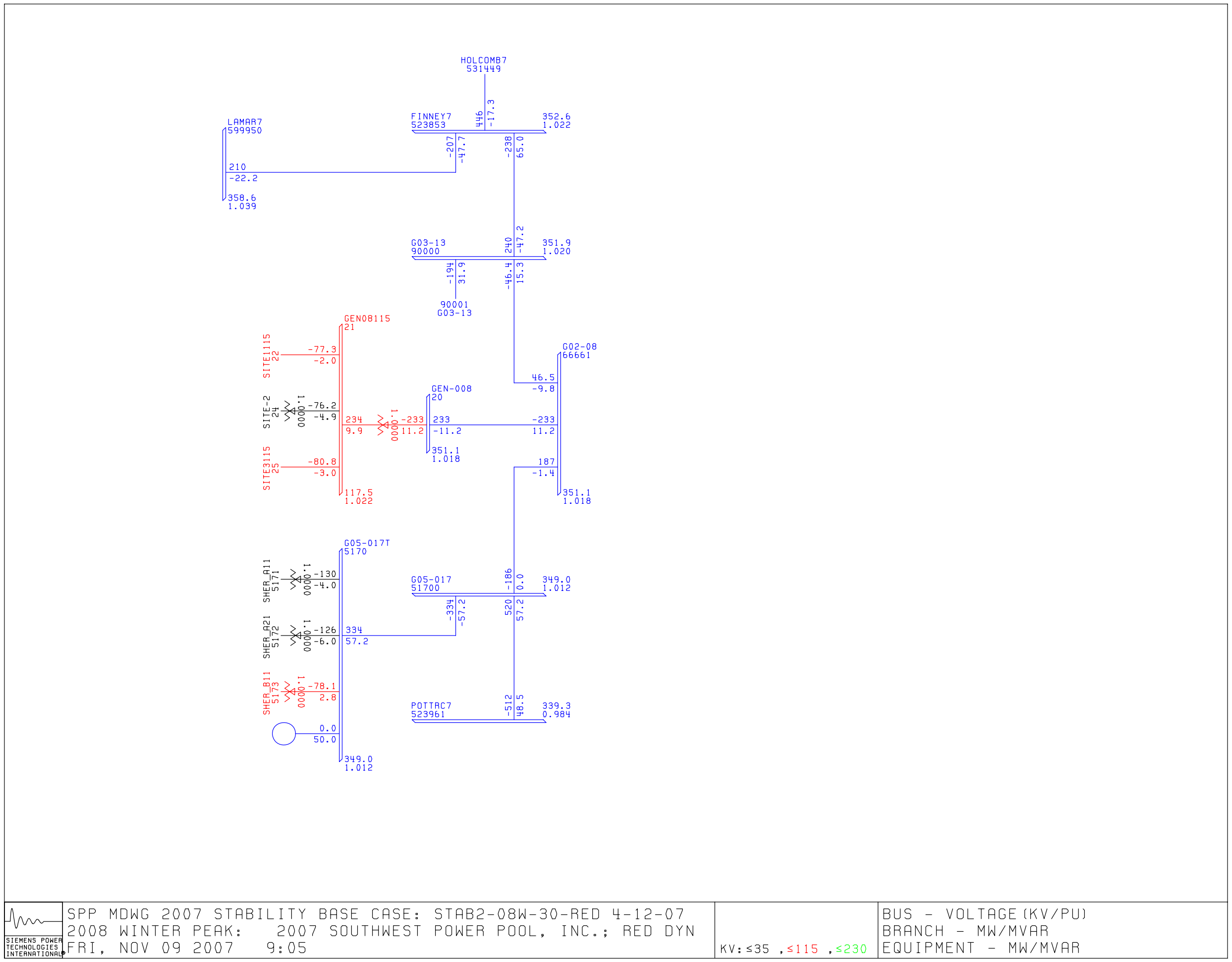

Figure 2-1 2008 Winter Peak Case without GEN-2006-044

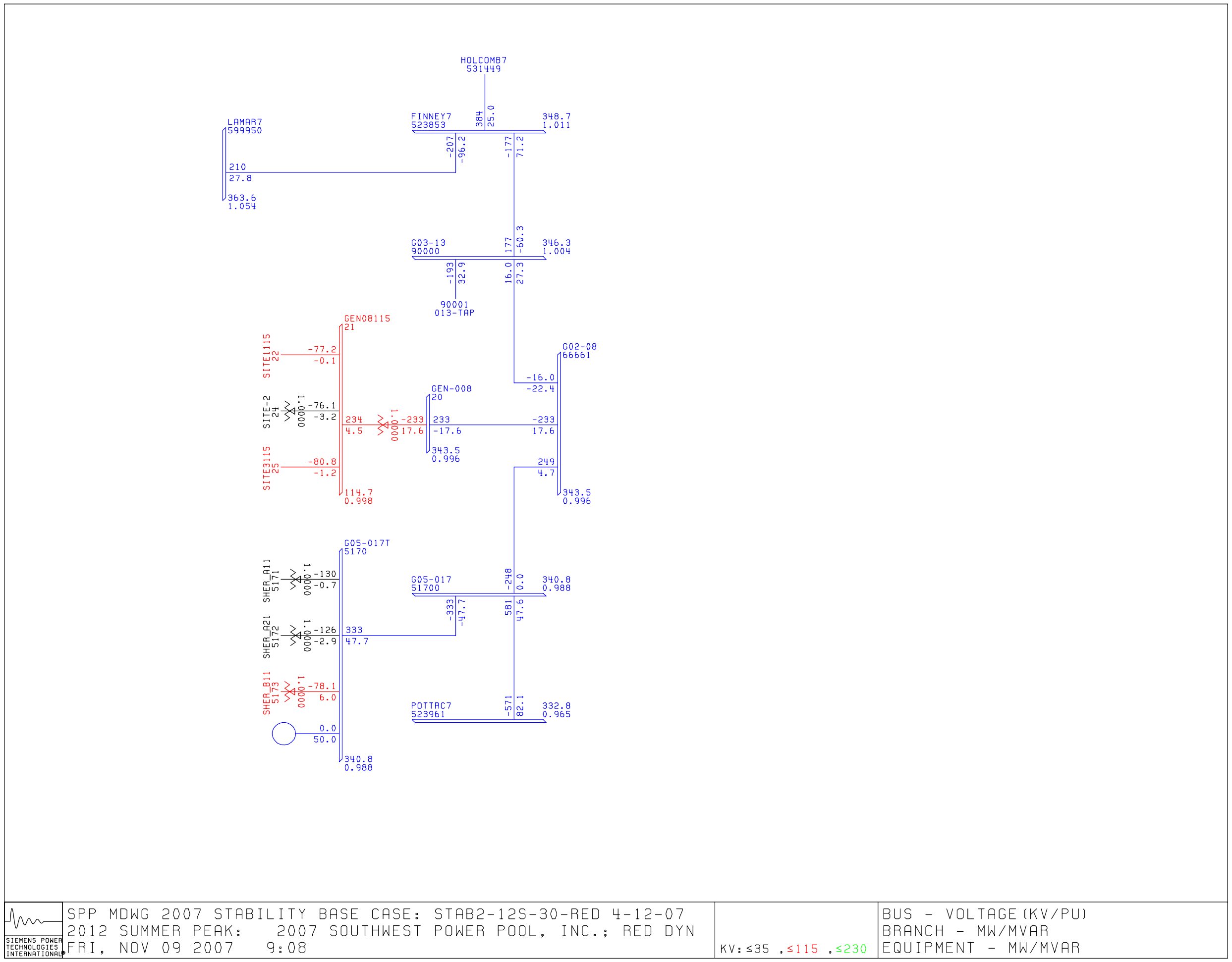

Figure 2-2 2012 Summer Peak Case without GEN-2006-044

GEN-2006-044 Wind Farm Power Flow Model

The GEN-2006-044 wind farm will consist of 190 Suzlon 2.1 MW wind turbine generators that will be split among three different collector substations. The 190 turbines are modeled as three equivalents as follows:

- Equivalent-1: equivalent of 31 Suzlon 2.1 MW wind turbine generators connected at SS-1 substation
- Equivalent-2: equivalent of 66 Suzlon 2.1 MW wind turbine generators connected at SS-2 substation
- Equivalent-3: equivalent of 93 Suzlon 2.1 MW wind turbine generators connected at SS-3 substation

See Figure 2-3. These equivalent generators are connected to equivalent 34.5 kV collector branches through equivalent generator step-up transformers (one equivalent transformer 0.60/34.5 kV for each equivalent generator). Each of the three 34.5/115 kV collector station transformers is explicitly modeled.

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The three substations are connected to the POI via three 115 kV lines and two parallel 115/345 kV transformers. The detailed process of wind farm model development is described in Appendix A.

All three collector systems are compensated individually at their 34.5 kV collector station buses. To compensate the reactive power losses, 11, 24, and 38 MVAR shunt capacitors are needed at Substation-1, Substation-2 and Substation-3 respectively. In order to maintain a unity power factor at the POI, a 45 Mvar shunt capacitor is needed at the 115 kV bus for both power flow cases (2008 Winter Peak and 2012 Summer Peak).

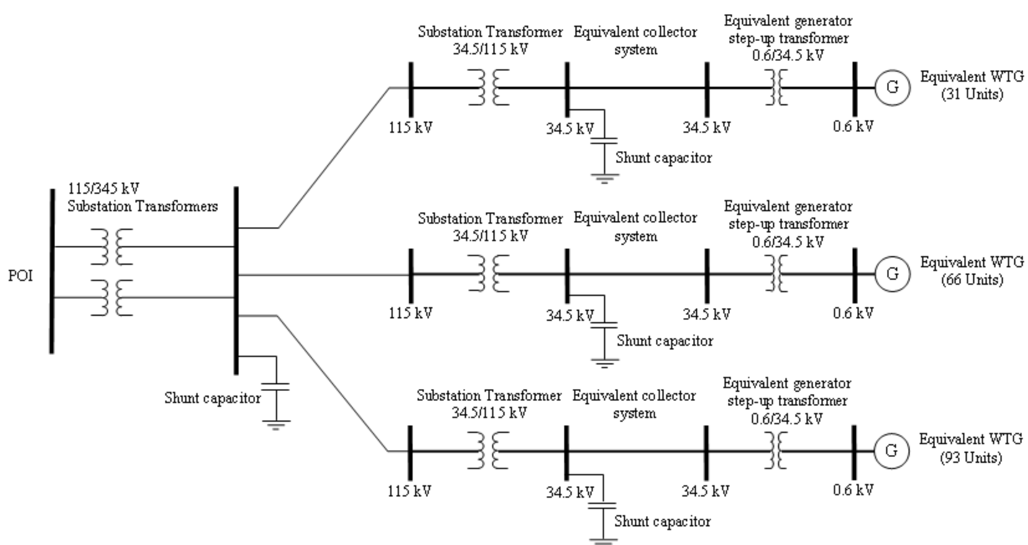

Figure 2-3 GEN-2006-044 Model One-line Diagram

Post-Project Dispatch

The GEN-2006-044 request is for the interconnection of 400 MW of wind-powered generation. The plant will connect to the Potter–Finney 345 kV transmission line at the same location as the GEN-2002-008 wind plant, bus 66661. To balance the additional 400 MW of generation, prior-queued and existing generation was scaled down in areas 502, 524, 525, 536, 540, 541, and 544, as shown in Table 2-1. Thus, two power flow cases with GEN-2006-044 were established:

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- *WP08-GEN-06-044.SAV* – a 2008 winter peak case
- *SP12-GEN-06-044.SAV* – a 2012 summer peak case

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.

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Table 2-1: GEN-2006-044 project details

System condition	MW	Location	Point of Interconnection	Sink
Winter Peak	400	Hansford County, Texas	Substation at Potter – Finney 345kV line (#66661)	Areas 502, 524, 525, 536, 540, 541, 544
Summer Peak	400	Hansford County, Texas	Substation at Potter – Finney 345kV line (#66661)	Areas 502, 524, 525, 536, 540, 541, 544

Stability Database

SPP provided the stability database in the form of PSS/E dynamic data files, "*gen-2006-044_08wp.dyr*" to model the 2008 Winter Peak configuration, and "*gen-2006-044_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-2006-044 was appended to the Pre-project data. The dynamic model provided for the Suzlon S88 wind turbines is called S88001. The provided object code file is called "S88001_MODEL_60_V201_V30.OBJ". This model was used for each of the three equivalent generators. The voltage trip settings included in this model are shown in Table 2-2.

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Table 2-2: Suzlon S88001 Voltage Trip Settings

V (pu)	time (s)
1.20	0.08
1.15	60.00
0.90	60.00
0.80	2.80
0.60	1.60
0.40	0.70
0.15	0.08

The PSS/E power flow and stability model data for GEN-2006-044 are included in Appendix B.

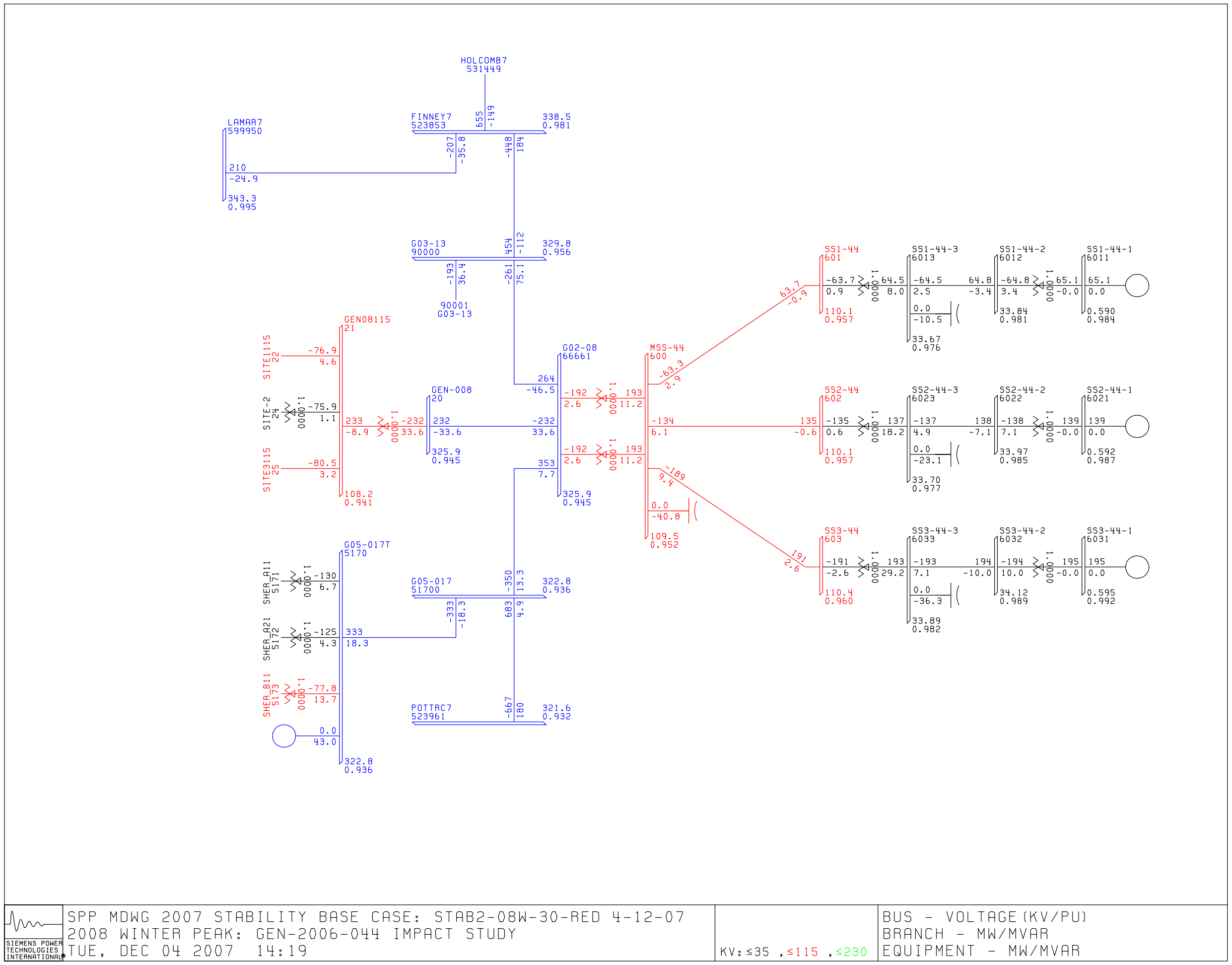

Figure 2-4 2008 Winter Peak Case with GEN-2006-044

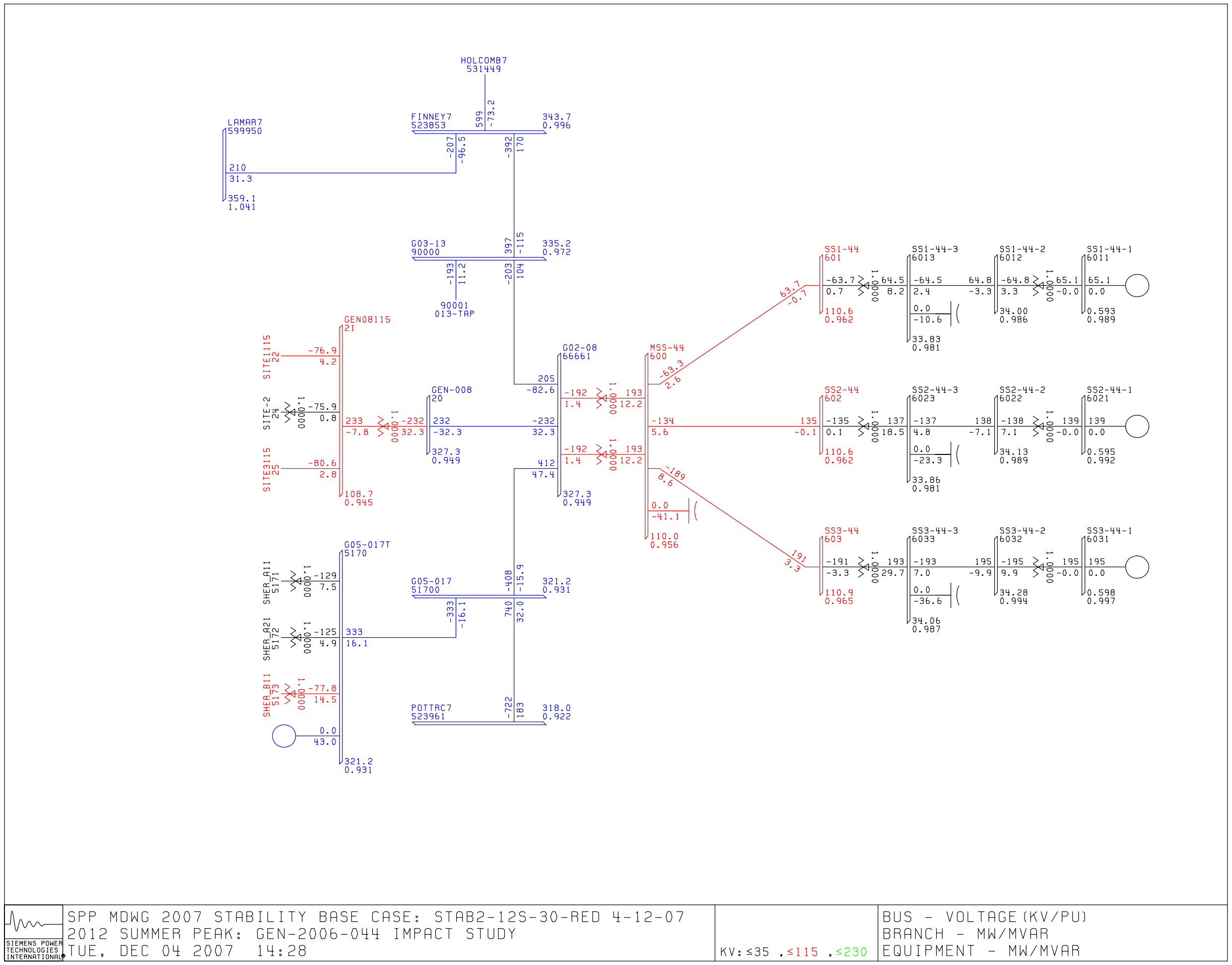

Figure 2-5 2012 Summer Peak Case with GEN-2006-044

Simulated Disturbances

Table 2-3 lists the faults simulated for stability analysis.

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Table 2-3 List of Faults for Stability Analysis

Fault Name	*Description*
FLT_1_3PH	a. Apply 3-phase fault at the GEN-2006-044 bus (66661). b. Clear fault after 4 cycles by removing the line from GEN-2006-044 to GEN-2003-013 345kV (66661 to 90000).
FLT_2_1PH	a. Apply 1-phase fault at the GEN-2006-044 bus (66661). b. Clear fault after 4 cycles by tripping the line from GEN-2002-008 to GEN-2003-013 345kV (66661 to 90000). c. Wait 30 cycles, and then re-close the phase in (b) into the fault. d. Apply fault for 4 cycles, then trip the line in (b), and remove fault.
FLT_3_3PH	a. Apply 3-phase fault at the GEN-2002-008 bus (66661). b. Clear fault after 4 cycles by removing the line from GEN-2002-008 to GEN-2005-017 345kV (66661 – 51700).
FLT_4_1PH	a. Apply 1-phase fault at the GEN-2002-008 bus (66661). b. Clear fault after 4 cycles by tripping the line from GEN-2002-008 – GEN-2005-017 345kV (66661 to 51700). c. Wait 20 cycles, and then re-close the line in (b) d. Apply fault for 4 cycles, then trip the line in (b) and remove fault.
FLT_5_3PH	a. Apply 3-phase fault at the Holcomb bus (531449). b. Clear fault after 4 cycles by removing the line from Holcomb – Finney (531449 – 523853).
FLT_6_1PH	a. Apply 1-phase fault at the Holcomb bus (531449). b. Clear fault after 4 cycles by tripping one phase on the line from Holcomb – Finney 345kV (531449-523853). c. Wait 30 cycles, and then re-close the phase in (b) into the fault. d. Apply fault for 4 cycles, then trip the line in (b).
FLT_7_3PH	a. Apply 3-phase fault at the Potter bus (523961). b. Clear fault after 4 cycles by removing the line from Potter – GEN-2005-017 (523961 – 51700).
FLT_8_1PH	a. Apply 1-phase fault at the Potter bus (523961). b. Clear fault after 4 cycles by removing the line from Potter – GEN-2005-017 (523961 – 51700). c. Wait 30 cycles, and then re-close the line in (b) d. Apply fault for 4 cycles, then trip the line
FLT_9_3PH	a. Apply 3-phase fault at the GEN-2005-017 bus (51700). b. Clear fault after 4 cycles by removing the line from Potter – GEN-2005-017 (523961 – 51700).

Fault Name	Description
FLT_10_1PH	a. Apply 1-phase fault at the GEN-2005-017 bus (51700). b. Clear fault after 4 cycles by removing the line from Potter – GEN-2005-017 (523961 – 51700). c. Wait 30 cycles, and then re-close the line in (b) d. Apply fault for 4 cycles, then trip the line
FLT_11_3PH	a. Apply 3-phase fault at the Grapevine bus (523771). b. Clear Fault after 5 cycles by removing line from Grapevine to Elk City (523771 – 511490). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_12_1PH	a. Apply 1-phase fault at the Grapevine bus (523771). b. Clear Fault after 5 cycles by removing line from Grapevine to Elk City (523771 – 511490). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_13_3PH	a. Apply 3-phase fault at the Plant X bus (525481). b. Clear Fault after 5 cycles by removing line from Potter – Plant x (523959 – 525481). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_14_1PH	a. Apply 1-phase fault at the Plant X bus (525481). b. Clear Fault after 5 cycles by removing line from Potter – Plant X (523959 – 525481). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_15_3PH	a. Apply 3-phase fault at the Blackhawk bus (523344). b. Clear Fault after 5 cycles by removing line from Blackhawk – Pringle (523266 – 523344). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_16_1PH	a. Apply 1-phase fault at the Blackhawk bus (523344). b. Clear Fault after 5 cycles by removing line from Blackhawk – Pringle (523266 – 523344). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_17_3PH	a. Apply 3-phase fault at the Potter 230kV bus (523959). b. Clear Fault after 5 cycles by removing line from Potter – Bushland 230kV (523959 – 524267). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
FLT_18_1PH	a. Apply 1-phase fault at the Potter 230kV bus (523959). b. Clear Fault after 5 cycles by removing line from Bushland – Potter 230kV (523959 – 524267). c. Wait 20 cycles, and then re-close line in (b) into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

Fault Name	Description
FLT_19_3PH	a. Apply 3-phase fault at the GEN-2002-008 345 kV bus (66661). b. Clear fault after 4 cycles by removing the 345 kV line from GEN-2002-008 to Mooreland.
FLT_20_3PH	a. Apply 3-phase fault at the GEN-2002-008 345 kV bus (66661). b. Clear fault after 4 cycles by removing the 3 winding transformer (345/230/13.2 kV).

2.3 STABILITY RESULTS – PASS 1

The results for the simulated disturbances in Pass 1 are summarized in Table 2-4. The plots showing the simulation results are included in Appendix C.

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The initial results showed instability and wind farm tripping for faults 1 through 10 in the post-project cases. These faults were repeated in the pre-project cases, and were stable in the pre-project scenario. As all of these faults are close to the GEN-2006-044 POI, their instability is thus attributed to the addition of the GEN-2006-044 wind plant.

Table 2-4 Results of Stability Simulations – Pass 1

	2008 Winter Peak			2012 Summer Peak		
FAULT	Pre-project	Post-project	Post-project with Line (GEN-2002-008 station to Mooreland)	Pre-project	Post-project	Post-project with Line (GEN-2002-008 station to Mooreland)
FLT_1_3PH	STABLE	UNSTABLE[2]	STABLE	STABLE	UNSTABLE[2]	STABLE
FLT_2_1PH	STABLE	UNSTABLE[2]	STABLE	STABLE	STABLE[4]	STABLE
FLT_3_3PH	STABLE[1]	UNSTABLE[2]	STABLE	STABLE[1]	STABLE[1,5]	STABLE[1]
FLT_4_1PH	STABLE[1]	UNSTABLE[2]	STABLE	STABLE[1]	STABLE[1,5]	STABLE[1]
FLT_5_3PH	STABLE	UNSTABLE[3]	STABLE[5]	STABLE	UNSTABLE[2,3]	STABLE[5]
FLT_6_1PH	STABLE	UNSTABLE[3]	STABLE[5]	STABLE	UNSTABLE[3]	STABLE[5]
FLT_7_3PH	STABLE	UNSTABLE[2]	STABLE[5]	STABLE	UNSTABLE[2]	STABLE[5]
FLT_8_1PH	STABLE	UNSTABLE[2]	STABLE[5]	STABLE	UNSTABLE[2]	STABLE[5]
FLT_9_3PH	STABLE	UNSTABLE[2]	STABLE[5]	STABLE	UNSTABLE[2]	STABLE[5]
FLT_10_1PH	STABLE	UNSTABLE[2]	STABLE[5]	STABLE	UNSTABLE[2]	STABLE[5]
FLT_11_3PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_12_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_13_3PH	---	STABLE	STABLE	---	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	STABLE	---	STABLE	STABLE
FLT_18_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_19_1PH	---	---	STABLE	---	---	STABLE

Notes:
[1] Generator 523431 is not settled at the end of simulation
[2] Several wind generators tripped for these faults.
[3] Network not converged for these faults
[4] GEN-2006-044 wind generators oscillate, not stable at the end of simulation
[5] GEN-2006-044 real and reactive powers oscillate

Steady-state Voltage Stability – QV Analysis

To consider if the simple addition of an SVC at GEN-2006-044 could fix the post-project problems, Reactive Power versus Voltage (QV) analysis was performed. SVCs were tested at the GEN-2006-044 345 and 115 kV buses, as shown in Figure 2-6. The left side of the curves with the negative slope represents the unstable region, and the right side of the curves with positive slope represents the stable region. Because there is no stable region in the normal voltage operating range (0.95 to 1.05 pu), reactive compensation alone is not a feasible solution.

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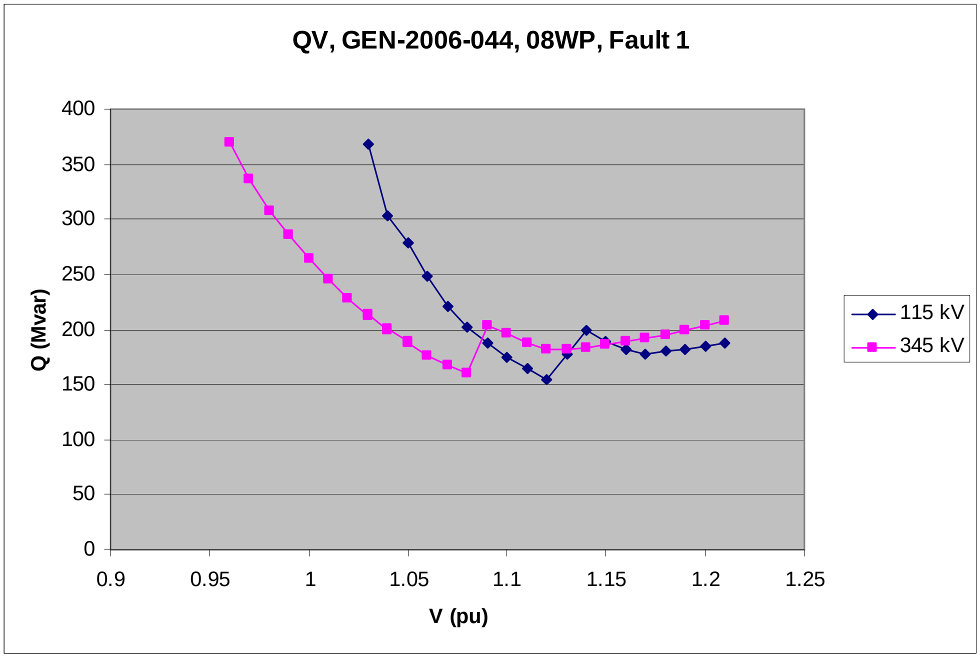

Figure 2-6 QV Curves for 2008 Winter Peak Case – Pass 1

New 345 kV Line from GEN-2002-008 Station to Mooreland

The addition of a new 345 kV line from the POI (GEN-2002-008 Station) to Mooreland was tested in dynamic simulations. This solution includes a 345/138 kV transformer connecting the new 345 kV line to the existing Mooreland 138 kV switchyard. Figure 2-7 and Figure 2-8 show the PSS/E one-line diagrams after the addition of the new 345 kV line for 2008 Winter Peak and 2012 Summer Peak respectively.

Faults 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 are mostly stable with this solution, with no wind farm tripping occurring, as summarized in Table 2-4. However, the GEN-2006-044 wind turbine power outputs, both MW and Mvar, show high-frequency oscillations. This seems to be a control instability in the turbine controls due to the weak network after the contingency. This performance is considered unacceptable.

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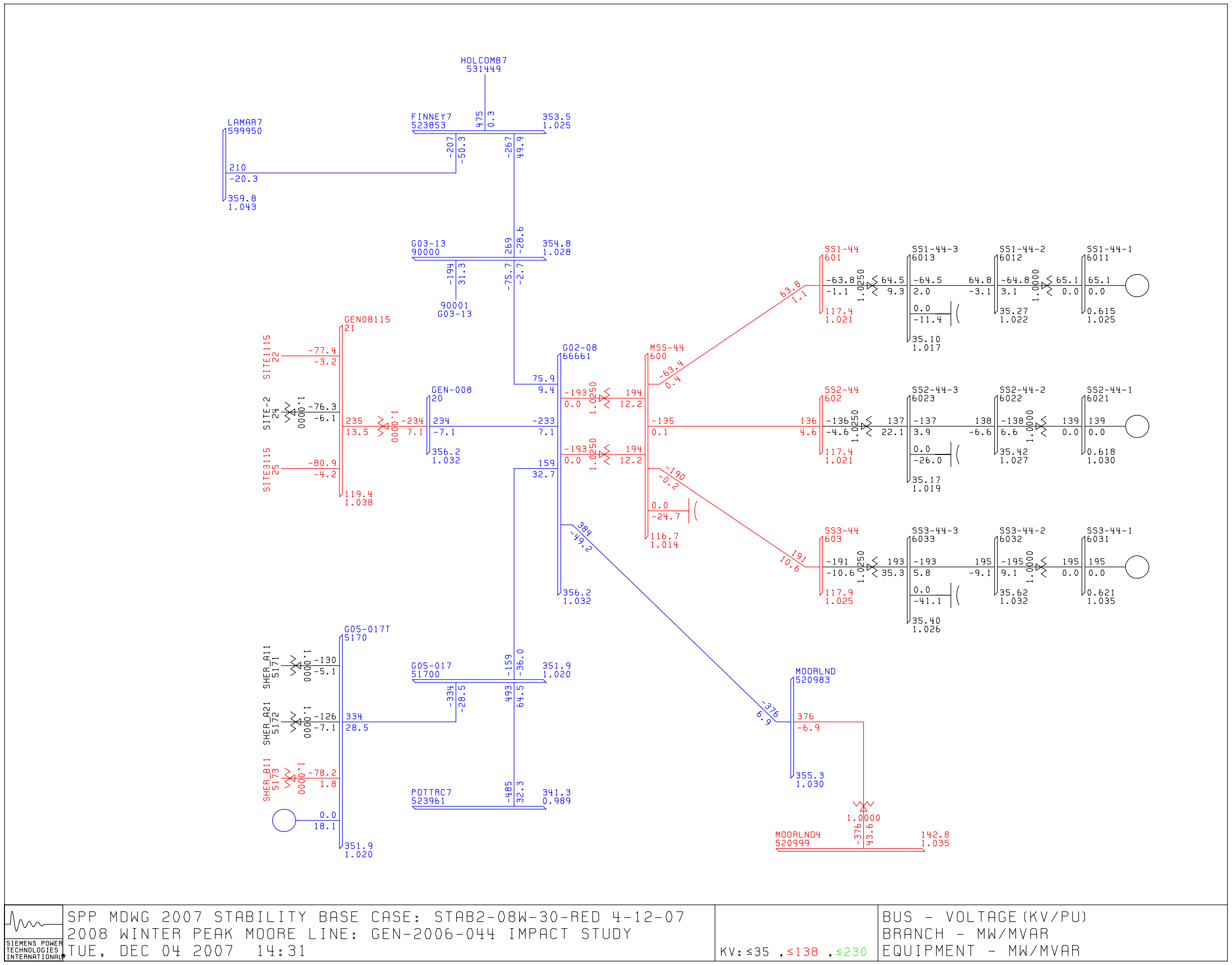

Figure 2-7 2008 Winter Peak Case with GEN-2006-044 with New 345 kV Line (GEN-2002-008 – Mooreland)

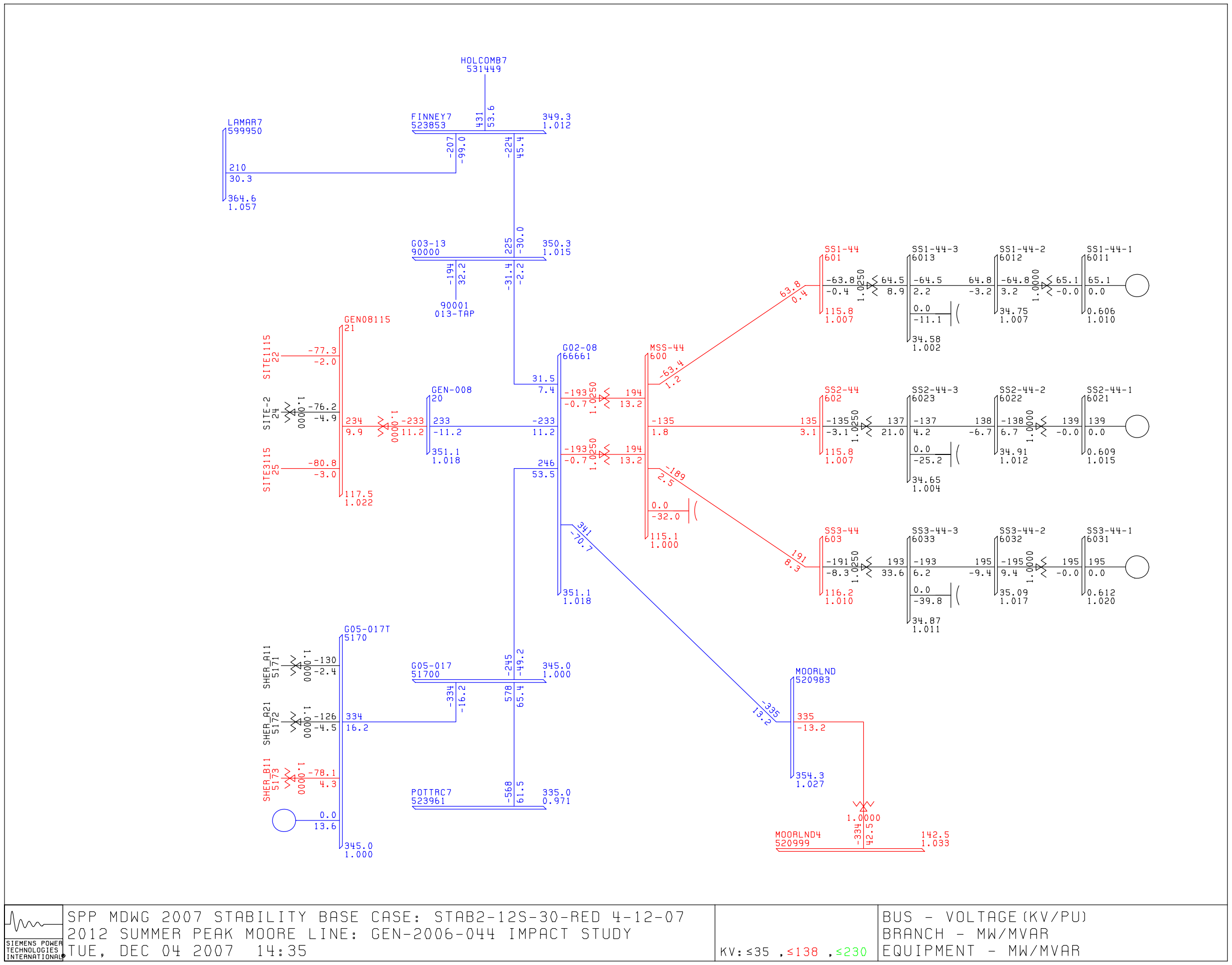

Figure 2-8 2012 Summer Peak Case with GEN-2006-044 with New 345 kV Line (GEN-2002-008 – Mooreland)

2.4 STUDY MODEL DEVELOPMENT – PASS 2

After analysis of the first set of base cases (Pass 1) showed unresolved stability problems, SPP indicated that there is a planned 345/230/115 kV tie called Hitchland located at the POI for GEN-2006-044 and GEN-2002-008. This upgrade is associated with a prior-queued project. SPP created new power flow cases including this upgrade (but *without* the 345 kV line option discussed in the previous section). This upgrade also includes various line upgrades and nearby prior-queued generation at 230 kV and below. The pre-project and post-project power flow diagrams for Pass 2 are given in Figure 2-10, Figure 2-11, Figure 2-12 and Figure 2-13.

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2.5 STABILITY RESULTS – PASS 2

All of the Pass 1 faults were simulated on the Pass 2 post-project case with GEN-2006-044 and the Hitchland project, and one new fault was added (FLT_20_3PH, fault and outage of the Hitchland 345/230 kV transformer). Any problem faults were simulated on the pre-project case without GEN-2006-044 for comparison.

In the 2008 winter peak post-project case with GEN-2006-044, Faults 5 and 6 are unstable, while the same faults are stable in the pre-project case. In the 2012 summer peak post-project case, Faults 1, 2, 5 and 6 are unstable, while the same faults are stable in the pre-project case. All simulated faults for Pass 2 are summarized in Table 2-5.

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These results indicate that the addition of GEN-2006-044 causes stability problems even with the proposed Hitchland 345/230/115 kV project in the base case.

A QV analysis was performed for Pass 2 to see if a reactive power source could fix the problems. See Figure 2-9. While the results are a little better than in Pass 1, the only stable voltage region is well above the acceptable operating range, and shunt reactive power compensation is not a viable solution.

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<u>New 345 kV Line from GEN-2002-008 Station to Mooreland</u>

To fix the stability problems arising after the addition of GEN-2004-044, the same proposed 345 kV line tested in Pass 1 was also tested in Pass 2 on the problem faults. The results are summarized in Table 2-5, and the power flow diagrams are given in Figure 2-14 and Figure 2-15. These results show that all stability problems are cleared up after adding the new 345 kV line to Mooreland and assuming the Hitchland 345/230/115 kV project is in service. With these upgrades, the final capacitor requirements at GEN-2006-044 are 10, 22, and 31 Mvar at the 34.5 kV substations and 45 Mvar at the 115 kV bus.

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Table 2-5 Results of Stability Simulations – Pass 2

	2008 Winter Peak			2012 Summer Peak		
FAULT	**Pre-project**	**Post-project**	**Post-project with Line (GEN-2002-008 station to Mooreland)**	**Pre-project**	**Post-project**	**Post-project with Line (GEN-2002-008 station to Mooreland)**
FLT_1_3PH	---	STABLE	STABLE	STABLE	UNSTABLE	STABLE
FLT_2_1PH	---	STABLE	STABLE	STABLE	UNSTABLE*	STABLE
FLT_3_3PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_4_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_5_3PH	STABLE	UNSTABLE	STABLE	STABLE	UNSTABLE*	STABLE
FLT_6_1PH	STABLE	UNSTABLE	STABLE	STABLE	UNSTABLE*	STABLE
FLT_7_3PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_8_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_9_3PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_10_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_11_3PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_12_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_13_3PH	---	STABLE	STABLE	---	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	STABLE	---	STABLE	STABLE
FLT_18_1PH	---	STABLE	STABLE	---	STABLE	STABLE
FLT_19_3PH	---	---	STABLE	---	---	STABLE
FLT_20_3PH	---	STABLE	STABLE	---	STABLE	STABLE

* Several wind farms tripped for these faults.

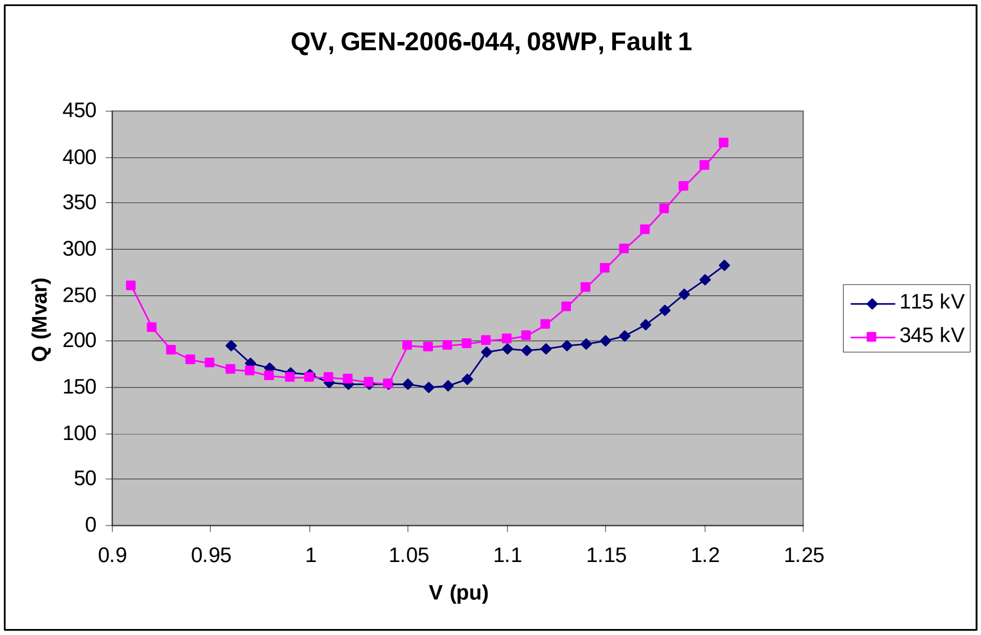

Figure 2-9 QV Curves for 2008 Winter Peak Case – Pass 2

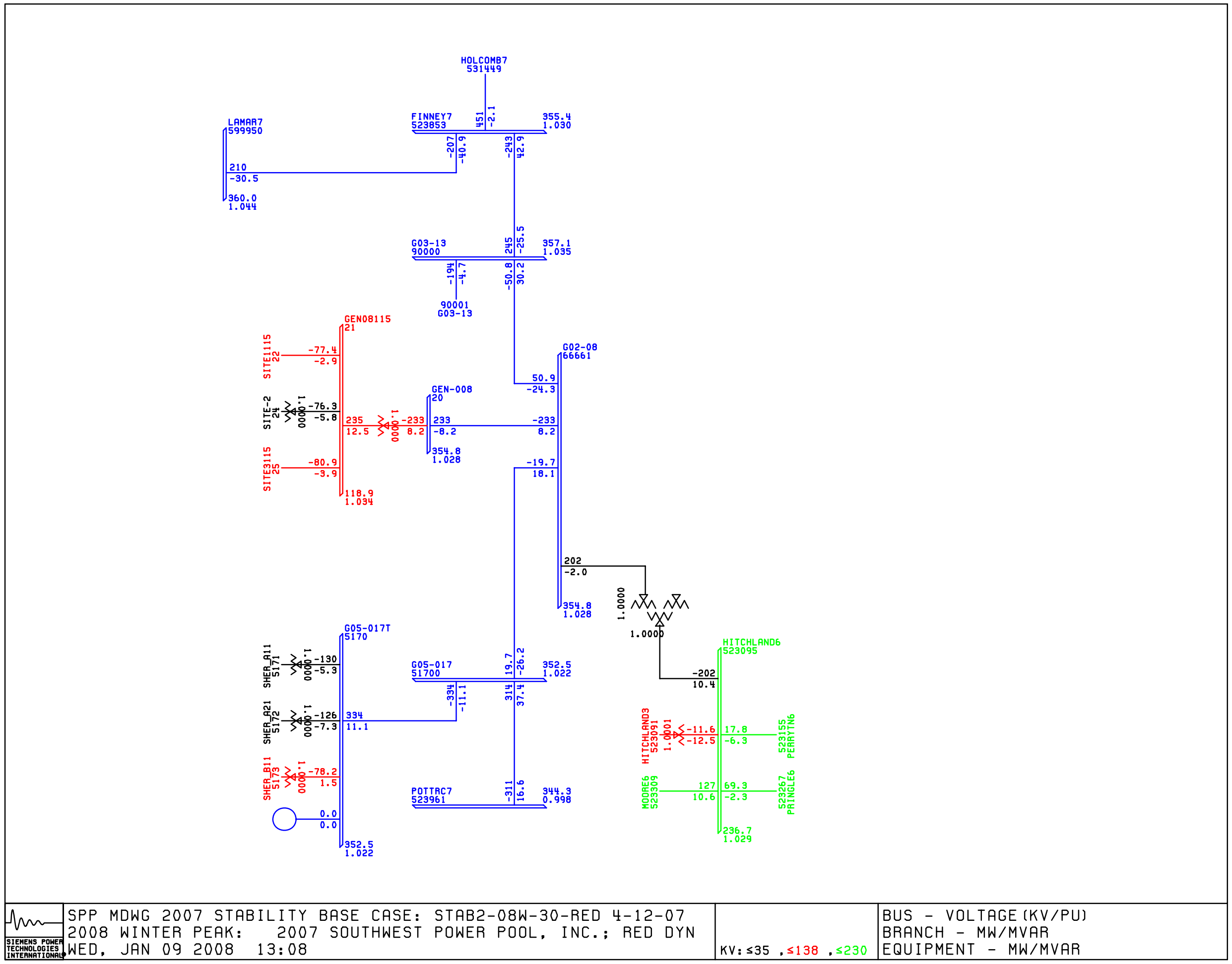

Figure 2-10 2008 Winter Peak Case without GEN-2006-044 – Pass 2

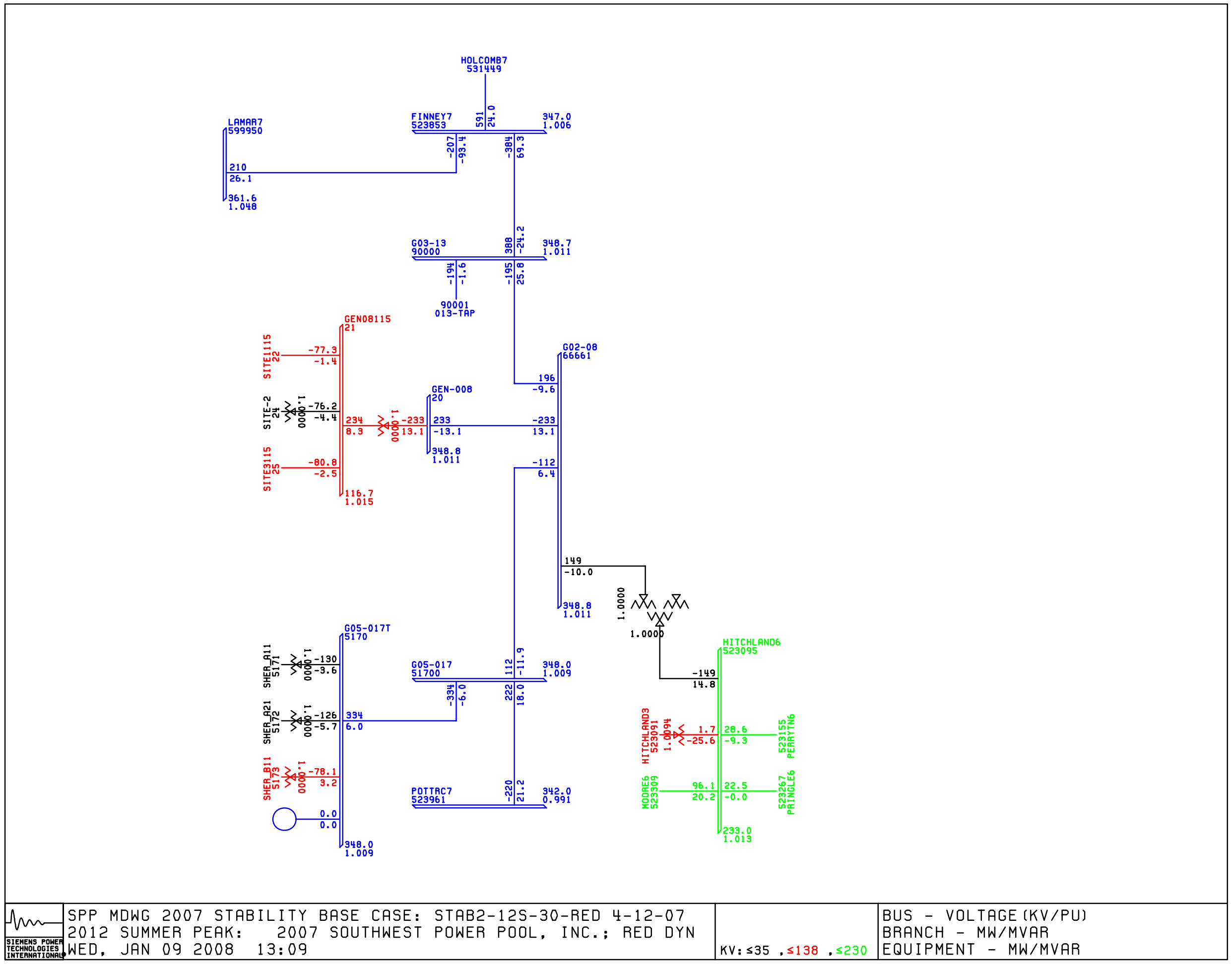

Figure 2-11 2012 Summer Peak Case without GEN-2006-044 – Pass 2

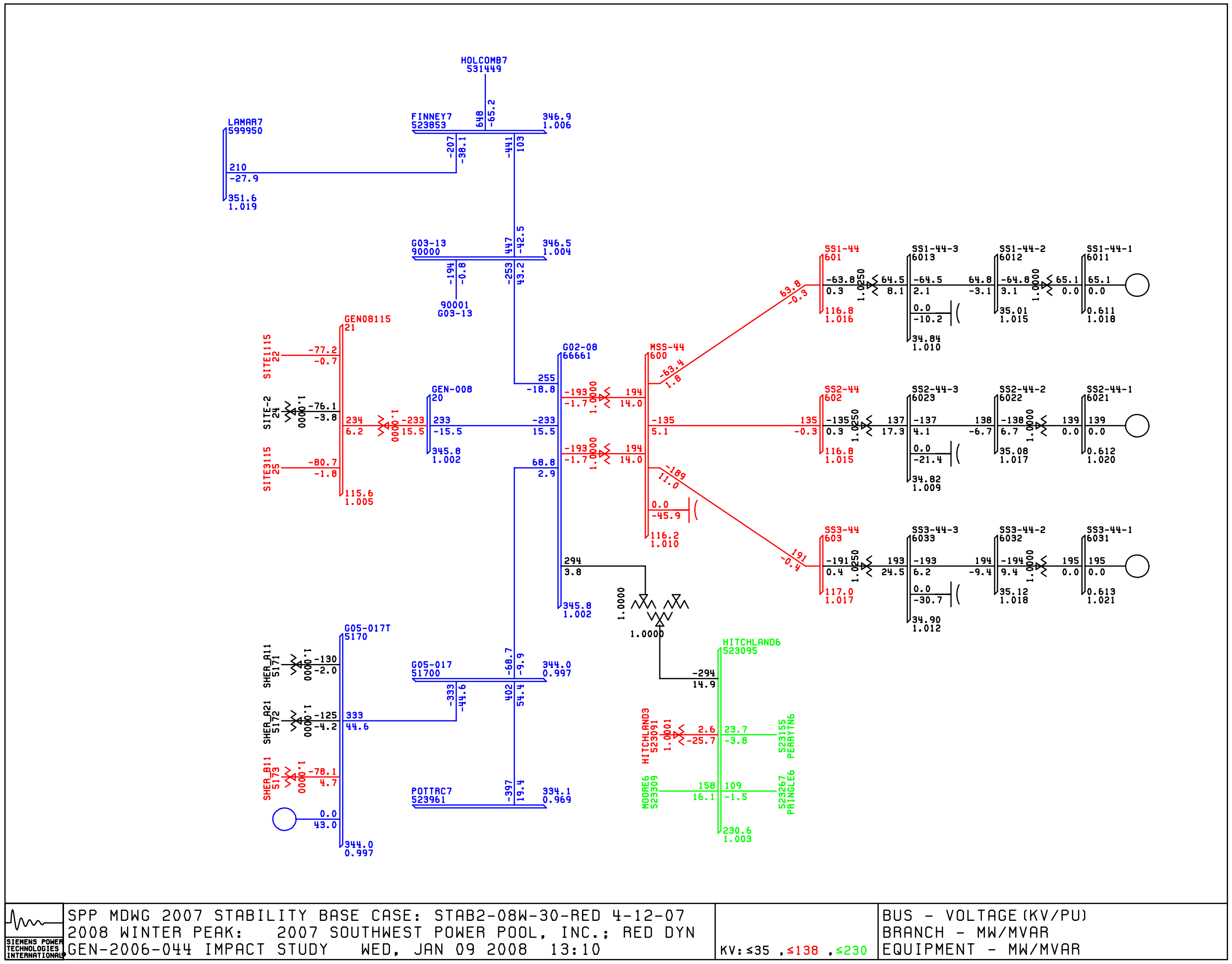

Figure 2-12 2008 Winter Peak Case with GEN-2006-044 – Pass 2

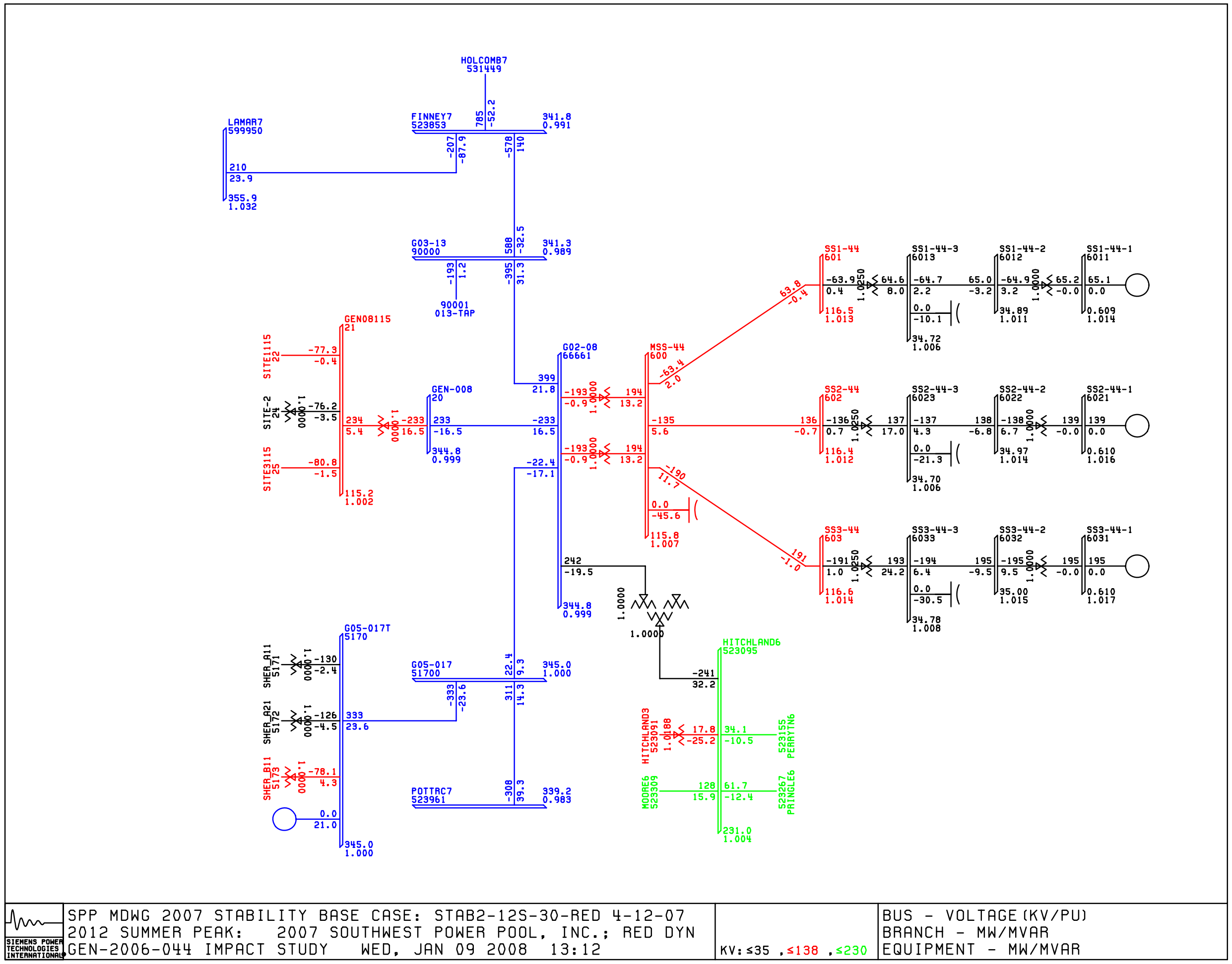

Figure 2-13 2012 Summer Peak Case with GEN-2006-044 – Pass 2

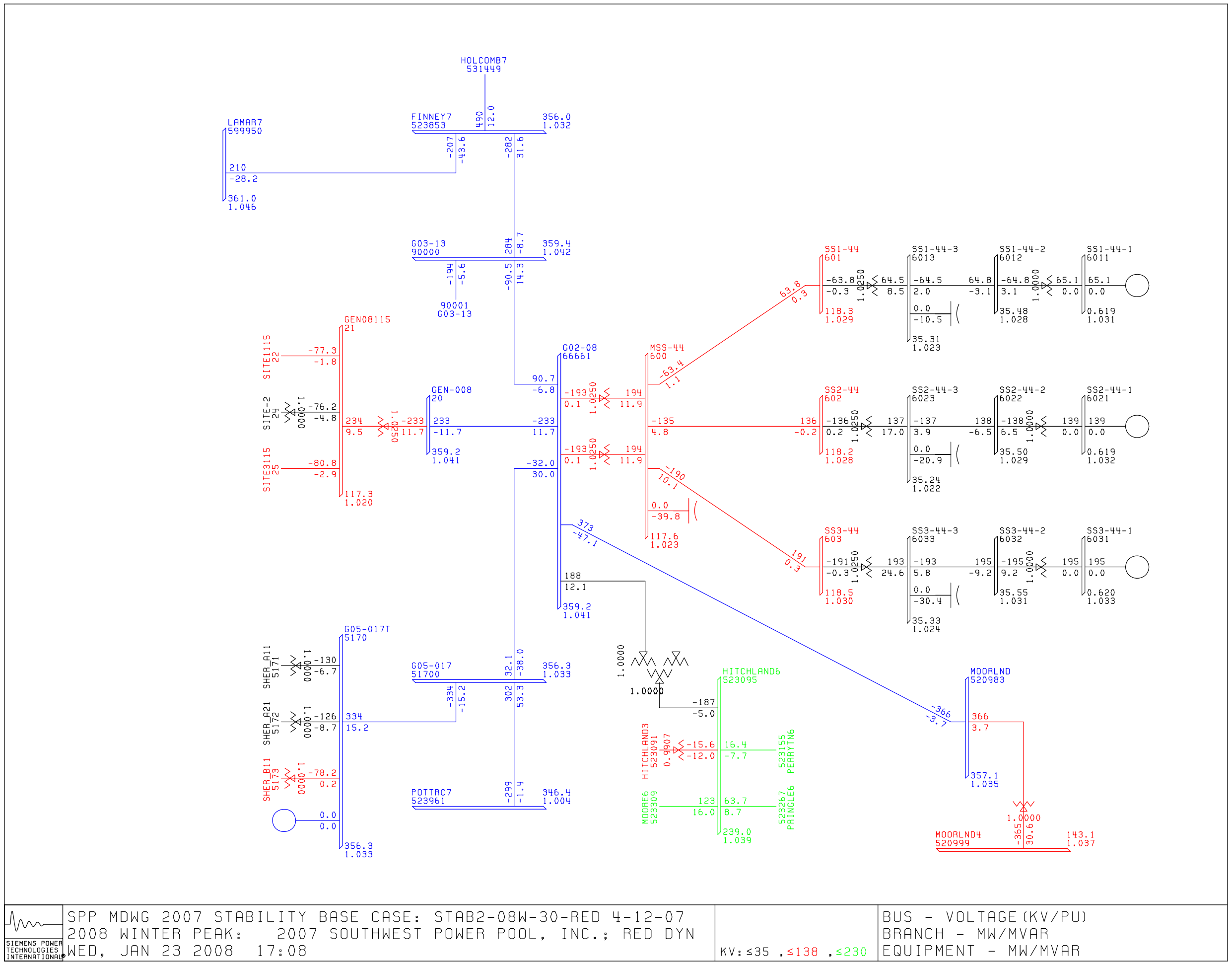

Figure 2-14 2008 Winter Peak Case with GEN-2006-044 and New 345 kV Line – Pass 2

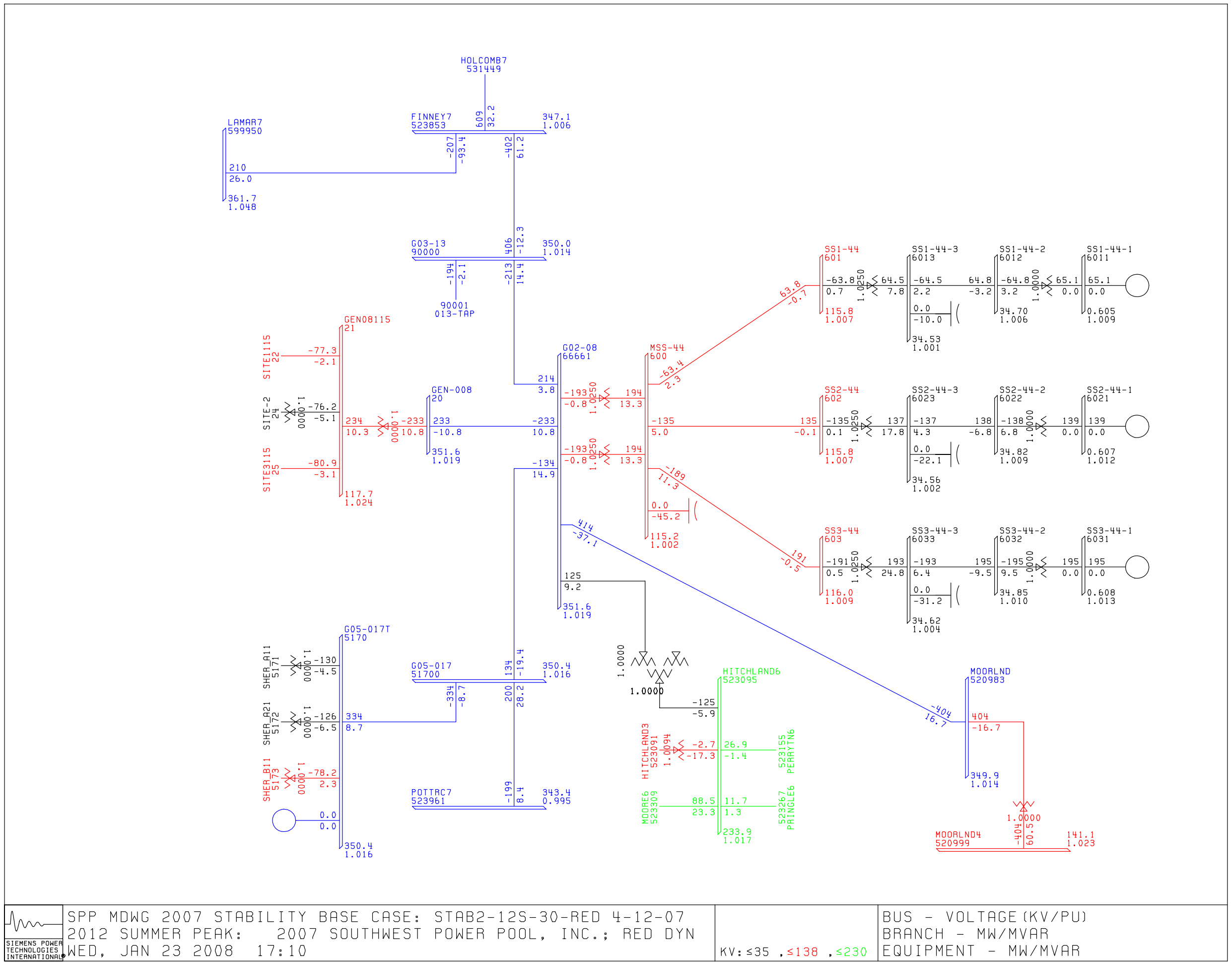

Figure 2-15 2012 Summer Peak Case with GEN-2006-044 and New 345 kV Line – Pass 2

3 CONCLUSIONS

The objective of this study was to evaluate the impact of the proposed GEN-2006-044 wind farm on the stability of SPP system. The study was performed for two system scenarios: the 2008 Winter Peak and the 2012 Summer Peak.

The system was unstable following faults at or near the POI after interconnection of the proposed project with the original base case. The same faults were stable in the pre-project cases. QV analysis showed that a shunt reactive power addition, such as an SVC or STATCOM, is not feasible to fix the stability problems. An upgrade featuring a new 345 kV line to Mooreland was studied, but the GEN-2006-044 plant still had unacceptable post-contingency oscillations.

A new base case was created with the planned Hitchland 345/230/115 kV tie, but there were still stability problems with GEN-2006-044 on-line. Finally, adding the 345 kV line to Mooreland, and still including the Hitchland 345/230/115 kV tie, made all stability problems go away with GEN-2006-044. This is the final recommended solution.

The final shunt capacitor requirements for GEN-2006-044, assuming installation of the Hitchland 345/230/115 kV tie and the new 345 kV line to Mooreland, are 10, 22, and 31 Mvar at Substation-1, Substation-2 and Substation-3 respectively, as well as 45 Mvar on the low side of the wind farm 345/115 kV transformers. The exact distribution of these Mvar can be adjusted among these locations by the wind project developer, but the total must result in 1.0 power factor at the POI.

FERC Order 661A Compliance – With the new 345 kV line from GEN-2002-008 station to Mooreland and the already-planned Hitchland 345/230/115 kV tie, the GEN-2006-044 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 – Pass 1

APPENDIX D - Plots for Stability Simulations – Pass 2