Southwest Power Pool

Impact Study for Generation Interconnection Request GEN–2008–005

SPP Tariff Studies
(#GEN-2008-005)

August 14, 2008

Executive Summary

<OMITTED TEXT> (Customer) has requested an Impact Study for the purpose of interconnecting an additional 14MW of hydroelectric generation within the control area of Grand River Dam Authority (GRDA) located in Mayes County, Oklahoma. The proposed point of interconnection is the Kerr 161kV and 115 kV substations. The proposed in-service date is January 9, 2009. This generation facility previously consisted of four (4) 28.5 MW turbines. The customer has requested to uprate each of these turbines to 32MW each.

A stability study was conducted by ABB Consulting and is included in Attachment 1. The stability study shows that the interconnection of proposed project does not have any adverse impact on the system stability in SPP area.

There are no direct assigned facilities or network upgrades associated with the interconnection of GEN-2008-005.

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 an Impact Study for the purpose of interconnecting an additional 14MW of hydroelectric generation within the control area of Grand River Dam Authority (GRDA) located in Mayes County, Oklahoma. The proposed point of interconnection is the Kerr 161kV and 115 kV substations. The proposed in-service date is January 9, 2009. This generation facility previously consisted of four (4) 28.5 MW turbines. The customer has requested to uprate each of these turbines to 32MW each.

Interconnection Facilities

The Customer has requested interconnecting an additional 14 MW of hydroelectric generation within the control area of Grand River Dam Authority (GRDA). The plant site is located in Mayes County, Oklahoma and will be interconnected into the existing Kerr 161kV and 115 kV substations.

There are also several other facilities that are assumed to be in service for the interconnection of this request. These facilities are listed in the powerflow analysis section. If any of these facilities are not constructed or previous queued projects drop out of the queue, this request will need to be restudied.

Table 1. Interconnection Facilities

FACILITY	ESTIMATED COST (2008 DOLLARS)
CUSTOMER – 13.8/115kV and 13.8/115/161 equipments.	*
CUSTOMER – 115kV and 161kV connections from GSU and reserve auxiliary to Kerr 161kV and 115 kV buses.	*
TOTAL	*

* Determined by Customer

Table 2. Network Upgrades

FACILITY	ESTIMATED COST (2008 DOLLARS)
None	
TOTAL	

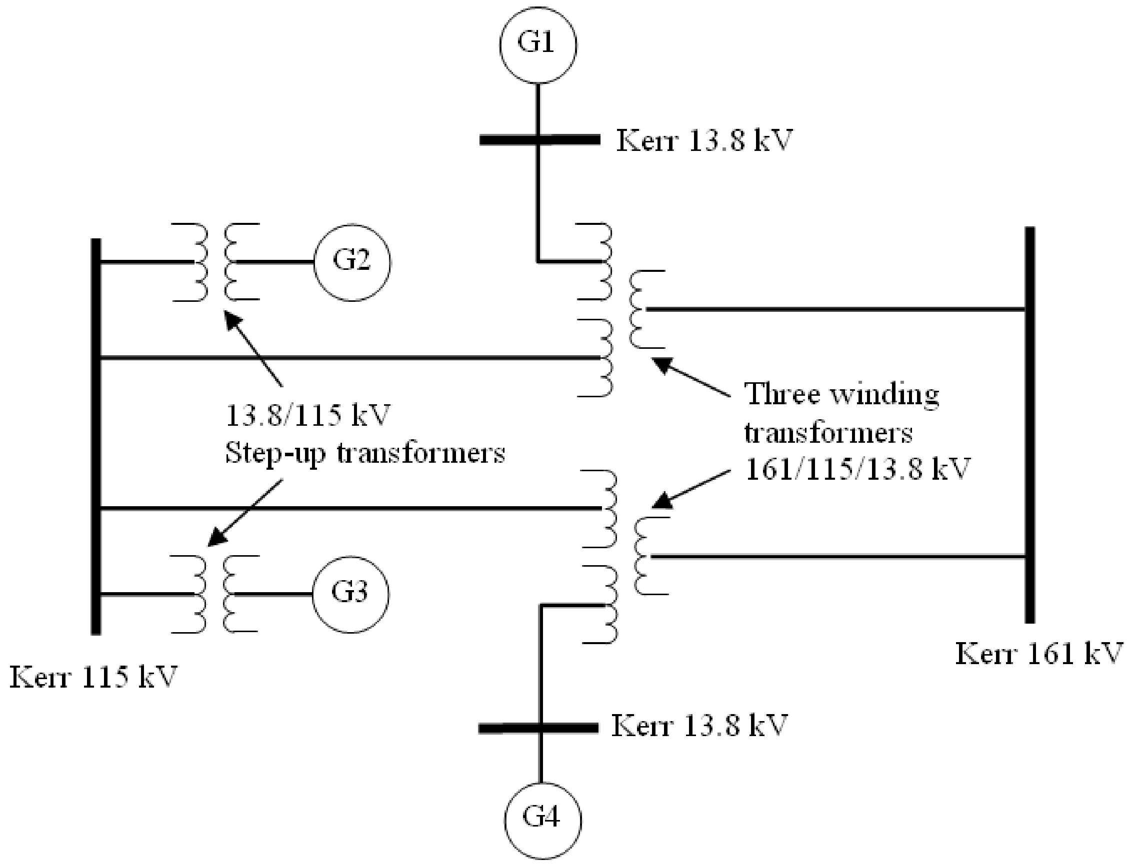

Figure 1. Proposed Interconnection Configuration
(Final design to be determined)

Powerflow Analysis

A powerflow analysis was conducted for the facility using modified versions of the 2008 winter peak, 2009 summer and winter peak, 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 January 9, 2009. 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 criteria violations for transmission facilities 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.

If any of these projects do not get constructed or if any prior queued generation interconnection request withdraws from the queue, this analysis will need to be re-evaluated.

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	FLINT CREEK - GENTRY REC 161KV CKT 1
AEPW	PRYOR JUNCTION (PRY-JCT1) 138/69/13.8KV TRANSFORMER CKT 1
EMDE	SUB 145 - JOPLIN WEST 7TH - SUB 439 - STATELINE 161KV CKT 1
EMDE	SUB 389 - JOPLIN SOUTHWEST - SUB 422 - JOPLIN 24TH & CONNECTICUT 161KV CKT 1
GRDA	412SUB - KANSAS TAP 161KV CKT 1
GRDA	412SUB - KERR 161KV CKT 1
SWPA	EUFAULA (EUFAULA1) 161/138/13.8KV TRANSFORMER CKT 1
AEPW	American Electric Power Corporation
EMDE	Empire District Electric Company
GRDA	Grand River Dam Authority
SWPA	Southwestern Power Administration

Table 4: Contingency Analysis

SEASON	OVERLOADED ELEMENT	RATING (MVA)	LOADING (%)	ATC (MW)	CONTINGENCY
09SP	PRYOR JUNCTION (PRY-JCT1) 138/69/13.8KV TRANSFORMER CKT 1	62	108	0	CATOOSA - INOLA TAP 138KV CKT 1
09WP	EUFAULA (EUFAULA1) 161/138/13.8KV TRANSFORMER CKT 1	105	101	1	GEN505578 2
09WP	EUFAULA (EUFAULA1) 161/138/13.8KV TRANSFORMER CKT 1	105	101	1	GEN505580 3
12SP	PRYOR JUNCTION (PRY-JCT1) 138/69/13.8KV TRANSFORMER CKT 1	62	113	0	CATOOSA - INOLA TAP 138KV CKT 1
12SP	412SUB - KERR 161KV CKT 1	328	104	0	FLINT CREEK - GRDA1 345KV CKT 1
12SP	412SUB - KANSAS TAP 161KV CKT 1	328	103	3	FLINT CREEK - GRDA1 345KV CKT 1
12WP	PRYOR JUNCTION (PRY-JCT1) 138/69/13.8KV TRANSFORMER CKT 1	62	102	6	CATOOSA - INOLA TAP 138KV CKT 1
17SP	SUB 389 - JOPLIN SOUTHWEST - SUB 422 - JOPLIN 24TH & CONNECTICUT 161KV CKT 1	223	110	0	SUB 292 - TIPTON FORD - SUB 389 - JOPLIN SOUTHWEST 161KV CKT 1
17SP	FLINT CREEK - GENTRY REC 161KV CKT 1	353	102	0	ECNTRTN7 345.00 - FLINT CREEK 345KV CKT 1
17SP	SUB 145 - JOPLIN WEST 7TH - SUB 439 - STATELINE 161KV CKT 1	268	100	10	SUB 110 - ORONOGO JCT. - SUB 452 - RIVERTON 161KV CKT 1
17SP	412SUB - KERR 161KV CKT 1	328	100	10	FLINT CREEK - GRDA1 345KV 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.

Stability Analysis

A transient stability analysis was conducted for the facility by ABB Consulting (ABB). The study is attached to this report. The stability analysis indicated that the interconnection of proposed project does not have any adverse impact on the system stability in SPP area.

This analysis assumed that the following projects were built and in service

If any of these projects do not get constructed or if any prior queued generation interconnection request withdraws from the queue, this analysis will need to be re-evaluated.

POWER SYSTEMS DIVISION
GRID SYSTEMS CONSULTING

IMPACT STUDY FOR GENERATION INTERCONNECTION REQUEST GEN-2008-005

FINAL REPORT

REPORT NO.: 2008-11797-R0
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ABB Inc – Grid Systems Consulting **Technical Report**

Southwest Power Pool	No.	2008-11797-R0
Impact Study for Generation Interconnection request GEN-2008-005	8/14/2008	# Pages 30

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Executive Summary

SPP has requested a generator interconnection study for a modification to an existing hydro power plant in Mayes County, Oklahoma. This hydro power plant is interconnected to the Kerr 161kV and 115kV buses in the Grand River Dam Authority (GRDA) control area. The existing plant has four turbines rated 30 MVA each with maximum power output of 28.5 MW each. The customer is now asking to uprate this plant to four units rated 34.5 MVA each with maximum power output of 32 MW each. The short circuit ratio of each generator has also been changed.

This uprating of a hydro power plant was studied under two different system loading scenarios - 2008 winter peak and 2012 summer peak.

The results indicate that the uprating of GEN-2008-005 does not have any adverse impact on system stability in SPP area.

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 requested a generator interconnection study for a modification to an existing hydro power plant in Mayes County, Oklahoma. This hydro power plant is interconnected to the Kerr 161kV and 115kV buses in the Grand River Dam Authority (GRDA) control area. The existing plant has four turbines rated 30 MVA each with maximum power output of 28.5 MW each. The customer is now asking to uprate this plant to four units rated 34.5 MVA each with maximum power output of 32 MW each. The short circuit ratio of each generator has also been changed.

This uprate of a hydro power plant was studied under two different system loading scenarios - 2008 winter peak and 2012 summer peak. Generators are located at the existing Kerr hydro facility. Two units are connected to the 115kV bus via 13.8/115 kV step-up transformers, and two units are connected to the 13.8 kV tertiaries of 161/115/13.8 kV autotransformers.

The objective of the impact study is to evaluate the impact on system stability after uprating the hydro power plant and its effect on the nearby transmission system and generating stations. Figure 1-1 shows the approximate geographic location of the interconnecting station in the SPP system, and Figure 1-2 shows the interconnection substation one-line diagram. The feasibility (power flow) study was not performed as a part of this study.

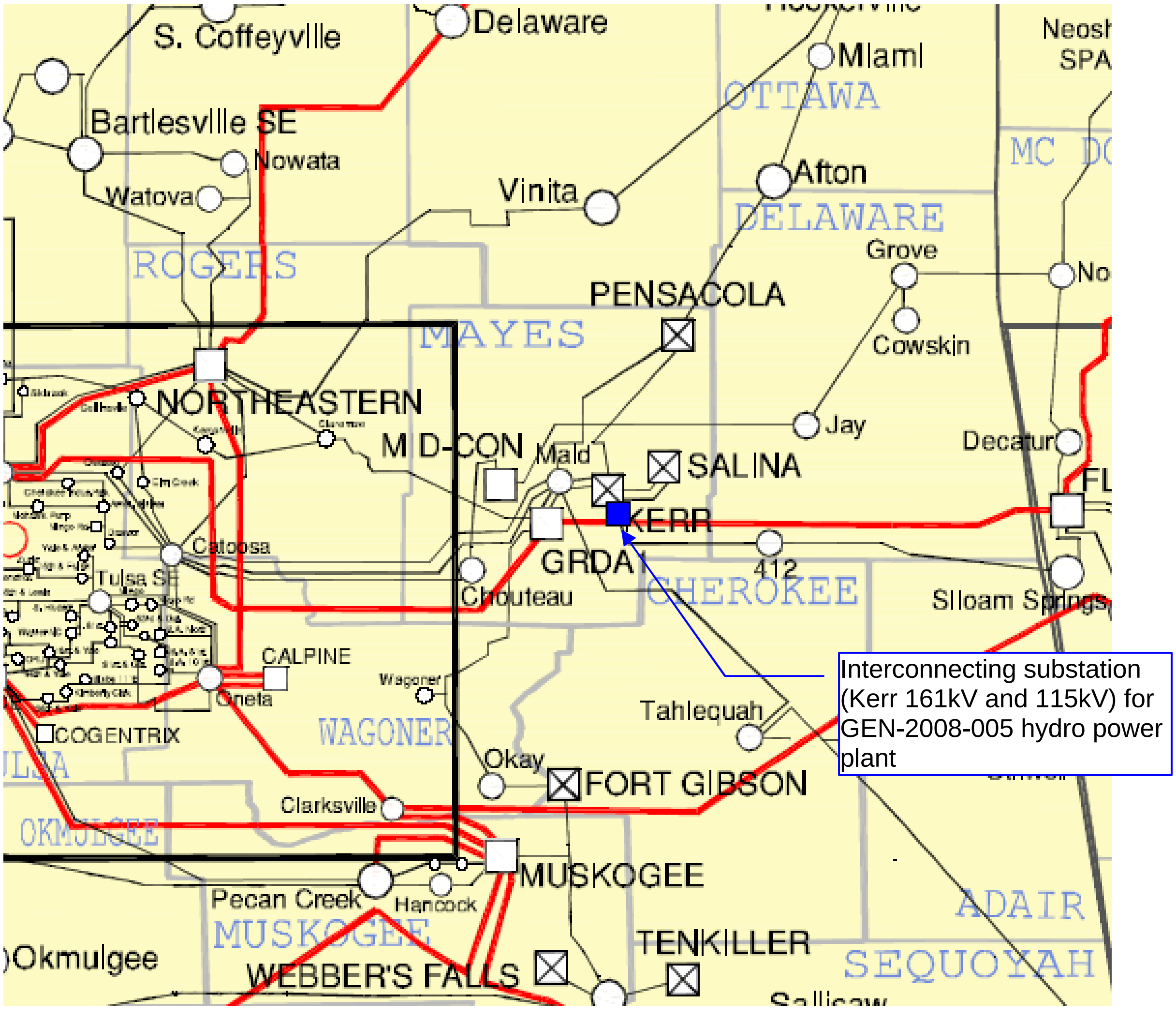

Figure 1-1 GEN-2008-005 Hydro Power Plant Location

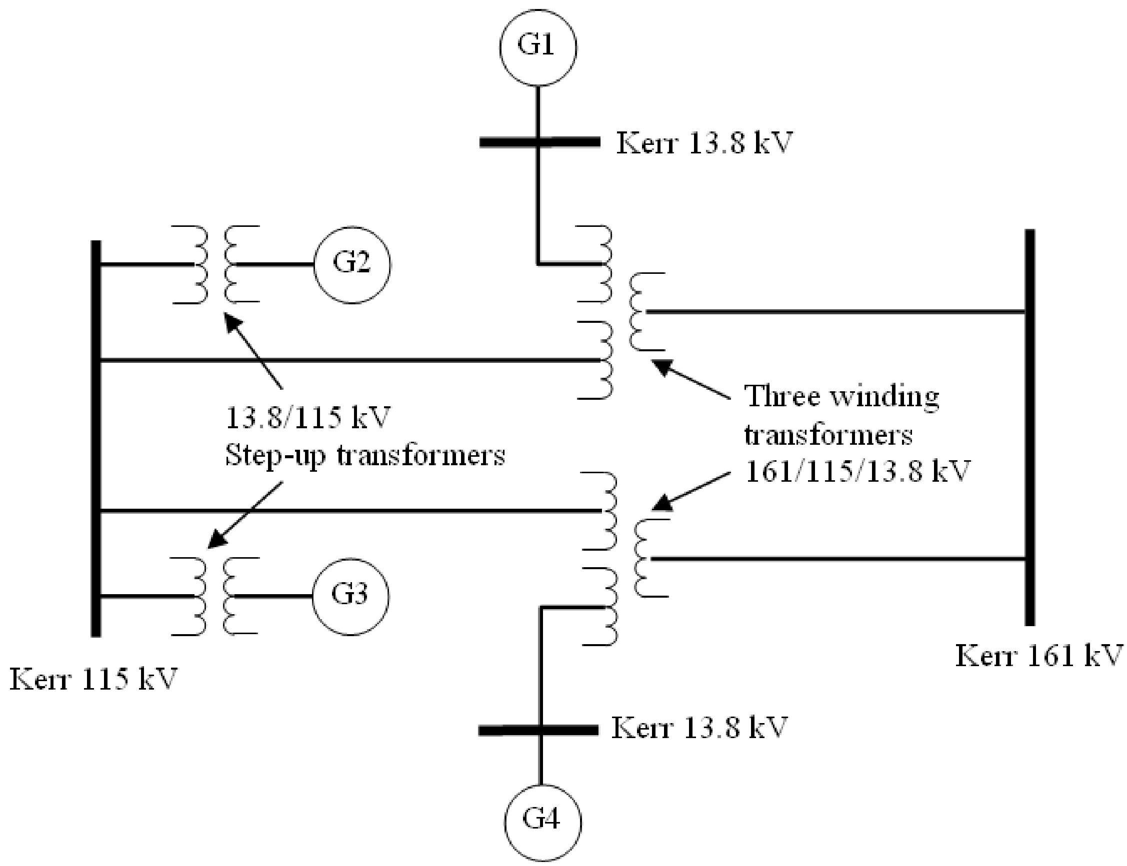

Figure 1-2 Hydro Power Plant One-line

2 STABILITY ANALYSIS

In this stability study, ABB investigated the stability of the system after the uprating of GEN-2008-005 for a series of faults specified by SPP in the vicinity of the proposed project. All of the simulations represent three-phase or single-phase faults cleared by primary protection in 5 cycles, re-closing after 30 more cycles with the fault still on, and then permanently clearing of the fault 5 cycles later with primary protection.

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."

Stability analysis was performed using the 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, such as wind turbines, was monitored as well.

Single-phase 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 estimated to give a positive sequence voltage at the fault location of approximately 60% of pre-fault voltage, which is a typical value.

2.2 STUDY MODEL DEVELOPMENT

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

Base Power Flow Cases

SPP supplied the following two (2) pre-project PSS/E power flow cases:

- *"gen-2008-005_08wp.sav"* representing Winter Peak conditions of the SPP system for the year 2008
- *"gen-2008-005_12sp.sav"* representing Summer Peak conditions of the SPP system for the year 2012

These pre-project cases were modified as below:

- Moving existing units 1 and 4 of Kerr hydro power plant to the tertiaries of the three winding transformers. This is a more accurate representation of the current and future connectivity.
- Deleting the transformer data embedded in units 1 and 4. The transformer impedances for units 2 and 3 are left as part of the generator data.
- Setting the voltage schedule for all four generators to achieve Qgen = 0.0.

This leads to development of two pre-project cases as below;

- *"gen-2008-005_08wp-PRE.sav"* representing the Winter Peak conditions of the SPP system prior to uprating of generations for the year 2008 with modification
- *"gen-2008-005_12sp-PRE.sav"* representing the Summer Peak conditions of the SPP system prior to uprating of generations for the year 2012 with modification

The power flows in the final Pre-project conditions are shown in Figure 2-1 and Figure 2-2.

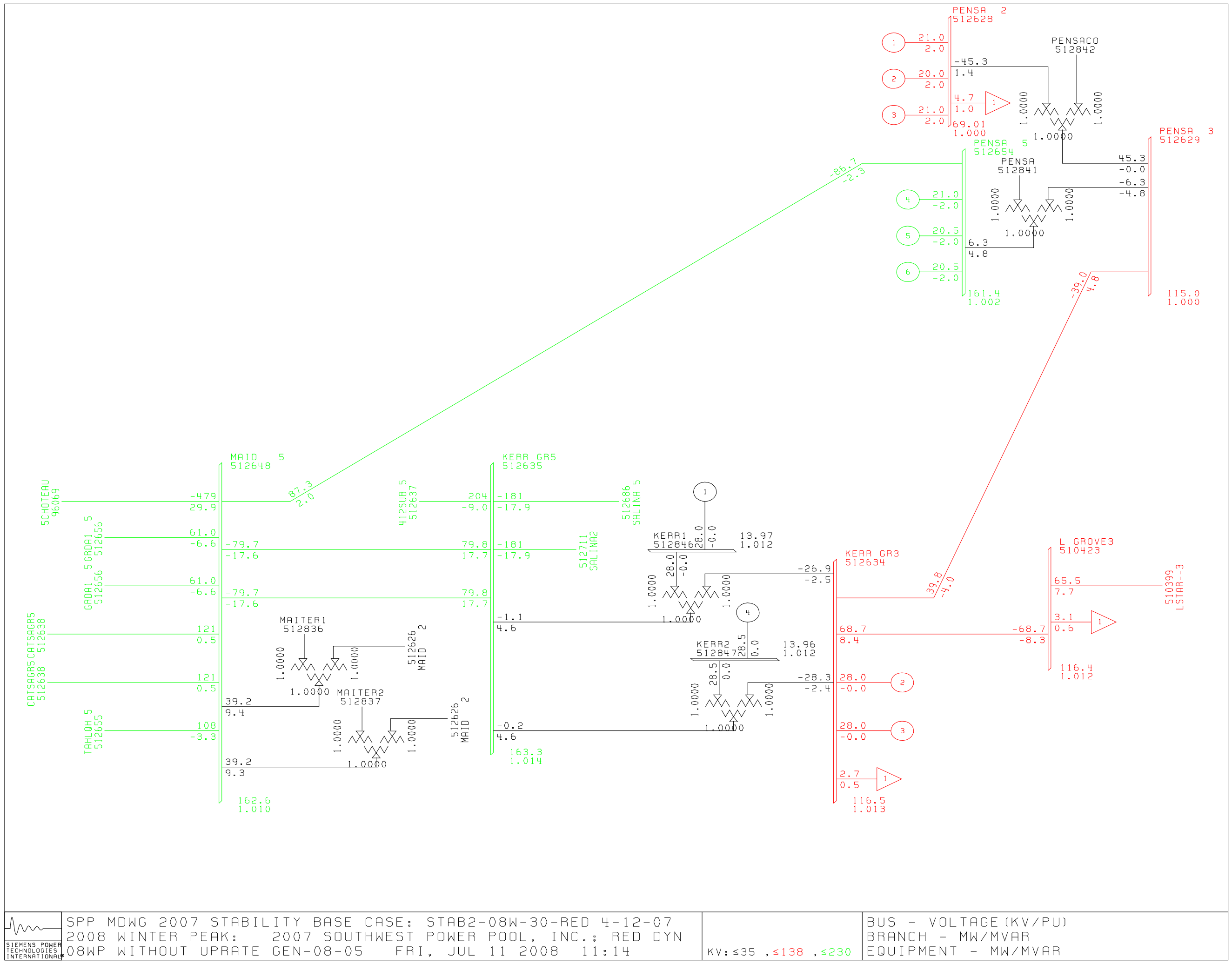

Figure 2-1 2008 Winter Peak case without uprating of GEN-2008-005

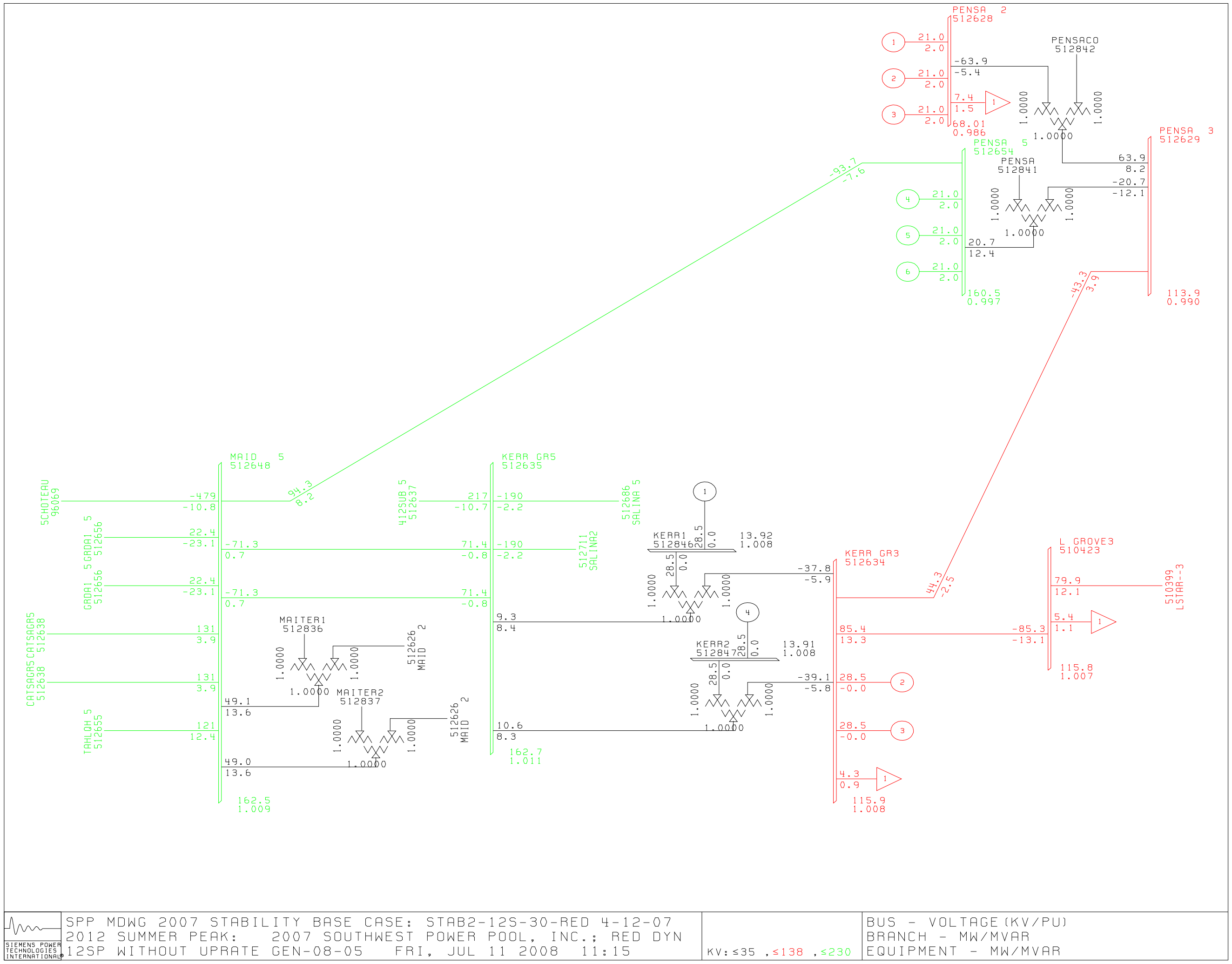

Figure 2-2 2012 Summer Peak case without uprating of GEN-2008-005

GEN-2008-005 Power Flow Cases

The proposed uprating of GEN-2008-005 is comprised of four hydro power generators. This hydro plant is interconnected to the Kerr 161 kV and 115 kV buses in the Grand River Dam Authority (bus #512634 and bus #512635). Two generators (G2 and G3) are modeled with embedded generator transformers and connected to Kerr 115 kV (bus #512634). The other two generators (G1 and G4) are connected to the tertiaries of autotransformers. The details of model development are described in Appendix A.

Thus two Post-project power flow cases were established:

- *gen-2008-005_08wp-POST.SAV – 2008 winter peak case with uprated GEN-2008-005*
- *gen-2008-005_12sp-POST.SAV – 2012 summer peak case with uprated GEN-2008-005*

Figure 2-3 and Figure 2-4 show a power flow one-line diagram with the GEN-2008-005 project for 2008 winter peak and 2012 summer peak system conditions respectively.

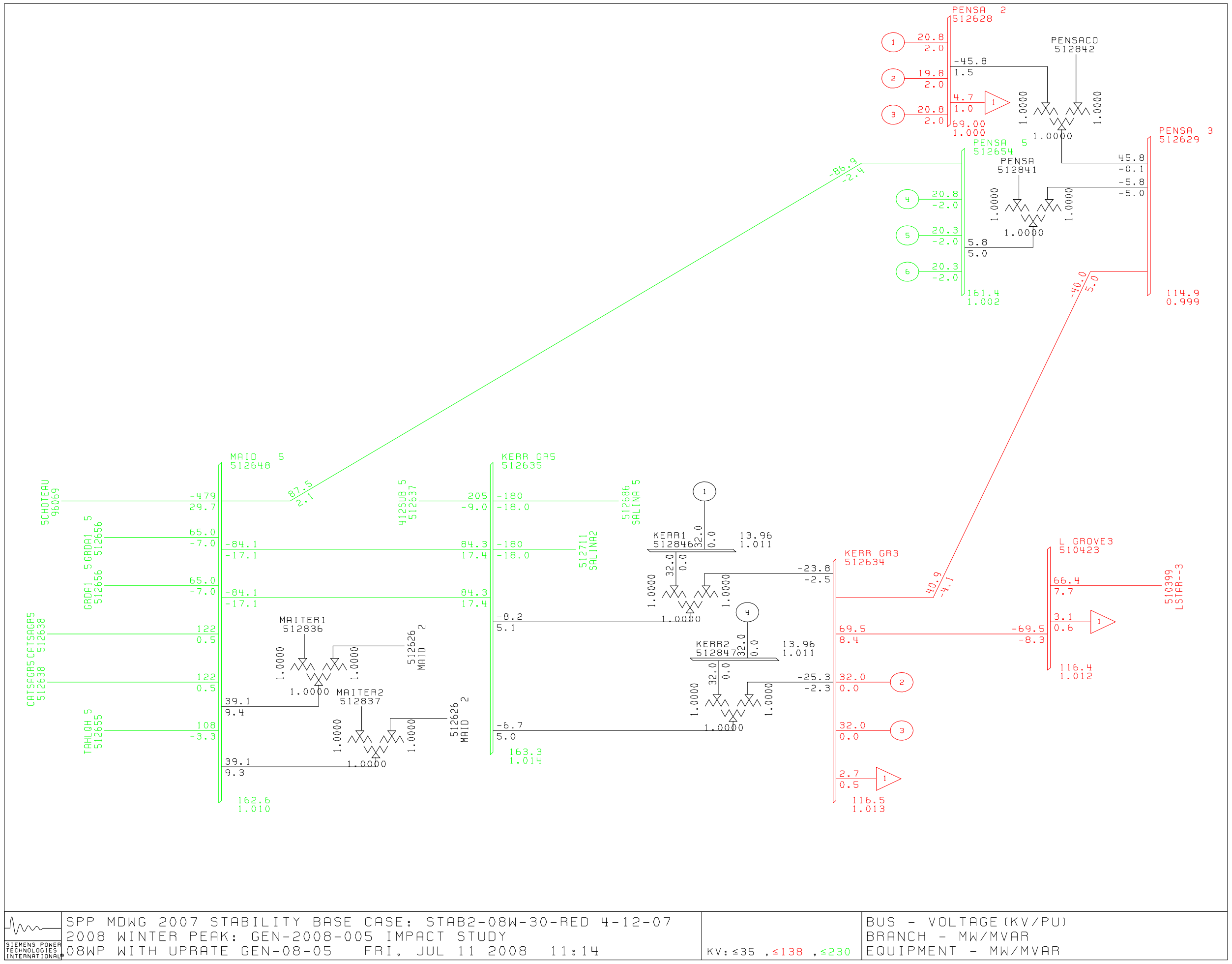

Figure 2-3 2008 Winter Peak case with uprating of GEN-2008-005

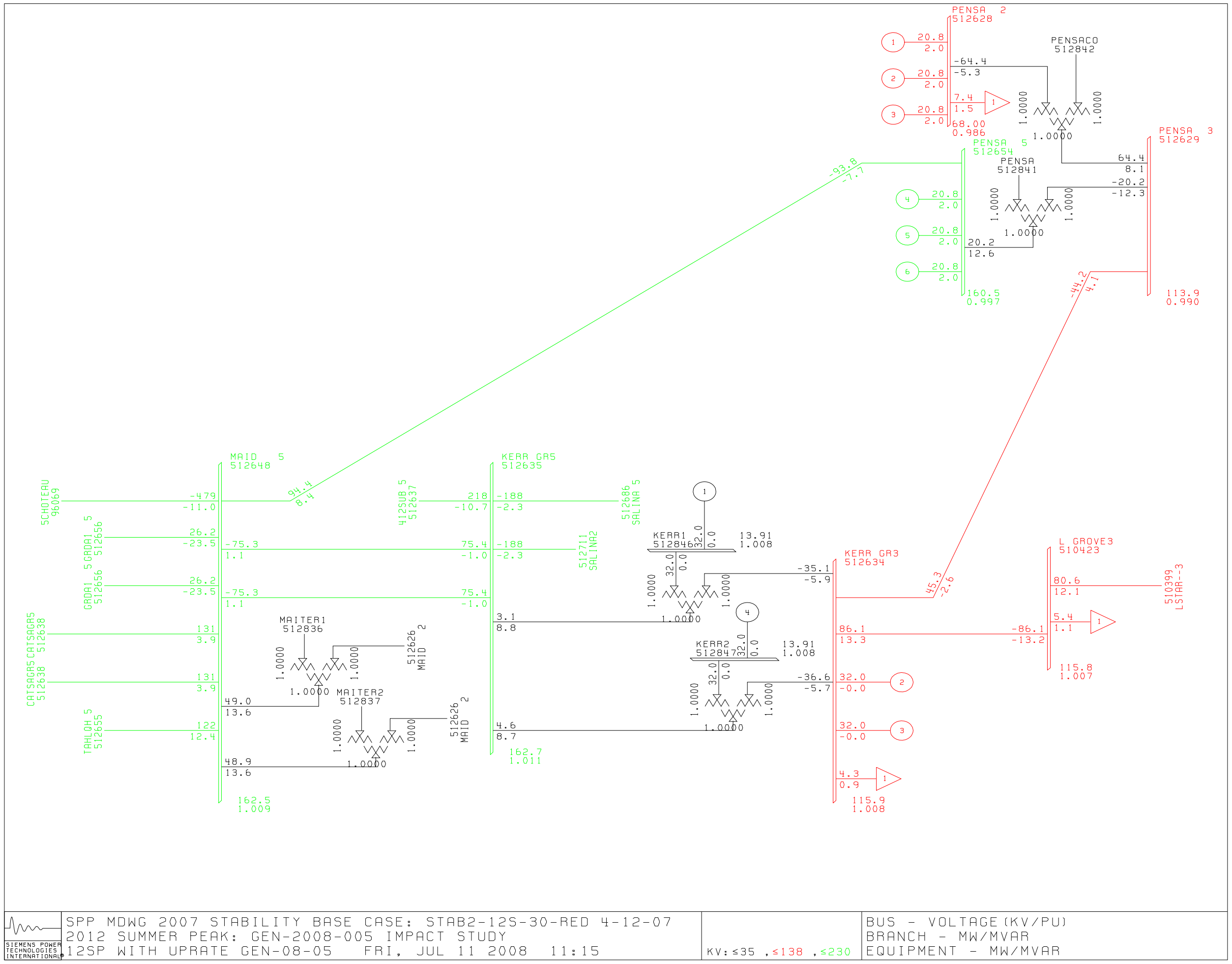

Figure 2-4 2012 Summer Peak case with uprating of GEN-2008-005

Stability Model

SPP provided the stability databases in the form of PSS/E dynamic data files - "*gen-2008-005_08wp.dyr*" to model the 2008 Winter Peak and "*gen-2008-005_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.

SPP provided the dynamic data for the proposed uprate of GEN-2008-005 project. The salient pole generator model, "GENSAL", was used for all four generators. The "HYGOV" governor model and "IEEET1" exciter model were also used for all four uprated generators.

The details of power flow and stability model representations for GEN-2008-005 are included in Appendix B.

Simulated Faults

Table 2-1 lists the disturbances simulated for stability analysis.

Table 2-1 List of Faults for Stability Analysis

Fault Name	*Description*
FLT_1_3PH	Three phase fault on the Kerr (#512635) – Maid (#512648) 161kV double circuit line, near Kerr. a) Apply Fault at Kerr (#512635). b) Clear Fault after 5 cycles by removing the Maid – Kerr 161kV ckt.1 and ckt.2 from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.
FLT_2_1PH	Single phase fault on the Kerr (#512635) – Maid (#512648) 161kV double circuit line, near Kerr. a) Apply Fault at Kerr (#512635). b) Clear Fault after 5 cycles by removing the Maid – Kerr 161kV ckt.1 and ckt.2 from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.
FLT_3_3PH	Three phase Fault on the Kerr (#512635) – 412 Sub (#512637) 161kV line, near Kerr. a) Apply Fault at Kerr (#512635). b) Clear Fault after 5 cycles by removing the 412 Sub – Kerr 161kV from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.
FLT_4_1PH	Single phase Fault on the Kerr (#512635) – 412 Sub (#512637) 161kV line, near Kerr. a) Apply Fault at Kerr (#512635). b) Clear Fault after 5 cycles by removing the 412 Sub – Kerr 161kV from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.
FLT_5_3PH	Three phase Fault on the Kerr (#512634) – Locust Grove (#510435) 115kV line, near Kerr. a) Apply Fault at Kerr (#512634). b) Clear Fault after 5 cycles by removing the Locust Grove – Kerr 115kV from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.

Fault Name	***Description***
FLT_6_1PH	Single phase Fault on the Kerr (#512634) – Locust Grove (#510435) 115kV line, near Kerr. a) Apply Fault at Kerr (#512634). b) Clear Fault after 5 cycles by removing the Locust Grove – Kerr 115kV from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.
FLT_7_3PH	Three phase Fault on the MAID (#512648) – GRDA1 (#512656) 161kV double circuit line, near MAID. a) Apply Fault at MAID (#512648). b) Clear Fault after 5 cycles by removing the double circuit from MAID to GRDA #1 from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.
FLT_8_1PH	Single phase Fault on the MAID (#512648) – GRDA1 (#512656) 161kV double circuit line, near MAID. a) Apply Fault at MAID (#512648). b) Clear Fault after 5 cycles by removing the double circuit from MAID to GRDA #1 from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.
FLT_9_3PH	Three phase Fault on the MAID (#512648) – Catoosa (#512638) 161kV double circuit line, near MAID. a) Apply Fault at MAID (#512648). b) Clear Fault after 5 cycles by removing the double circuit from MAID to Catoosa from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.
FLT_10_1PH	Single phase Fault on the MAID (#512648) – Catoosa (#512638) 161kV double circuit line, near MAID. a) Apply Fault at MAID (#512648). b) Clear Fault after 5 cycles by removing the double circuit from MAID to Catoosa from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.
FLT_11_3PH	Three phase Fault on the MAID (#512648) – Pensacola (#512654) 161kV double circuit line, near MAID. a) Apply Fault at MAID (#512648). b) Clear Fault after 5 cycles by removing the double circuit from MAID to Catoosa from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.

Fault Name	Description
FLT_12_1PH	Single phase Fault on the MAID (#512648) – Pensacola (#512654) 161kV double circuit line, near MAID. a) Apply Fault at MAID (#512648). b) Clear Fault after 5 cycles by removing the double circuit from MAID to Catoosa from service. c) Wait 30 cycles; and reclose into the fault d) Clear fault after 5 cycles by removing the line from service.

2.3 STUDY RESULTS

The three phase and single phase faults listed above were simulated. Responses of the hydro power plant and other nearby generators were monitored. The results for the simulated disturbances are summarized in Table 2-2. Plots showing the simulation results are included in Appendix C.

The results of the simulations indicate that GEN-2008-005 and all other generators in the vicinity of the project will be stable following all simulated faults. There are sustained oscillations observed in the angles and speeds of generators connected at buses 512628 and 512654. These oscillations were also observed in the pre-project case without uprating of GEN-2008-005. Hence, the uprating of GEN-2008-005 project does not have any adverse impact on the system stability in SPP area.

Table 2-2: Results of Stability Simulations

FAULT	Winter peak 2008		Summer peak 2012	
	Pre-project	Post-project	Pre-project	Post-project
FLT_1_3PH	STABLE**	STABLE**	STABLE	STABLE
FLT_2_1PH	STABLE	STABLE	STABLE	STABLE
FLT_3_3PH	STABLE	STABLE	STABLE	STABLE
FLT_4_1PH	STABLE	STABLE	STABLE	STABLE
FLT_5_3PH	STABLE	STABLE	STABLE	STABLE
FLT_6_1PH	STABLE	STABLE	STABLE	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

** Poorly-damped oscillations on some generators

3 CONCLUSIONS

The objective of this study is to evaluate power system stability after uprating the GEN-2008-005 hydro power plant. The study was performed for two system scenarios: 2008 Winter Peak and 2012 Summer Peak.

The results indicate that the uprating of GEN-2008-005 does not have any adverse impact on system stability in SPP area.

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 with Gen-008-005