Interconnection Evaluation Study Report

Resource Solicitation Process

St. Joseph 300 MW Wind Farm

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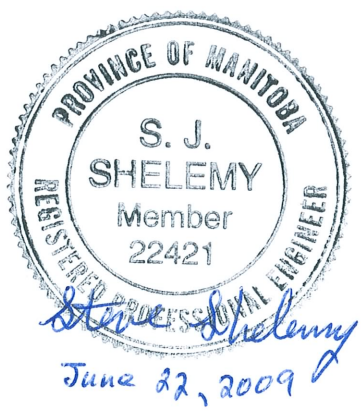
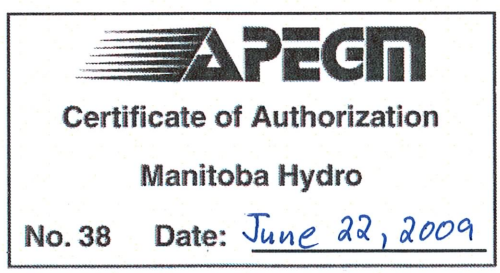
0	S. Shelemy G. Fuerst	D. Jacobson	March 24, 2009	Initial Release
1	Steve Shelemy		June 10, 2009	Section 1& 5.1: Clarified the coordination with USA generator queues. Section 1: Add reference to Minnkota's Maple River Wind Report. Section 5.5 & 5.7 Clarified impacts of firm service from G904 and G380.





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1. Summary

An Interconnection Evaluation Study (IES) has been performed to determine the Manitoba Hydro Interconnection Facilities necessary to connect a 300 MW wind farm to the Manitoba Hydro transmission system. Manitoba Hydro Transmission System Interconnections Generation Queue Date: December 14, 2007.

As part of a Resource Solicitation Process, the Solicitor has submitted ten potential options for the interconnection of up to 300 MW of wind generation on to the Manitoba Hydro transmission system in the Interconnection Evaluation Study Agreement. The Solicitor has requested that all options be considered a Manitoba Hydro Network Resource. The Solicitor ultimately selected the St. Joseph site as the most viable option. The bulk of the Interconnection Evaluation Study represents the St Joseph 300 MW option. Due to time concerns, the Solicitor directed Manitoba Hydro to Report on only the St. Joseph option in the Interconnection Study Report.

The Solicitor originally submitted two wind turbine types to be included in this study. These include the GE 1.5 MW SLE wind turbine and the Mitsubishi MWT95/2.4 wind turbine. Both are doubly-fed wound rotor induction generators. The 300 MW Exploratory Study [1] has determined that the GE 1.5 MW SLE wind turbine generator meets Manitoba Hydro Interconnection Criteria. This study will utilize some of the results of that report. In this report, to ensure turbine manufacturer confidentiality, these two turbine types will henceforth be referenced as Turbine A and Turbine B.

The IES is based on the assumption that the proposed generation will be designated as a Manitoba Hydro (MH) Network Resource taking Network Resource Interconnection Service (NRIS) under the Open Access Interconnection Tariff (OAIT). **As a Manitoba Hydro Network Resource both interconnection and delivery evaluations are combined together in this study.** NRIS requires Interconnection Facilities and Interconnection System Upgrades, along with any required Network Upgrades. As a Network Resource, the impacts of scheduling to the nearest generation and Network Load were evaluated. The Dorsey HVDC generation was identified as the nearest sink. MH's Network Load is located entirely within the Province of Manitoba. Therefore, the new generation will not require the need to increase transfer levels on the Manitoba to Ontario, Saskatchewan or U.S. boundaries. This IES determined the impact of interconnecting the wind generation on the existing MH transmission system by means of steady-state ac power flow analysis and stability analysis.

AC contingency analysis was performed for N-1 and N-2 contingencies during system intact conditions. The 2014 base cases include the Riel station. The prior queued Energy Resource (ER) Erikson wind generation was not included in this analysis.

For this study an attempt was made to coordinate with the generator interconnection queues of other Transmission Owners/Operators including MISO, Minnkota, and WAPA. Prior queued USA generator facilities that may impact this project were included and modelled at an output level indicated in the table below:

Project Number	Transmission Provider	Project Identifier	Peak Output (MW)	Modelled Output (MW)
GM0100	Minnkota	Langdon 1	100	46
GM0200	Minnkota	Langdon 2	60	
GM0300	Minnkota	Langdon 3	40.5	
G380	MISO	Rugby	150	150
GI-0404	WAPA	Killdeer	8	8
G474	MISO	Elbow Lake	20	20
GI-0503	WAPA	Minot	100	100
G531	MISO	Stanton	68	68
G619	MISO	Tamarac	50	49.5
G645 – G788	MISO	Ladish	50 + 49	100
GI-0614a	WAPA	Culbertson	99	8
GI-0616	WAPA	Groton/Leland	81	48.6
G767	MISO	Diamond Willow		19.5
GI-0707a	WAPA	Groton/Leland	286	200
GI-0708	WAPA	Culbertson	120	120
G821	MISO	Sheynne Audubon	201	200
G132	MISO	Tatanka	180	180
GI-0615	WAPA	Hilken/Wilton	50	49.5
GI-0208	WAPA	Ponoma	40	40
GI-0316 - GI-0608	WAPA	Groton 1 & 2		39

The Maple River Wind project (Pillsbury) was not included in models for this study. This project is already in-service however it has a Minnkota Power Cooperative queue date of January 3, 2008 which is after the Manitoba Hydro queue date of December 14, 2007 for St. Joseph Wind. Studies for this project were completed on July 25, 2008 and include a sensitivity to the 300 MW generation addition at Letellier. The report to this project is located at http://www.minnkota.com.

Major transmission facilities added include the Langdon to Hensel 115 kV line and the Arrowhead to Weston 345 kV line. Also included is the North Dakota Export NDEX increase to NDEX = 2080.

The interconnection of the 300 MW St. Joseph wind farm resulted in several thermal overloads of lines and station equipment. Thermal overloads were identified on the following transmission lines; Letellier to Drayton 230 kV line (L20D), and Glenboro to Cornwallis 230 kV line (G37C). Stations requiring equipment upgrades include Letellier, and Cornwallis.

This study determined that Turbine A failed to meet the Manitoba Hydro Transmission Interconnection Criteria for voltage control at the point of interconnection. Turbine B was found to exhibit satisfactory transient performance. **A complete transient evaluation will be conducted in the Interconnection Facilities Study once the developer has finalized turbine manufacturer and addressed turbine performance inadequacies.**

1.1. Network Resource Interconnection Service:

For Network Resource Interconnection Service of the full 300 MW the required system upgrades are as follows:

Transmission Owner Interconnection Facilities are as follows:

Option 1:

- 7.75 km new 230 kV transmission line from wind farm to the Letellier 230 kV station (12/10/2008).
- Letellier 230 kV Station (1500 Amps minimum):
  - New breaker (R4).

Option 2:

- two 7.75 km (15.5 km total) new 230 kV transmission line from wind farm to the Letellier 230 kV station (12/10/2008).
- Letellier 230 kV Station (1500 Amps minimum):
  - two New breakers (R4 & R5).

The Interconnection System Upgrades are as follows:

- Letellier 230 kV Station upgrades (1500 Amps minimum):
  - L20D risers.
  - D7A & B, D6A & B switches.
  - R6 CT.
  - R7 CT.
  - R8 CT.
  - Various riser and bus upgrades.

The Network System Upgrades are as follows:

- L20D re-conductored with 954 ACSS at 150 deg C design rating.
- G37C re-conductored/restructure to 795 ACSS at 150 deg C design rating.
- Cornwallis 230 kV Station (1200 Amps minimum):

- G37C risers.
- Various bus bar upgrades.

Without the upgrades to L20D, G37C, and Cornwallis 230 kV Station, Network Resource Interconnection Service is available for 0 (zero) MW output from the St. Joseph Wind Farm.

A planning level cost estimate of the Manitoba Hydro Interconnection Facilities, Interconnection System Upgrades, and Network Upgrades necessary to connect a 300 MW wind farm to the Letellier 230 kV station bus was calculated. The total costs were estimated to be Option 1: $19,200,000 (+ 50%) and Option 2: $24,000,000 (+ 50%).

1.2. Energy Resource Interconnection Service:

Without the upgrades to L20D, G37C, and Cornwallis 230 kV Station, Network Resource Interconnection Service is available for 0 (zero) MW output from the St. Joseph Wind Farm. Energy Resource Interconnection Service for some of the St. Joseph Wind Farm output may be possible under certain system conditions. Energy Resource Interconnection Service is highly dependent upon system conditions as identified below and no guarantee is made to its short or long term availability.

MHEX Import Conditions:

NDEX (MW)	St. Joseph Wind Output (MW)	Comments
0 < NDEX < 2080	0	No available transmission capacity.

MHEX Export Conditions:

NDEX (MW)	St. Joseph Wind Output (MW)	Comments
NDEX < 550	0	No available transmission capacity.
NDEX > 1200	300	Non-firm transmission capacity available.
550 < NDEX < 1200	-	Operating guides to determine output.

For Energy Resource Interconnection Service, operating guides will be developed identifying the maximum St. Joseph Wind output permitted for given system conditions. The required system upgrades for ERIS are as follows:

Transmission Owner Interconnection Facilities are as follows:

Option 3:

- 7.75 km new 230 kV transmission line from wind farm to the Letellier 230 kV station (12/10/2008).
- Letellier 230 kV Station (1500 Amps minimum):
  - New breaker (R4).

Option 4:

- two 7.75 km (15.5 km total) new 230 kV transmission line from wind farm to the Letellier 230 kV station (12/10/2008).
- Letellier 230 kV Station (1500 Amps minimum):
  - two New breakers (R4 & R5).

The Interconnection System Upgrades are as follows:

- Letellier 230 kV Station upgrades (1500 Amps minimum):
  - L20D risers.
  - D7A & B, D6A & B switches.
  - R6 CT.
  - R7 CT.
  - R8 CT.
  - Various riser and bus upgrades.

A planning level cost estimate of the Manitoba Hydro Interconnection Facilities and Interconnection System Upgrades necessary to connect a 300 MW wind farm to the Letellier 230 kV station bus was calculated. The total costs were estimated to be Option 3: $4,800,000 (+ 50%) and Option 4: $9,600,000 (+ 50%).

2. Introduction

2.1. Background Information

This report documents the results of an Interconnection Evaluation Study for a 300 MW wind farm near the town of St. Joseph, Manitoba. The proposed in-service date is year 2011.

The Solicitor has indicated that the wind farm collector station could be built in Section 22, Township-Range 1-2E. For the purposes of the study, the Generator's distribution station is assumed to be the shortest direct route, 7.75 km away from the Letellier 230 kV station. For simulations only a single interconnection line was studied.

The distribution station voltage level was assumed to be 34.7 kV. One 34.7 - 230 kV transformer was modeled between the collector system and the high voltage grid to step up the voltage to 230 kV. A 7.75 km 230 kV line from the Manitoba Hydro system at the Letellier 230 kV station is connected to the high side of the step up transformer. This connection point is identified as the Point of Interconnection (POI).

A 230 kV switching station is located at Letellier. Three 230 kV lines terminate in this station. A 64.0 km tie-line extends to Drayton U.S.A., (L20D), 79.5 km line extends to Laverendrye, (Y51L), and an 120.0 km line terminates at St. Leon via Stanley (S60L). Two 230 – 66 kV distribution transformers serve local area load. A third 230 – 66 kV transformer bank will be added in 2010. Figure 2.1 and 2.2 are a single line diagrams showing the existing and future facilities connected to the Letellier 230 kV station.

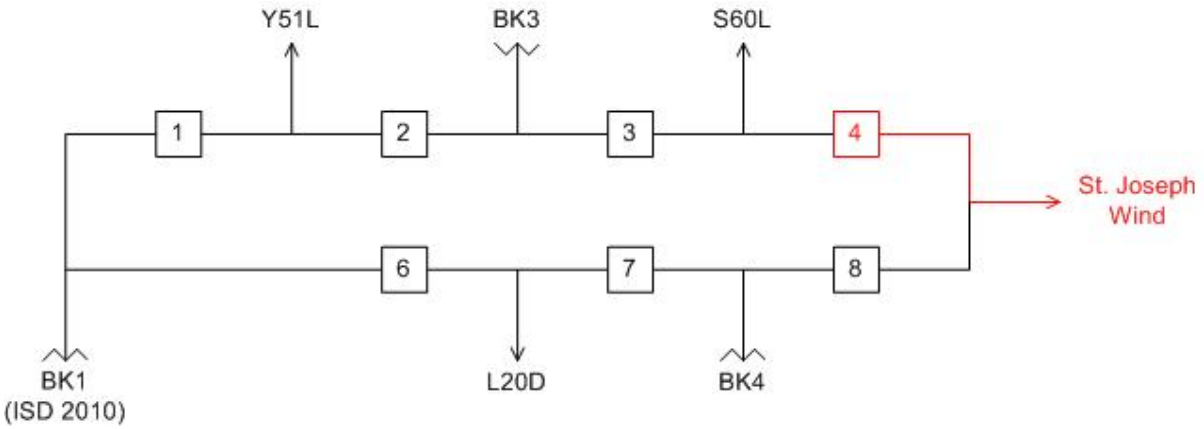


Fig. 2.1: Option 1: Letellier 230 kV Station Conceptual Diagram.

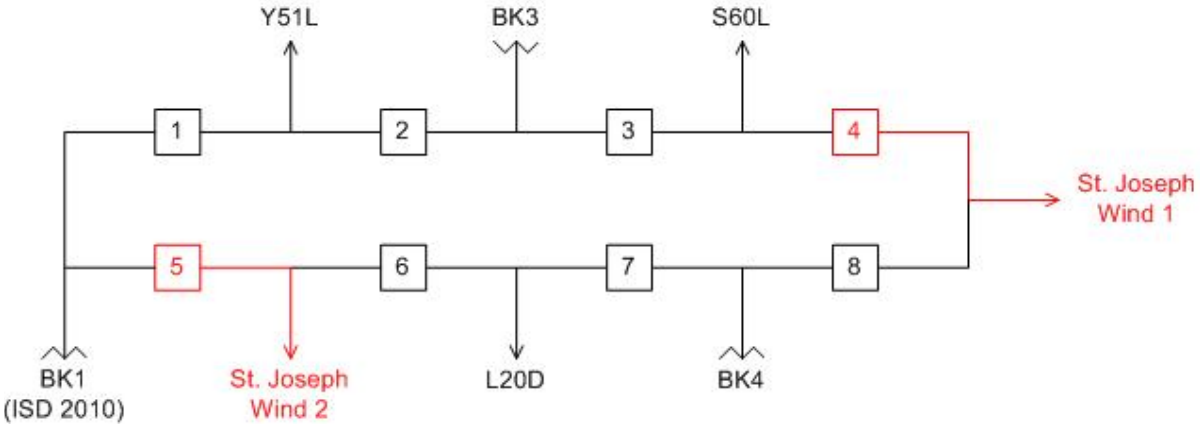


Fig. 2.2: Option 2: Letellier 230 kV Station Conceptual Diagram.

For Option 1, the major Interconnection Facilities required to connect the wind farm into the 230 kV station bus include one 230 kV circuit breaker within the Letellier station (and associated equipment) plus a single 7.75 km 230 kV line (12/10/2008). The line is assumed to have a 954 MCM ACSR conductor, 100 deg C design temperature (419 MVA summer thermal rating). A minimum of one motor-operated disconnect is required at the Point of Interconnection (i.e. high side of Generator's 34.7-230 kV step-up transformer). MH requires visual isolation as well as the ability to automatically isolate the Generation Facility. The Generator must provide a circuit breaker near the point of interconnection. It is not MH's practice to provide primary protection for Generator's equipment due to liability concerns.

For Option 2, the major Interconnection Facilities required to connect the wind farm into the 230 kV station bus include two 230 kV circuit breakers within the Letellier station (and associated equipment) plus two 7.75 km 230 kV lines. The line is assumed to have a 954 MCM ACSR conductor, 100 deg C design temperature (419 MVA summer thermal rating). A minimum of one motor-operated disconnect is required at the Point of Interconnection (i.e. high side of Generator's 34.7-230 kV step-up transformer). MH requires visual isolation as well as the ability to automatically isolate the Generation Facility. The Generator must provide a circuit breaker near the point of interconnection. It is not MH's practice to provide primary protection for Generator's equipment due to liability concerns.

2.2. Objectives

The Interconnection Evaluation Study objectives are to determine:

- Facilities required to electrically connect the generator to the MH electrical system,
- Adequacy of reactive power facilities,
- System reliability limitations (i.e. equipment overloads, voltage violations),
- Planning level cost estimates of transmission facilities.
- Identify the impact the new generating facilities have on the interconnected system.

If the Solicitor chooses to proceed, the Interconnection Facilities Study phase will:

- Address the system reliability limitations,
- Determine short circuit impacts (e.g. circuit breaker replacement),
- Determine a good faith cost estimate of all the interconnection facilities,
- Determine a good faith construction schedule estimate,
- Full transient stability analysis.
- Determine protection requirements (e.g. breaker fail, wind farm cross trip, etc.),
- Perform Constrained interface analysis,
- Complete outstanding steady state analysis with final the Letellier Station configuration,
- Satisfy any requirements of the Regional Reliability Organization.

3. Interconnection System and Network Upgrades

There are two types of Interconnection Services available:

1. Energy Resource Interconnection Service (ERIS)
   As stated in the Manitoba Hydro Open Access Interconnection Tariff (OAIT), "ERIS allows the Generator to connect the Facility to the System and be eligible to deliver the Facility's output using the existing firm or non-firm capacity of the Transmission System on an "as available" basis. ERIS does not in and of itself convey any right to deliver electricity to any specific customer or Point of Delivery." ERIS requires Interconnection Facilities and Interconnection System Upgrades, but not Network Upgrades.

2. Network Resource Interconnection Service (NRIS)
   As stated in the Manitoba Hydro Open Access Interconnection Tariff (OAIT), "NRIS allows the Generator's Facility to be designated as a Network Resource, up to the Facility's full output, on the same basis as existing Network Resources interconnected to Manitoba Hydro's System. NRIS in and of itself does not convey any right to deliver electricity to any specific customer or Point of Delivery." NRIS requires Interconnection Facilities, Interconnection System Upgrades and Network Upgrades.

Interconnection System Upgrades are the minimum necessary upgrades required to interconnect to the MH system and meet reliability criteria. A re-dispatch to the nearest existing Manitoba Hydro network resource is used as a test for Interconnection System Upgrades. For St. Joseph, this MH network resource is Dorsey. Where a facility is overloaded, dynamic line rating equipment could be installed to allow the operators to send a timely MW curtailment level to the plant, or equipment upgrades could be implemented.

Network Upgrades are the upgrades required when the Manitoba Hydro Transmission System is studied at peak load, and other load levels deemed appropriate by Manitoba Hydro, under a variety of severely stressed conditions, to determine whether, with the Facility at full output, the aggregate of generation in Manitoba can be delivered to the aggregate load on the transmission system, consistent with Manitoba Hydro's reliability criteria and procedures. In other words, it is necessary to be able to re-dispatch to all generators and load without requiring pre-contingency curtailment or violating post-contingency voltage and loading criteria. A generation cross-trip scheme may be considered as an alternative to new lines or re-conductoring if the special protection system (SPS) is made fully redundant and the cross-trip amount is less than Manitoba Hydro's operating reserves.

Interconnection System Upgrades and Network Upgrades are separately identified.

The Solicitor has requested NRIS, therefore both Interconnection System Upgrades and Network Upgrades are identified.

3.1. Transmission Owner Interconnection Upgrades

The transmission owner interconnection facility upgrades have been identified as:

Option 1: Single 300 MW interconnection

Letellier 230 kV Station (1500 Amps minimum).

- New breaker (R4)
- L20D risers
- D7A & B, D6A & B disconnects
- R6 CT, R7 CT, R8 CT
- Various riser/bus upgrades

One new 7.75 km 230 kV transmission line from wind farm point of interconnection to the Letellier 230 kV station will have to be built.

Option 2: Two 150 MW interconnections

Letellier 230 kV Station (1500 Amps minimum).

- Two new breakers (R4 & R5)
- L20D risers
- D7A & B, D6A & B switches
- R6 CT, R7 CT, R8 CT
- Various riser/bus upgrades

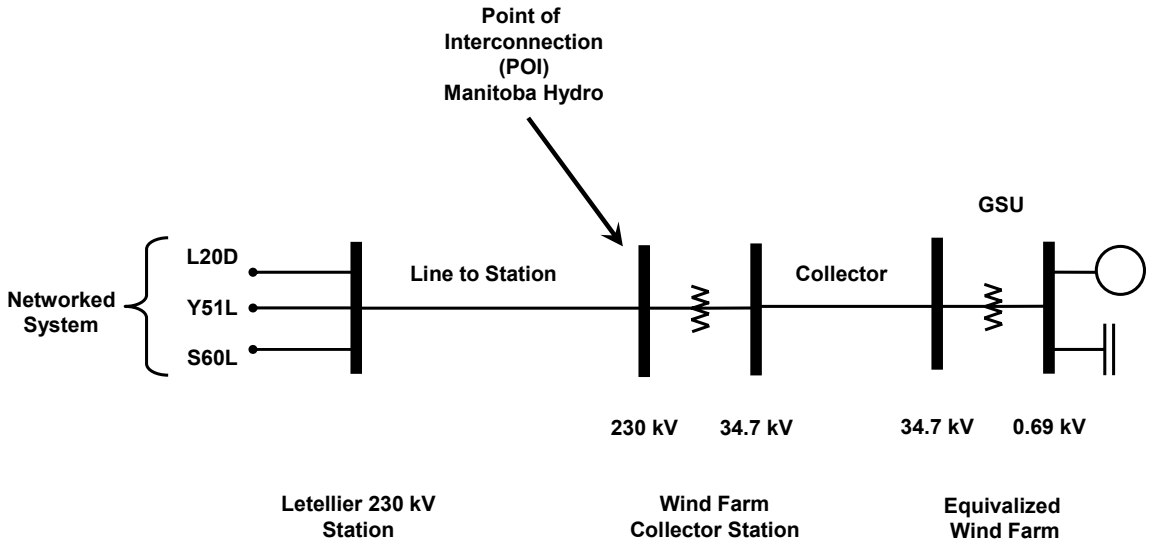
Two new 7.75 km (15.5 km total) 230 kV transmission lines from the two wind farm points of interconnection to the Letellier 230 kV station. Substantial station re-design may be necessary to accommodate the two new transmission lines. The final station layout will be determined for the Interconnection Facilities Study.

4. Wind Turbine Model

The Solicitor has submitted two wind turbines types to be considered for each scenario for this study. These include the GE 1.5 MW SLE wind turbine and the Mitsubishi MWT95/2.4 wind turbine. Both are doubly-fed wound rotor induction generators and are capable of fast voltage control over a power factor operation range of 0.95 overexcited to 0.9 under-excited. The GE 1.5 MW SLE wind turbine normal mode of operation is voltage control while the Mitsubishi MWT95/2.4 normal mode of operation is power factor control.

For the purposes of this study, the 300 MW wind farm is represented as one aggregate generator operating at 690 V. The aggregate generator is stepped up to 34.7 kV via a 337.5 MVA transformer. Data for the 34.7 kV collector system was not available at the time of this study and was modelled as a zero impedance line. The 34.7 kV collector system is stepped up to the 230 kV connection voltage level via a 334 MVA transformer of 2.83% impedance. A 7.75 km 230 kV transmission line connects the St. Joseph wind farm to the 230 kV Letellier Station.

Detailed PSS/E user models representing the DFIG turbine are used to perform the stability analysis.



5. Steady State AC Power Flow Analysis (VSAT)

The Solicitor has requested the proposed generation facility be considered a Network Resource Interconnection Service (NRIS). As a network resource, the impacts of scheduling to the Dorsey HVDC generation at peak and off-peak loading conditions were evaluated.

5.1. Study Power Flow Models

Steady state post-disturbance analysis was performed using the following 2009 and 2014 power flow models from the 2004 MAPP series:

- 2009 Summer peak
- 2009 Summer off-peak
- 2009 Winter peak
- 2014 Summer peak
- 2014 Summer off-peak
- 2014 Winter peak

Steady state post-disturbance analysis for both 2009 and 2014 models was performed at the known most stressed transfers conditions for Manitoba Hydro to U.S.A. transfer (MHEX), North Dakota transfer (NDEX), Manitoba/Ontario transfer (MH-OH), Saskatchewan to U.S.A. transfer (B10T), and Ontario to U.S.A. transfer (F3M). Manitoba to Saskatchewan net transfers was zero. Minnesota to Wisconsin transfers (MWSI) were permitted to "float" after initially being set to its maximum achievable level with existing Twin Cities loading and generation in the 2004 series MAPP models. The IPLAN, "*setexports.irf*" was then used to adjust the simultaneous case to the transfer levels shown in Table 5.1. Table 5.2 indicates the level of Manitoba generation for each scenario.

Table 5.1: Study Scenarios.

Case	Season Load Year	MHEX [MW] south	NDEX [MW] east	B10T [MW] south	F3M [MW] south	MWSI [MW] east	MH-OH [MW] east	MH-SP [MW] west net
1	SUPK09	1940	2080	165	150	1185	200	0
2	SUPK09	1930	300	165	150	830	200	0
3	SUPK09	-700	2080	-165	-100	380	0	0
4	SUPK09	-700	0	-165	-100	-65	0	0
5	WIPK09	-700	2080	-165	-100	480	0	0
6	WIPK09	-700	0	-165	-100	45	0	0
7	SUOP09	2175	2080	165	150	1610	200	0
8	SUOP09	2175	300	165	150	1260	200	0
9	SUOP09	-700	2080	-165	-100	1094	0	0
10	SUOP09	-700	0	-165	-100	670	0	0
11	SUPK14	1938	2080	165	150	760	200	0
12	SUPK14	1938	300	165	150	180	200	0
13	SUPK14	-700	2080	-165	-100	-320	0	0
14	SUPK14	-700	0	-165	-100	-990	0	0
15	WIPK14	-700	2080	-165	-100	386	0	0
16	WIPK14	-700	0	-165	-100	-990	0	0
17	SUOP14	2175	2080	165	150	1370	200	0
18	SUOP14	2175	300	165	150	850	200	0

Table 5.2: Manitoba Hydro Generation.

	2009					2014			
	Summer Peak		Summer Off-Peak		Winter Peak	Summer Peak		Summer Off-Peak	Winter Peak
	MHEX		MHEX		MHEX	MHEX		MHEX	MHEX
Plant	1938	-700	2175	-700	-700	2085	-700	2175	-700
Limestone	1337	746	1254	338	953	1362	656	1221	1023
Long Spruce	1025	550	924	249	702	1004	484	900	784
Kettle	1198	598	1082	256	787	1118	504	988	859
Jenpeg	168	136	136	136	136	168	168	168	140
Kelsey	252	180	230	180	150	253	253	255	271
Grand Rapids	480	60	460	60	460	480	160	480	160
Pine Falls	91	46	90	28	37	94	19	95	37
McArthur Falls	56	28	60	18	23	57	12	57	23
Great Falls	138	64	145	40	52	139	23	139	52
Seven Sisters	166	68	170	41	54	165	33	165	54
Slave Falls	65	29	70	20	25	68	14	68	25
Pointe du Bois	74	45	79	32	39	79	24	79	39
Brandon	385	0	0	0	98	387	0	0	0
Selkirk	144	0	0	0	0	145	0	0	0
Wuskwatim	0	0	0	0	0	200	200	202	200
St. Leon Wind	99	99	99	99	99	99	99	99	99
Total	5678	2648	4798	1496	3614	5817	2648	4914	3765

For the purposes of this Interconnection Evaluation Study an attempt was made to coordinate with the generator interconnection queues of other Transmission Owners/Operators including MISO, Minnkota, and WAPA. With the intent of stressing USA to Manitoba loop flows, prior queued USA generator facilities that may impact this project were dispatched at 100% of their firm output level as indicated in their respective generator interconnection queues. Output from these facilities were sunk to load in their respective zones (i.e. North Dakota generating facilities were sunk to North Dakota load, Minnesota generating facilities to Minnesota load, etc.). These include:

- GM0100, GM0200 Langdon 1 (46 MW). 66881
- GM0300 Langdon 2 (46 MW). 66881
- G380 Rugby (150 MW). 90180
- GI-0404 Killdeer (8 MW). 99011
- G474 Elbow Lake (20 MW). 63171
- GI-0503 Minot (100 MW). 67158

• G531	Stanton (68 MW).*	63003
• G619	Tamarac (49.5 MW).	62525
• G645 – G788	Ladish (100 MW).	63645
• GI-0614a	Culbertson (8 MW)	99013
• GI-616	Groton/Leland (48.6 MW)	67165
• G767	Diamond Willow (19.5 MW).	67393
• GI-0707a	Groton/Leland (200 MW)	67164
• GI-0708	Culbertson (120 MW)	67300
• G821	Sheynne Audubon (200 MW).	63311
• G132	Tatanka (180 MW).	67399
• GI-0615	Hilken/Wilton (49.5 MW)	67301
• GI-0208	Ponoma (40 MW).	67292
• GI-0316 - GI-0608	Groton 1 & 2 (39 MW).120	67274

* G531 was included in ZONE 102 in the set up IDEV provided by WAPA and therefore was scaled with NDEX level.

For transient analysis this wind generation was reduced to 20% of its rated output.

5.2 Contingencies

The following contingencies were studied using Powertech's Voltage Stability Analysis Tool (VSAT):

- System Intact.
- N-1 contingencies for all transmission lines and transformers 100 kV and above within Manitoba
- N-1 contingencies for all transmission lines and transformers 100 kV and above within the following areas: Saskatchewan (672), Xcel Energy (600), Minnesota Power (608), Great River Energy (618), Ottertail Power (626), Western Area Power Administration (652), Dairyland Power Cooperative (680), Southern Minnesota Municipal Power Agency (613), and Muscatine Power & Water (633).
- N-2 contingencies for all 110 kV and above double circuit outages in Manitoba and breaker fail outages approximately two buses back from the Letellier Station.
- N-2 contingencies of multiple circuit lines 115 kV and above as included in the standard Northern MAPP contingency file.

5.3 Monitored Subsystems

- Branch MVA and MW loading and bus voltages in following areas were monitored and recorded for post processing screening: Manitoba Hydro (667), Saskatchewan (672), Xcel Energy (600), Minnesota Power (608), Great River Energy (618), Ottertail Power (626), Western Area Power Administration (652), and Muscatine Power & Water (633).
- Branch MVA and MW loading and bus voltages in following zones were monitored and recorded for post processing analysis: North Dakota (90,990), Excel South Dakota (603), Nebraska Public Power District (640), WAPA (653,654), Basin Electric Power Cooperative (659), and Northwestern Energy (663).

5.4 Impacted Facilities Screening Criteria

5.4.1 Manitoba Hydro Facilities

In general, Manitoba Hydro does not utilize an emergency or post-contingency thermal rate for its transmission facilities. Manitoba Hydro thermal loading criteria does not allow short-term overload above the normal rating or Rate A for single contingency (Category B) events. D602F, L20D, and G82R have a short-term 110% overload capability. A short-term overload of up to 115% may be allowed for multiple contingency events (Category C such as double circuit common tower outages) on a case-by-case basis. If a short-term overload rating is applied, it is necessary to be able to reduce the loading to the steady state thermal rating within 30 minutes of the overload occurrence.

If the overloaded segment of a transmission line is station equipment rather than the line conductor, the overload capability for that piece of equipment will be individually assessed.

When comparing the pre-wind facility and post-wind facility contingency output files, an impacted Manitoba facilities are those which satisfy all three of the following conditions:

i. The facility is loaded post-facility above its normal rating (Rate A) for system intact or for contingency conditions.
ii. The addition of the facility causes the distribution factor to exceed PTDF ≥ 5% for system intact conditions or OTDF ≥ 3% for a contingency.
iii. The increase in loading of the facility for system intact or the contingency is greater than or equal to 1 MW.

In addition to overload issues an impacted facility includes any bulk transmission system bus 100 kV and above in the 'vicinity' of the new facility for which:

1. Bus voltage violates the bus voltage criteria,
2. Bus voltage changed more than 0.01 p.u.

5.4.2 USA Facilities

When comparing the pre-facility and post-facility system intact and contingency files, a "Significantly Affected Facility" or Impacted Facility must satisfy all three of the following conditions:

i. The facility is loaded post-facility above its normal rating (Rate A) for system intact or the facility is loaded post-facility above its emergency post-contingency (Rate C) for contingency conditions.
ii. The addition of the facility causes the distribution factor to exceed PTDF ≥ 5% for system intact conditions or OTDF ≥ 3% for a contingency.
iii. The increase in loading of the facility for system intact or the contingency is greater than or equal to 1 MW.

In addition to overload issues an impacted facility includes any bulk transmission system bus 100 kV and above in the 'vicinity' of the new facility for which:

3. Bus voltage violates the facility owners voltage criteria[4],
4. Bus voltage changed more than 0.01 p.u.

5.5 Steady State Post Contingency Results

The following section provides details on the impacted facilities identified in steady state post contingency analysis. Steady state system intact and post disturbance facility loadings were recorded for thermal overloads above Rate A and that have an OTDFs greater than or equal to 2%. These results were then manually check to determine if an emergency rating (Rate C) exists for that facility, any special protection schemes, or a manual re-simulation of the contingency to confirm results. The significantly impacted facilities listed in tables 5.1 to 5.5 and are summarized below. System upgrades to these impacts are discussed in Section 5.5.2.1.

- Letellier to Drayton 230 kV line (L20D): 545 MVA (post-contingency overload)
- Glenboro to Cornwallis 230 kV line (G37C): 460 MVA (post-contingency overload).
- Glenboro to Rugby 230 kV line (G82R): 484 MVA (post-contingency overload).
- Laverendrye to Letellier 230 kV line (Y51L): 454 MVA (post-contingency overload).
- Drayton 115/230 kV transformer: 253 MVA (post-contingency overload).

No voltage violations exceeding a 1% deviation threshold in the vicinity of the St. Joseph Wind farm.

5.5.1 System Intact: Post Facility Overloads

Table 5.1 is a list of new system intact overloads (or base case overloads which changed by more than 0.01 MVA) after the addition of the St. Joseph wind farm. No post facility overloads were identified for winter peak load MHEX import conditions for the 2009 scenario.

Table 5.1: System Intact Post-Facility Overloads.

Scenario	Overloaded Branch	Pre-facility Overloads		Post-facility Overloads				Comment
		MVA	% Rate A	MVA	ΔMW	% Rate A	PTDF %	
SUOP09 MHEX Export	L20D	-	-	436.63	57.30	104.08%	19.10%	Upgrade required.
	D602F	1836.13	106.01%	-	-	-	-	Base case overload result of increase in NDEX = 2080.
SUOP09 MHEX Import	G37C	284.91	101.86%	316.49	30.90	113.15%	10.30%	150 MW Rugby Wind Farm. NDEX = 2080.
		265.70	94.99%	302.01	31.83	107.98%	10.61%	Turn Rugby Wind Off. NDEX = 2080. Clear up base case overload. Upgrade Required for St. Joseph.
	G82R	337.92	100.87%	342.92	4.17	102.36%	1.39%	150 MW Rugby Wind Farm. Conductor rating of 390 MVA. Change OOS Relay setting. Occurs at NDEX = 2080.
		303.60	90.63%	306.60	3.80	91.52%	1.27%	Turn Rugby Wind Off. Clear up pre/post overloads. NDEX = 2080.
SUPK09 MHEX Export	61705 BABBITT7 to 61708 VIRGNIA7	197.57	219.52%	209.39	0.34	232.65%	0.11%	Below 3% PTDF threshold.
	61702 LASKIN 7 to 61705 BABBITT7	212.71	217.06%	224.30	0.28	228.88%	0.09%	
	63245 WILTON 7 to 63246 BEMIDJI7	-	-	125.6	5.71	104.66%	1.90%	
SUPK09 MHEX Import	G37C	355.74	127.19%	386.76	29.29	138.28%	9.76%	150 MW Rugby Wind Farm. NDEX = 2080.
		340.88	121.87%	372.11	29.92	133.04%	9.97%	Turn Rugby Wind Off. Base case overload result of NDEX = 2080
		335.4	119.91%	365.7	29.90	130.75%	9.97%	Turn Rugby Wind Off. NDEX = 1950 Without new Winnipeg to Letellier line.

Table 5.1: System Intact Post-Facility Overloads (Continued).

Scenario	Overloaded Branch	Pre-facility Overloads		Post-facility Overloads				Comment
		MVA	% Rate A	MVA	ΔMW	% Rate A	PTDF %	
SUPK09 MHEX Import	G82R	399.65	118.38%	404.99	3.83	120.89%	1.28%	150 MW Rugby Wind Farm. Conductor rating of 390 MVA Occurs at NDEX = 2080.
		359.33	107.26%	364.51	4.10	108.68%	1.37%	Turn Rugby Wind Off. Base case overload result of NDEX = 2080
		347.20	103.64%	350.00	3.50	104.47%	1.17%	Turn Rugby Wind Off. NDEX = 1950 Without new Winnipeg to Letellier line.
SUOP14 MHEX Export	L20D	460.89	109.89%	508.49	45.71	121.21%	15.24%	Upgrade required.
SUPK14 MHEX Export	63050 WILLMAR4 to 66550 GRANITF4	191.71	160.43%	194.43	2.70	162.71%	0.90%	Below 3% PTDF threshold.
	L20D	-	-	475.95	64.98	113.46%	21.66%	Upgrade required.
SUPK14 MHEX Import	63050 WILLMAR4 to 66550 GRANITF4	228.86	191.52%	231.07	1.61	193.36%	0.54%	Below 3% PTDF threshold.
	G82R	358.62	107.05%	361.59	2.73	107.94%	0.91%	150 MW Rugby Wind Farm. OOS Relay 335 MVA. Occurs at NDEX = 2080.
		324.4	96.72%	328.3	4.50	98.00%	1.50%	Turn Rugby Wind Off. Clear up pre/post overloads.
	G37C	274.40	98.11%	304.18	31.23	108.75%	10.41%	150 MW Rugby Wind Farm. Occurs at NDEX = 2080.
		262.20	93.74%	292.86	8.53	108.70%	2.84%	Turn Rugby Wind Off. Occurs at NDEX = 2080 Clear up base case overloads. Upgrade Required for St. Joseph.
WTPK14 MHEX Import	63050 WILLMAR4 to 66550 GRANITF4	176.81	147.95%	179.75	2.95	150.42%	0.98%	Below 3% PTDF threshold.
	60136 MAPLE R7 to 66754 MAPLE R4	222.62	119.05%	225.29	-0.22	120.48%	-0.07%	
	G82R	370.56	110.61%	376.45	5.00	112.37%	1.67%	150 MW Rugby Wind Farm. OOS Relay 335 MVA. Occurs at NDEX = 2080.
		320.3	95.61%	336.11	5.62	100.33%	1.87%	Turn Rugby Wind Off. Clear up pre/post overloads.

5.5.2 System Intact: Significantly Affected Facilities

Tables 5.2 to 5.6 in Appendix A , list the significantly affected facilities identified in this study. Steady state post disturbance facility loadings were recorded for thermal overloads above Rate A and that have an OTDFs greater than or equal to 2%. These results were then manually screened with the significantly impacted facilities. If a facility is impacted post contingency it is then determined if an emergency rating exists for that facility. The significantly affected facilities are in red text. These results were then manually check to determine if an emergency rating (Rate C) exists for that facility, any special protection schemes, or a manual re-simulation of the contingency to confirm results.

5.5.2.1 System Intact: Impacted USA Facilities

Impacted USA Facilities are found during MHEX export conditions.

Impacted Facilities for MHEX Export Conditions:

- DRAYTON 230/115 kV Transformer #2.

This transmission facility is overloaded following a disturbance which involves the loss of Drayton to Prairie 230 kV line. The maximum overload identified was 253 MVA. The loss of this facility is associated with a Manitoba DC reduction. The Interconnection Facilities Study will address the need to increase the level of DC reduction associated with the loss of the Drayton to Prairie 230 kV line.

5.5.2.2 System Intact: Impacted Manitoba Facilities

Impacted Manitoba Facilities can be broken down into two situations. Impacted facilities during MHEX export conditions and impacted facilities during MHEX import conditions. These facilities include both lines and stations and will need to be upgraded.

Impacted Lines for MHEX Export Conditions:

- L20D - 230kV line from Letellier to Drayton.

Line L20D overloads for disturbances which involve either the loss of one of the lines out of Letellier Station (Y51L or S60L) during export conditions. The line rating for L20D between Letellier & Drayton stations is 419 MVA in the summer. This study determined that a minimum summer rating of 545 MVA is required. The line is limited by the existing conductor, the risers and the switch at Letellier station.

The existing type of conductor, for L20D, is 954 ACSR SD T7 and sagged to 100 deg C. The entire length will need to be re-conductored with 954 ACSS (or similar) at 150 deg C design rating due to the overload condition.

The risers and switches at Letellier will also have to be changed to match the new line rating. After these changes are done, the new summer rating will be 608 MVA.

Impacted Lines for MHEX Import Conditions:

The following three lines are found to overload following any disturbance which involves the loss of one of the St. Joseph Wind farms (150MW), a loss of any line out of the Letellier station, or the loss of the 500 kV line. The impacted facilities overload during summer and winter MHEX import conditions. There is a possibility that dynamic monitoring of G37C, Y51L and G82R may negate the need to upgrade these facilities.

- G37C - 230kV line from Cornwallis to Glenboro S (MHEX Import)

The line rating for G37C between Cornwallis and Glenboro S stations is 280 MVA in the summer. This study determined that a minimum summer rating of 460 MVA is required. The line is limited by the existing conductor, the risers at Cornwallis station.

The existing type of conductor, for G37C, is 795 ACSR SD T5 and sagged to 75 deg C. It will need to be re-conductored with 795 ACSS at 150 deg C design rating due to the overload condition.

There is expected to be significant structural modification to accommodate the new conductor as this line was originally built as a 115 kV line.

The risers at Cornwallis will also have to be changed to match the new line rating. After these changes are done, the new summer rating will be 544 MVA.

Cornwallis 230 kV Station Upgrades will include G37C risers and various bus bar upgrades.

- Y51L - 230kV line from Letellier to Laverendrye (MHEX Import)

The line rating for Y51L between Letellier to Laverendrye stations is 419 MVA in the summer. This study determined that a minimum summer rating of 454 MVA is required. The line is limited by the existing conductor.

The existing type of conductor, for Y51L, is 954 ACSR SD T7 and sagged to 100 deg C. It will need to be re-conductored with 795 ACSS at 150 deg C design rating due to the overload condition.

After these changes are done, the new summer rating will be 544 MVA.

The upgrade of Y51L will not be necessary if the proposed St. Vital to Letellier 230 kV line is built. The new line to Winnipeg will mitigate overloads on this line. Temporary operating guides may be required for the interim period until this line is built. Refer to Table 5.6.

- G82R - 230kV line from Glenboro S to Rugby (MHEX Import)

The 230kV line from Glenboro S to Rugby, G82R, has been identified as being marginally impacted by the addition of the St. Joseph Wind farm. However three prior queued USA projects are found to significantly impact this line during MHEX import conditions. One is the Transmission Service Request to increase NDEX to 2080 (ISD 2009) MW the other is the addition of 300 MW wind generation to the Rugby area (two projects). The generation interconnections and the NDEX transmission increase are both found to overload G82R during MHEX import conditions. It is presently unclear which of these projects will cover the G82R upgrades. If no upgrades are made it is expected that during MHEX import conditions, NDEX will back down to 1950 MW and the Rugby wind farms will be curtailed to 0 MW.

With all three projects in-service this study identified the following upgrades for G82R. The line rating for G82R between Glenboro S & Rugby stations is 390 MVA in the summer. The Glenboro out-of-step relay is set at 335 MVA. This study determined that a minimum summer rating of 484 MVA is required. The line is limited by the existing conductor and the riser at Glenboro South station.

The existing type of conductor, for G82R, is 954 ACSR 54/7 and sagged to 100 deg C. It will need to be re-conductored with 795 ACSS at 150 deg C design rating due to the overload condition.

The Riser at Glenboro S will also have to be changed to match the new line rating. After these changes are done, the new summer rating will be 544 MVA.

The out-of-step relay at Glenboro may have to be reset.

Glenboro South 230 kV Station upgrades will include riser/ bus between R1 & R6, G82R riser and, G82R wave trap.

The St. Joseph Wind Developer will not be responsible for G82R upgrades.

5.6 New Winnipeg to Letellier 230 kV Line Sensitivity (2014)

In the event that the proposed Winnipeg to Letellier 230 kV is not built, a sensitivity was included to determine the impact without this line.

If the Winnipeg to Letellier 230 kV line is not built, the generator can not receive firm transmission service for the full 300 MW wind farm output whenever MHEX is importing. Before firm service can be granted the Letellier to Laverendrye 230 kV line, Y51L must be upgraded as identified in Section 5.5

Table 5.6: Post Contingency: Impact of the St. Vital to Letellier 230 kV Line.

Scenario	Impacted Branch	Existing System		St. Vital to Letellier 230 kV Line	
		Overload %	DF %	Overload %	DF %
SUOP MHEX Export	L20D	114.76	33.11	106.20	31.87
	DONALDSON to DRAYTON	109.09	6.39	108.72	4.21
SUPK MHEX Export	L20D	108.15	33.21	101.94	32.52
	DONALDSON to DRAYTON	109.31	6.50	108.67	4.73
SUPK MHEX Import	G37C	131.34	23.84	111.73	12.78
	Y51L	**108.40**	**61.54**	**58.00**	**76.76**
WTPK MHEX Import	FORBES to BLACKBERRY	114.60	6.41	113.63	4.59

5.7 Rugby Wind Farm Sensitivity

There are two prior queued wind interconnection requests in the Rugby area, both for 150 MW each (300 MW total) and both requesting firm transmission service. These are MISO projects G380 and G904. As firm transmission service was not granted at the time of this study, this study assumed that only one of these projects would most likely receive firm transmission service. This assumption must be verified for the Interconnection Facilities Study (IFS).

This Interconnection Evaluation Study included a system intact sensitivity analysis with and without 150 MW of firm generation injection at Rugby for the firm year round Manitoba Hydro TSR of MHEX = 700 MW north. It was assumed that the most stressed conditions occur when NDEX = 2080 MW for summer peak and off-peak load conditions. The sink for the 150 MW Rugby wind was to North Dakota load located within the NDEX boundary. Under these conditions it was identified that 150 MW of generation injected at Rugby (without the St. Joseph Wind Farm) causes system intact overloads on the 230 kV lines G82R and G37C with approximate PTDF's of 20% and 9% respectively (Appendex B). Table 5.7 compares the PTDF's of these lines for each project.

Table 5.7: Comparison of the System Intact PTDF's for G82R and G37C for G380/G904 and St. Joseph Wind Projects.

Impacted Facility	150 MW Rugby & 0 MW St. Joseph	0 MW Rugby & 300 MW St. Joseph	150 MW Rugby & 300 MW St. Joseph
G82R	20%	1%	1%
G37C	9%	11%	10%

Based on the transmission service request queue dates Table 5.8, Manitoba Hydro is responsible for upgrading G37C .

Table 5.8: TSR Queue Dates:

Project	TSR Queue Date	Firm TSR (MW)
St. Joseph Wind	December 14, 2007	300
G904	Not submitted.	150
G380	January 26, 2009	40

It should be noted that the increase in NDEX from 1950 to 2080 is also found to overload G82R and G37C when MHEX is importing. It is not clear whether or not the increase of NDEX to 2080 includes MHEX import conditions.

5.8 Langdon Wind Farm Sensitivity

In the Minnkota Power Cooperative Generator Interconnection Queue there are three prior queued projects, GM0100 (September 11 2006), GM0200 (November 13 2006), and GM00300 (July 31, 2007) for 99 MW, 60 MW and 40.5 MW respectively (total 199.5 MW). This wind farm is located on the Langdon – Hensel 115 kV line which is part of the Drayton 115 kV network. Only 46 MW of the total 199.5 MW has firm transmission service. This wind farm is currently in-service.

To determine the impact of both the St. Joseph Wind Farm and Langdon Wind Farm on local loading in the Drayton area this evaluation study included a sensitivity analysis with the Langdon Wind Farm at its non-firm output of 199.5 MW. The following observations are made Tables 5.9 and 5.10 in Appendix C:

- The out-year case (2014) is the worst for local Drayton area overloads.
- Flows on L20D are reduced when Landon Wind is at 199.5 MW.
- Following a contingency which includes the loss of the Drayton to Prairie 230 kV line, the Drayton to Donaldson 115 kV and the Donaldson to Warsaw 115 kV lines overload up to 120.07% and 124.28% of Rate A with OTDF's of up to 5.26% and 3.38% respectively.

It is not in Manitoba Hydro's Tariff to upgrade facilities to protect non-firm transmission service. The DC reduction settings for the Drayton to Prairie 230 kV line will need to be increased to protect the Drayton 230/115 kV transformers for the 46 MW of firm service as identified in Section 5.5. Manitoba Hydro recognizes that this increase in DC reduction may also fix the post contingency overloads on the Drayton to Donaldson 115 kV and the Donaldson to Warsaw 115 kV lines. Manitoba Hydro will work with Minnkota Power Cooperative to identify a reasonable solution.

6. Transient Stability Analysis

The impact of the proposed St. Joseph wind farm generation and transmission additions on the transient performance of the transmission system was studied. This included two types of analysis. The first involved an examination of the turbine capabilities in comparison with Manitoba Hydro Interconnection Criteria. The second involved transient simulation in which voltage profiles and system damping were reviewed to ensure that the transmission system will function within transient criteria following a transient event on the system.

6.1 Turbine Capabilities

This section describes the turbine frequency, voltage and reactive power capabilities in comparison with the MH interconnection requirements. The next section will demonstrate these capabilities through transient stability simulations.

6.1.1 Turbine Over-frequency / Under-frequency Ride-Through Capability

Section 3.7 of MH Transmission System Interconnection Requirements document [1] states that a typical generator connected to the MH network should stay connected if the frequency remains within the limits given in Table 6.1.

Table 6.1: MH Frequency Ride-Through Requirements.

Time	Under-frequency	Over-frequency
Continuous	59.0-60.0 Hz	60.0-61.5 Hz
10 minutes	59.0-58.7 Hz	61.5-62.0 Hz
30 seconds	58.7-57.5 Hz	62.0-63.5 Hz

The DFIG turbine frequency protection based ride-through capability is summarized in Table 6.2. and 6.3.

Table 6.2: DFIG Turbine A Frequency Ride-Through Protection Based Capability.

Time	Under-frequency	Over-frequency
Continuous	59.0-60.0 Hz	60.0-61.0 Hz
0.30 seconds	50.0-59.0 Hz	61.0-70.0 Hz

Table 6.3: DFIG Turbine B Frequency Ride-Through Protection Based Capability.

Time	Under-frequency	Over-frequency
Continuous	57.5-60.0 Hz	60.0-61.5 Hz
30 seconds	-	61.5-62.5 Hz
10 seconds	56.5-57.5 Hz	-

With the current protection settings, Turbine A does not have adequate under-frequency ride-through capability. In Manitoba frequency may drop below 57.5 Hz or rise above 63.5 Hz following a major disturbance that results in the Manitoba system from being separated from the North American Grid. Turbine B does not have adequate over-frequency ride-through capability.

6.1.2 Turbine Over-voltage / Under-voltage Ride-Through Capability

Table 6.4 summarizes Manitoba Hydro's dynamic voltage tolerance criteria for a wind turbine at a 230 kV Point of Interconnection following a local or remote disturbance. The worst system overvoltage cases typically occur when large amounts of power from the HVdc system are lost (e.g. trip of Manitoba-USA 500 kV line followed by an HVdc reduction, or a permanent or temporary block of a bipole). Note that a generator must remain connected for a switching surge (voltages >1.30 pu for a duration of 33 milliseconds).

Table 6.4: MH Over- and Under-voltage Requirements at the Point of Interconnection.

Over-Voltage		Under-Voltage	
Duration	**Voltage (pu)**	**Duration**	**Voltage (pu)**
Continuous	1.00 to 1.10	Continuous	0.90 to 1.00
2 sec.	1.10 to 1.30	2 sec.	0.70 to 0.90
200 ms.	1.30	500 ms.	0.70
33 ms.	> 1.30	250 ms.	0.00 to 0.50
		100 ms.	0.00

Figure 6.1 below graphically represents the MH voltage criteria.

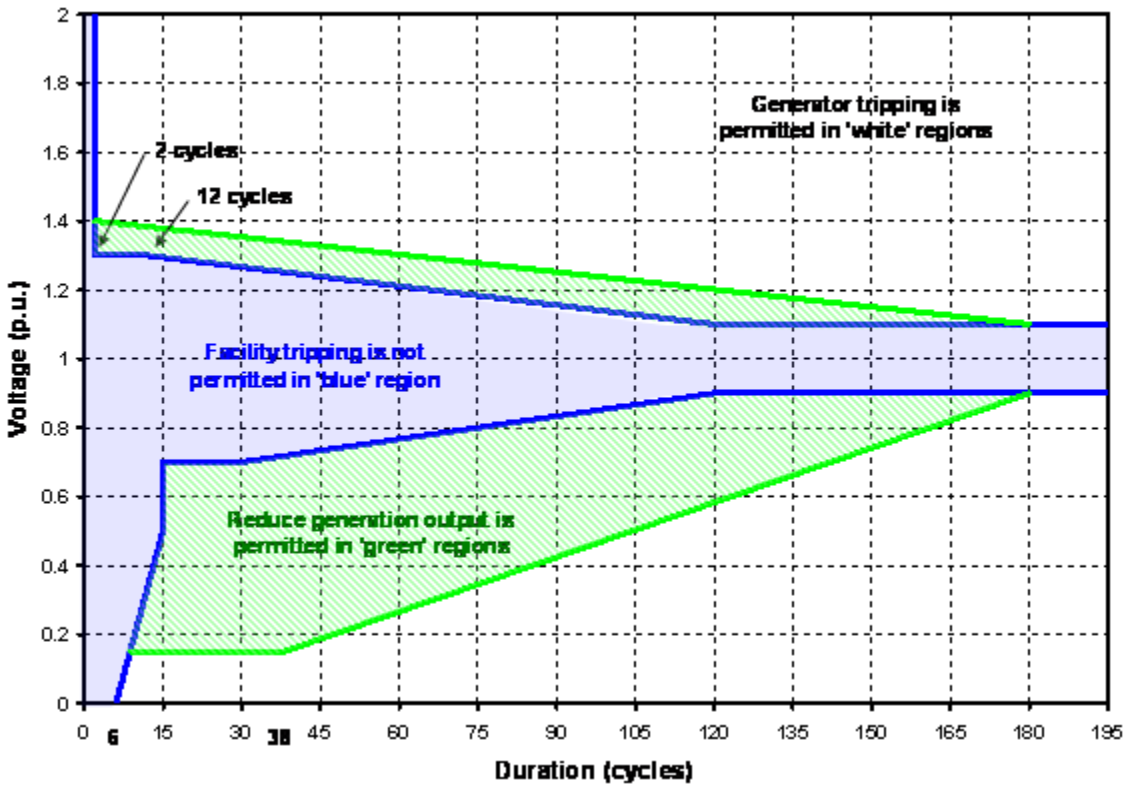


Fig. 6.1. Manitoba Hydro Voltage variation criteria at a 230 kV bus.

The generator voltage protection settings for the DFIG wind turbines used in this study are given in Table 6.5 and 6.6 below

Table 6.5: Turbine A Voltage Protection Settings.

Over-Voltage		Under-Voltage	
Duration	**Voltage (pu)**	**Duration**	**Voltage (pu)**
continuous	1.00 to 1.20	continuous	0.90 to 1.00
150 ms.	> 1.20	3.0 sec.	0.85 to 0.90
		2.842	0.75 to 0.85
		2.525	0.65 to 0.75
		2.208	0.55 to 0.65
		1.892	0.45 to 0.55
		1.575	0.35 to 0.45
		1.258	0.25 to 0.35
		0.942	0.20 to 0.25
		783 ms.	0.025 to 0.20
		150 ms.	< 0.025

Table 6.6: Turbine B Voltage Protection Settings.

Over-Voltage		Under-Voltage	
Duration	**Voltage (pu)**	**Duration**	**Voltage (pu)**
continuous	1.00 to 1.10	continuous	0.75 to 1.00
1.0 sec.	1.10 to 1.15	1.9 sec.	0.50 to 0.75
0.1 sec.	1.15 to 1.30	1.2 sec.	0.30 to 0.50
0.02 sec.	> 1.30	0.7 sec.	0.15 to 0.30

Based on the protection settings, neither turbine appears meet Manitoba Hydro's voltage criteria. Transient simulations for critical disturbances were conducted to determine how the turbine performance is reflected at the point of interconnection. Preliminary transient stability analysis confirms, for line-to-ground and three-phase-to-ground faults, the under-voltage ride-through capability of both turbines meet Manitoba Hydro's under-voltage criteria at the point of interconnection. Full testing of the wind facility over-voltage tolerance has not been completed. Initial studies indicate that for one of the turbine types the turbine control mode following line-to-ground or three-phase-to-ground faults which are 'near' to the POI, result in a high voltage 'spike' immediately after the fault clears. While this high voltage spike is not found to impact transient stability and quickly decays to within normal transient voltage criteria, control settings should be reviewed and modified to minimize this voltage spike as there is a possibility that the turbine itself may trigger its own over-voltage protection and trip off. Figure 6.2 below illustrates and example of this unacceptable operation.

6.1.3 Reactive Power Requirements

The Manitoba Hydro Transmission System Interconnection Requirements document [1] states that any Generation Facility greater than 10 MW comprised of induction type generators (such as may be connected to wind turbines) must be able to provide reactive support that is able of controlling the voltage level by adjusting the machine's power factor between a minimum of 0.95 over-excited and 0.95 under-excited when the generator is generating name plate capacity measured at the Point of Interconnection. The power factor requirements could be larger depending on transient stability analysis.

The DFIG wind turbines used in this study have inherent fast reactive power control capability. According to the manufacturers specifications the reactive power ranges from 0.95 over-excited to 0.9 under-excited for the turbine used in this study. This corresponds to +98.75 MVar to -145.00 MVar for the composite St Joseph wind farm, and under the assumption that the reactive power requirements of the wind farm collector system will be supplied through other reactive power sources, the turbines meet the minimum Manitoba Hydro reactive power requirements. Transient simulation will verify if there are any additional reactive power requirements at the Point of Interconnection.

6.2 Transient Simulation

This section describes the transient simulation results.

The transient simulation analysis was not completed for this study, as unacceptable transient behaviour was identified following a SLG Fault with breaker fail. This is described in more detail below.

6.2.1 Study Stability Models

A total of sixteen base case system models were in the transient stability analysis. These include cases 1 to 8 and 11 to 18 listed in Table 1. These encompass the 2009 and 2014 years at peak and off-peak loading conditions for both MHEX import and export conditions. Two levels of NDEX was studied for each scenario.

6.2.2 Disturbances

The following NERC category B (single component) and C (multiple components) disturbances were tested to determine the impact of the St. Joseph generator on the transient performance of the transmission system:

1. System intact, 3-phase normal clearing faults at Letellier on L20D, Glenboro on G82R, Richer on R50M, Forbes on D602F, Dorsey on D602F, Dorsey on D602M (2014), and Riel on (M602F).

2. System intact, single line-to-ground stuck breaker (slow clearing) faults including SLG with breaker fail at Letellier on L20D cleared by tripping Y51L, SLG with breaker fail at Letellier on L20D cleared by tripping Bank 4, SLG with breaker fail at

Letellier on Y51L cleared by tripping L20D, SLG with breaker fail at Letellier on Y51L cleared by tripping Bank 3, SLG with breaker fail at Letellier on S60L cleared by tripping Bank 3, SLG with breaker fail at Letellier on Bank 3 cleared by tripping L20D, SLG with breaker fail at Letellier on Bank 3 cleared by tripping Y51L, and SLG with breaker fail at Letellier on Bank 4 cleared by tripping S60L

6.2.3 Transient Stability Results

Unacceptable wind farm behaviour was identified for one of the turbine types examined in this study. The unacceptable behaviour occurred following a SLG fault with breaker fail at Letellier on Y51L with the fault clearing by tripping L20D. After the fault has cleared and the 230 kV system voltage has recovered above 0.95 p.u., the turbine control mode switches and results in a reduction in the turbine MVar output. This leads to a drop in both the turbine terminal voltage and Letellier bus initiating further control mode switching. The net result is an indefinite oscillation of wind farm MW output as illustrated in the Figure 6.2 below.

It should be noted that post disturbance voltage criteria permits a low voltage of 0.90 p.u. for up to thirty minutes.

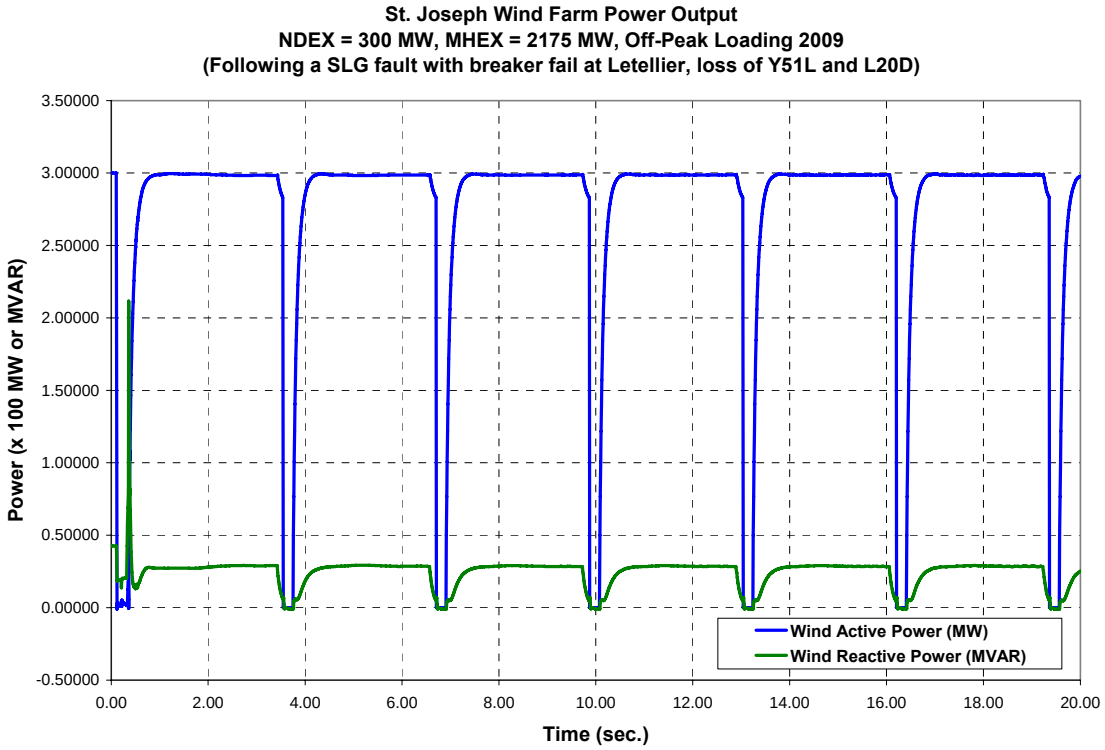


Fig. 6.2. Unacceptable Wind Farm Behaviour.

Manitoba Hydro requires that the generator provide voltage control at the Point of Interconnection. The Solicitor has been informed of this unacceptable transient performance and is working with the potential wind developer to correct this problem. A full transient analysis with the proposed solution will be conducted in the facilities stage if the Solicitor chooses to move forward.

7. Planning Level Cost Estimate

Transmission facility costs to connect the St. Joseph wind farm to the Manitoba Hydro system are calculated for planning purposes.

High level planning cost estimates were requested for each of the scenarios in this study using interconnection upgrades identified in the 300 MW Exploratory Study [5], [6]. For upgrades which did not receive a high level planning estimate, the following preliminary (+/-50%) unit cost estimates are used to determine the cost estimate:

1. Riser replacement: $100,000/site
2. Current Transformer(CT) replacement: $200,000/site

Two options were considered first, a single 230 kV interconnection to the Letellier Station and secondly, two 230 kV interconnections to the Letellier Station. A breakdown of planning level cost estimates for the Interconnection Facilities, Interconnection System Upgrades, and Network Upgrades is provided in Tables 7.1 to 7.4.

For Network Resource Interconnection Service, the total cost estimate including Transmission Owner Interconnection Facilities, Interconnection System Upgrades, and Network System Upgrades that are required to interconnect the St. Joseph wind farm to the Manitoba Hydro system is Option 1: $19.2 million (+/-50%) and Option 2: $24.0 million (+/-50%).

For Energy Resource Interconnection Service, the total cost estimate including Transmission Owner Interconnection Facilities and Interconnection System Upgrades, that are required to interconnect the St. Joseph wind farm to the Manitoba Hydro system is Option 3: $4.8 million (+/-50%) and Option 4: $9.6 million (+/-50%).

Table 7.1: Option 1: Network Resource Interconnection Service: Single 300 MW Interconnection

	Facility	Equipment Upgrade	Cost $ (millions)
Transmission Owner Interconnection Facilities	230 kV line from St. Joseph wind to Letellier Station	7.75 km new transmission line 954 MCM ACSR @ 100 C conductor (minimum 419 MVA summer)	1.9
	Letellier 230 kV Station	1 - 230 kV breaker, 3 CT's, 2 Disconnects, 4 CVT's, protection, communications, structures and others required to interconnect St. Joseph Wind.	2.6
Interconnection System Upgrades	Letellier 230 kV Station	Upgrade station to minimum 1500 Amps Risers, switches, CT's	0.3
Network System Upgrades	L20D	Re-conductor 64 km to 954 ACSS @ 150 C conductor (minimum 540 MVA summer)	7.2
	G37C	Re-conductor 64 km to 795 ACSS @ 150 C conductor Significant structural modifications (minimum 460 MVA summer)	7.1
	Y51L	Re-conductor 80 km to 795 ACSS @ 150 C conductor (minimum 460 MVA summer)	Operating Guide until new Winnipeg to Letellier 230 kV line
	Cornwalllis 230 kV Station	Upgrade station to minimum 1200 Amps G37C risers, and various bus bar	0.1
Total Cost			19.2 (+/-50%)

Table 7.2: Option 2: Network Resource Interconnection Service: Two 150 MW Interconnections

	Facility	Equipment Upgrade	Cost $ (millions)
Transmission Owner Interconnection Facilities	230 kV line from St. Joseph wind to Letellier Station	2 x 7.75 km new transmission line 954 MCM ACSR @ 100 C conductor (minimum 419 MVA summer)	3.8
	Letellier 230 kV Station	2 - 230 kV breakers, 6 CT's, 4 Disconnects, 8 CVT's, protection, communications, structures and others required to interconnect St. Joseph Wind.	5.5
Interconnection System Upgrades	Letellier 230 kV Station	Upgrade station to minimum 1500 Amps Risers, switches, CT's	0.3
Network System Upgrades	L20D	Re-conductor 64 km to 954 ACSS @ 150 C conductor (minimum 540 MVA summer)	7.2
	G37C	Re-conductor 64 km to 795 ACSS @ 150 C conductor Significant structural modifications (minimum 460 MVA summer)	7.1
	Y51L	Re-conductor 80 km to 795 ACSS @ 150 C conductor (minimum 460 MVA summer)	Operating Guide until new Winnipeg to Letellier 230 kV line
	Cornwalllis 230 kV Station	Upgrade station to minimum 1200 Amps G37C risers, and various bus bar	0.1
Total Cost			24.0 (+/-50%)

Table 7.3: Option 3: Energy Resource Interconnection Service: Single 300 MW Interconnection

	Facility	Equipment Upgrade	Cost $ (millions)
Transmission Owner Interconnection Facilities	230 kV line from St. Joseph wind to Letellier Station	7.75 km new transmission line 954 MCM ACSR @ 100 C conductor (minimum 419 MVA summer)	1.9
	Letellier 230 kV Station	1 - 230 kV breaker, 3 CT's, 2 Disconnects, 4 CVT's, protection, communications and others required to interconnect St. Joseph Wind.	2.6
Interconnection System Upgrades	Letellier 230 kV Station	Upgrade station to minimum 1500 Amps Risers, switches, CT's	0.3
Total Cost			4.8 (+/-50%)

Table 7.4: Option 4: Energy Resource Interconnection Service: Two 150 MW Interconnections

	Facility	Equipment Upgrade	Cost $ (millions)
Transmission Owner Interconnection Facilities	230 kV line from St. Joseph wind to Letellier Station	2 x 7.75 km new transmission line 954 MCM ACSR @ 100 C conductor (minimum 419 MVA summer)	3.8
	Letellier 230 kV Station	2 - 230 kV breakers, 6 CT's, 4 Disconnects, 8 CVT's, protection, communications and others required to interconnect St. Joseph Wind.	5.5
Interconnection System Upgrades	Letellier 230 kV Station	Upgrade station to minimum 1500 Amps Risers, switches, CT's	0.3
Total Cost			9.6 (+/-50%)

8. References

[1] Manitoba Hydro Transmission System Interconnection Requirements, Revision 0, December 2003, http://www.hydro.mb.ca/business_customer/tariffsummary.shtml.

[2] MHEB 300 MW Wind Exploratory Study, http://oasis.midwestiso.org/documents/Mheb/Exploratory_Study_Report-final.pdf

[3] MAPP Design Review Subcommittee Policies and Procedures, June 2007.

[4] MAPP Members Reliability Criteria and Study Procedures Manual, February 2008.

[5] Memo from Chuck Steele to Ron Mazur dated 2008 04 10: Wind RFP – Various Locations.

[6] Email from Ray Jakilazek to Steve Shelemy dated 2008 03 27: Wind Farm Estimates. With attached excel spreadsheets: *"Letellier – St. Joseph WF.xls"* and *"Letellier – St. Joseph,Dominion City & Rosenfeld WF.xls"*

Appendix A

Steady State Post-Contingency Tables

Table 5.2: Post Contingency: Significantly Affected Facilities Category B (2009).

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
SUOP09 MHEX Export	L20D	419.50	110.27%	462.58	62.93	20.98%	(S53G) Re-conductor Line.
			111.42%	467.41	59.64	19.88	(TRIP CENTRE GEN 66748)
	D602F	1732.10	103.34%	1789.95	19.09	6.36%	Y51L Emergency = 1905.3 MVA
	63255 DONALDS7 to 66705 DRAYTON7	180.00	108.88%	195.98	19.43	6.48%	(DRAYTON to PRAIRIE 230). Emergency = 200 MVA
SUOP09 MHEX Import	**G37C**	**279.70**	**139.15%**	**389.20**	**62.38**	**20.79%**	**(Y51L) 150 MW Rugby wind. NDEX = 2080**
			133.23%	**372.64**	**62.40**	**20.80**	**(Y51L) Rugby wind off. NDEX = 2080**
	Y51L	**419.50**	**101.10%**	**424.11**	**184.32**	**61.44%**	**(G37C) (Disappears with Rugby wind off).**
	G82R	**335.00**	**108.88%**	**364.75**	**24.92**	**8.31%**	**(ST. JOSEPH WIND) 150 MW Rugby wind. NDEX = 2080 Emergency = 429.4 MVA**
			98.90%	**331.6**	**25.2**	**8.40%**	**(ST. JOSEPH WIND) Rugby wind off. NDEX = 2080**
	61627 SHANNON4 to 66753 RUNNING4	370.00	101.96%	377.25	18.39	6.13	(D602F) Emergency = 407 MVA NDEX = 0.
SUPK09 MHEX Export	L20D	419.50	101.80%	427.05	58.41	19.45%	(TRIP CENTRE GEN 66748) Emergency = 460.5 MVA
			104.65%	439.02	56.80	18.93	(RAMSEY to BALTA 230) Emergency = 460.5 MVA
	63245 WILTON 7 to 63246 BEMIDJI7	120.00	142.43%	170.92	7.30	2.43%	(HUBBARD to AUDUBON) Emergency = 132 MVA
	63246 BEMIDJI7 to 66710 NARY 7	120.00	109.02%	130.83	7.32	2.44%	(HUBBARD to AUDUBON) Emergency = 132 MVA

Table 5.2: Post Contingency: Significantly Affected Facilities Category B (2009) Continued.

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
SUPK09 MHEX Import	**Y51L**	**419.50**	**100.14%**	**420.10**	**226.81**	**75.60%**	**(S60L) 150 MW Rugby Wind. NDEX = 2080**
			101.30%	**424.95**	**224.68**	**74.89%**	**(S60L) Rugby Wind off. NDEX = 2080**
			108.40%	**454.73**	**184.68**	**61.54%**	**(G37C) 150 MW Rugby Wind. NDEX = 2080 (Disappears for Rugby wind off).**
	G37C	**279.70**	**164.71%**	**460.70**	**72.13**	**24.04%**	**(Y51L) 150 MW Rugby Wind. NDEX = 2080**
			158.47%	**443.24**	**60.42**	**20.14%**	**(Y51L) Rugby wind off. NDEX = 2080**
			144.85%	**405.15**	**47.93**	**15.89%**	**(D14S) Rugby wind off (Changes critical Disturbance) NDEX = 2080**
	G82R	**335.00**	**127.03%**	**425.54**	**22.27**	**7.42%**	**(ST. JOSEPH WIND) 150 MW Rugby wind. NDEX = 2080. Emergency = 429.4 MVA**
			113.15%	**379.05**	**18.53**	**6.18%**	**(ST. JOSEPH WIND) Rugby wind off. NDEX = 2080.**
	34006 LAKEFLD3 to 60331 LKFLDXL3	568.00	104.88%	595.72	47.80	15.93%	(ST. JOSEPH WIND) Emergency = 625 MVA
	63245 WILTON 7 to 63246 BEMIDJI7	120.00	116.82%	140.18	8.33	2.78%	(HUBBARD to AUDUBON) Emergency = 132 MVA Below 5% OTDF threshold.

Table 5.2: Post Contingency: Significantly Affected Facilities Category B (2009) Continued.

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
WTPK09 MHEX Import	Leland Olds Transformer 1	500.00	100.30%	501.50	25.33	8.44%	(ST. JOSEPH WIND) Emergency = 600 MVA
	Leland Olds Transformer 2	250.00	105.73%	264.32	13.36	4.45%	(ST. JOSEPH WIND) Emergency = 300 MVA
	G82R	**335.00**	**132.83%**	**444.98**	**21.20**	**7.07%**	**(ST. JOSEPH WIND) 150 MW Rugby wind. NDEX = 2080. Emergency = 479 MVA**
			117.94%	**395.10**	**12.00**	**4.00%**	**(ST. JOSEPH WIND) Rugby wind off. NDEX = 2080.**
			144.43%	**483.86**	**30.96**	**10.32%**	**(D602F) 150 MW Rugby wind. NDEX = 2080.**
			127.76%	**428.0**	**3.80**	**1.27%**	**(D602F) Rugby wind off. NDEX = 2080.**
	G37C	**414.30**	**107.00%**	**443.30**	**66.09**	**22.03%**	**(Y51L) 150 MW Rugby wind. NDEX = 2080**
			103.08%	**427.06**	**63.72**	**21.24%**	**(Y51L) Rugby wind off. NDEX = 2080**
	61627 SHANNON4 to 66753 RUNNING4	477.00	85.7%	408.82	24.63	8.21%	(D602F) Emergency = 525 MVA NDEX = 0
	63245 WILTON 7 to 63246 BEMIDJI7	120.00	112.68%	135.22	7.93	2.64%	(HUBBARD to AUDUBON) Emergency = 202.7 MVA

Table 5.3: Post Contingency: Significantly Affected Facilities Category C (2009).

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
SUOP09 MHEX Export	D602F	1732.10	103.47%	1792.20	20.65	6.88%	(BRK FAIL Y51L & BNK 2) Emergency = 1905.3 MVA
	L20D	419.50	105.00%	440.48	91.27	30.42%	(BRK FAIL S60L & S53G) Emergency = 460.5 MVA
	Drayton Transformer 2	187.00	120.19%	224.75	26.96	8.99%	(BRK FAIL DRAYTON to PRAIRIE & DRAYTON BNK 1) Emergency = 251 MVA
SUOP09 MHEX Import	**Y51L**	**419.5**	**103.65%**	**434.80**	**223.75**	**74.58%**	**(BRK FAIL D14S & S53G) 150 MW Rugby wind. NDEX = 2080.**
			104.38%	**437.87**	**226.22**	**75.41%**	**(BRK FAIL D14S & S53G) Rugby wind off. NDEX = 2080.**
	G37C	**279.20**	**139.59%**	**390.44**	**96.06**	**32.02%**	**(BRK FAIL L20D & Y51L) 150 MW Rugby wind. NDEX = 2080.**
			132.76%	**371.06**	**96.63**	**32.21%**	**(BRK FAIL L20D & Y51L) Rugby wind off. NDEX = 2080.**
	G82R	**335.00**	**105.29%**	**352.72**	**18.36**	**6.12%**	**(BRK FAIL S60L & ST. JOSEPH WIND) 150 MW Rugby Wind NDEX = 2080 Emergency = 429.4 MVA (Disappears for Rugby off).**

Table 5.3: Post Contingency: Significantly Affected Facilities Category C (2009) Continued.

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
SUPK09 MHEX Export	L20D	419.50	103.23%	433.05	58.63	19.54%	(TIOGA to LOGAN) Emergency = 460.5 MVA
	Drayton Transformer 2	187.00	113.36%	211.98	23.74	7.91%	(BRK FAIL DRAYTON to PRAIRIE & DRAYTON BNK 1) Emergency = 251 MVA
	63245 WILTON 7 to 63246 BEMIDJI7	120.00	104.81%	125.77	13.73	4.58%	(BRK FAIL Y51L & BNK 2) Emergency = 157.2 MVA
	63246 BEMIDJI7 to 66710 NARY 7	120.00	110.44%	132.52	7.23	2.41%	(HUBBARD to AUDUBON) Emergency = 132 MVA Below 5% OTDF threshold.
SUPK09 MHEX Import	**Y51L**	**419.50**	**106.26%**	**445.76**	**228.78**	**76.26%**	**(BRK FAIL D145S & S53G) 150 MW Rugby Wind NDEX = 2080**
			106.69%	**447.56**	**226.78**	**75.59%**	**(BRK FAIL D145S & S53G) Rugby Wind off. NDEX = 2080**
	G37C	**279.70**	**159.91%**	**447.27**	**104.03**	**34.68%**	**(BRK FAIL L20D & Y51L) 150 MW Rugby Wind NDEX = 2080**
			152.60%	**426.82**	**106.18**	**35.39%**	**(BRK FAIL L20D & Y51L) Rugby Wind off. NDEX = 2080**
	G82R	**335.00**	**108.66%**	**364.01**	**22.25**	**7.42%**	**(BRK FAILS60L & St. Joseph) 150 MW Rugby Wind NDEX = 2080 Emergency = 429.4 MVA**
			113.59%	**308.52**	**19.53**	**6.51%**	**(BRK FAILS60L & St. Joseph) Rugby Wind off NDEX = 2080**
	34006 LAKEFLD3 to 60331 LKFLDXL3	568.00	103.62%	588.56	45.83	15.28%	(BRK FAIL S60L & ST. JOSEPH WIND) Emergency = 625 MVA

Table 5.3: Post Contingency: Significantly Affected Facilities Category C (2009) Continued.

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
SUPK09 MHEX Import	63245 WILTON 7 to 63246 BEMIDJI7	120.00	118.41%	142.09	8.20	2.73%	(HUBBARD to AUDUBON) Emergency = 157.2 MVA
	61784 INTPHAS7 to 82365 FT FRANC 1	162.00	104.18%	168.77	89.68	29.89%	(FORBES MULTI-CIRCUIT) Emergency = 190 MVA
	Leland Olds Transformer 2	500.0	105.79%	528.95	11.06	3.69%	(FORBES MULTI-CIRCUIT) Emergency = 600 MVA
WTPK09 MHEX Import	**G37C**	**414.30**	**103.85%**	**430.25**	**114.68**	**38.23**	**(BRK FAIL L20D & Y51L) 150 MW Rugby Wind NDEX = 2080**
			103.19%	**427.52**	**63.80**	**21.27%**	**(BRK FAIL L20D & Y51L) Rugby Wind off NDEX = 2080**
	G82R	**335.00**	**131.60%**	**440.85**	**21.38**	**7.13%**	**(BRK FAIL S60L & ST. JOSEPH WIND.) 150 MW Rugby Wind NDEX = 2080 Emergency = 429.4 MVA (Disappears for Rugby off).**
	63041COAL CR4 to 63049 STANTON4	478.00	105.47%	504.15	6.18	2.06%	(DICKINSON MULTI-CKT) Emergency = 473.3 MVA
	Leland Olds Transformer 1	250.00	104.10%	260.25	11.02	3.67%	(BRK FAIL S60L & ST. JOSEPH WIND) Emergency = 300 MVA
	63049 STANTON4 to 67106 LELANDO4	478.00	137.18%	655.72	6.37	2.12%	(DICKINSON MULTI-CKT) Emergency = 438.2 MVA
	63245 WILTON 7 to 63246 BEMIDJI7	120.00	114.77%	137.72	7.79	2.60%	(HUBBARD to AUDUBON) Emergency = 202.7 MVA

Table 5.4: Post Contingency: Significantly Affected Facilities Category B (2014).

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
SUOP14 MHEX Export	L20D	419.50	106.20%	445.51	95.61	31.87%	(Y51L) Emergency = 460.5 MVA
			129.84%	544.69	46.89	15.63%	(TRIP CENTRE GEN 66748)
	66752 DRAYTON4 to 66755 PRAIRIE4	389.00	109.49%	425.92	34.15	11.38%	(DONALDS to DRAYTON) Emergency = 428 MVA
	DRAYTON XFORMER 1	140.00	105.26%	147.36	10.77	3.59%	(DRAYTON XFORMER 2) Emergency = 161 MVA
	63255 DONALDS7 to 66705 DRAYTON7	198.00	108.72%	215.26	12.63	4.21%	(DRAYTON to PRAIRIE) Emergency = 200 MVA Below 5% OTDF threshold.
	63255 DONALDS7 to 66714 WARSAW 7	100.00	110.56%	110.56	7.77	2.59%	(DRAYTON to PRAIRIE) Emergency = 110 MVA Below 5% OTDF threshold.
SUPK14 MHEX Export	L20D	419.50	101.94%	427.64	97.57	32.52%	(Y51L) Emergency = 460.5 MVA
			125.10%	524.79	45.88	15.29%	(BALTA to RAMSEY 230)
	66752 DRAYTON4 to 66755 PRAIRIE4	389.00	103.49%	402.58	34.26	11.42%	(DONALDS to DRAYTON) Emergency = 428 MVA
	DRAYTON XFORMER 1	140.00	108.53%	151.94	10.94	3.65%	(DRAYTON XFORMER 2) Emergency = 161 MVA
	60203 COON CK7 to 62090 PRKWOOD7	315.5	116.49%	367.53	8.52	2.84%	(COON CK to WCNRAPD) Emergency =347.1 MVA
	63255 DONALDS7 to 66705 DRAYTON7	198.00	108.67%	215.16	14.18	4.73%	(DRAYTON to PRAIRIE) Emergency = 200 MVA Below 5% OTDF threshold.
	63255 DONALDS7 to 66714 WARSAW 7	100.00	105.68%	105.68	8.88	2.96%	(DRAYTON to PRAIRIE) Emergency = 110 MVA
	61676 HIBBARD7 to 61680 WNTR ST7	182.00	101.19%	184.17	23.26	7.75%	(ARROWHD to GARY) Emergency = 200 MVA

Table 5.4: Post Contingency: Significantly Affected Facilities Category B (2014) Continued.

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
SUPK14 MHEX Export	67307 BISM NW7 to 67343 HESKETT7	119.50	107.80%	128.82	7.64	2.55%	(MANDANS to MANDANW) Emergency = 148.4 MVA
SUPK14 MHEX Import	**G37C**	**279.70**	**111.73%**	**312.51**	**38.34**	**12.78%**	**(Y51L) NDEX = 2080. 150 MW Rugby Wind.**
			125.86%	**352.28**	**68.60**	**22.87%**	**(Y51L) NDEX = 2080. Rugby wind off.**
	G82R	**335.00**	**113.56%**	**380.43**	**19.96**	**6.65%**	**(ST. JOSEPH WIND) NDEX = 2080 150 MW Rugby Wind. Emergency = 429.5 MVA**
			102.61%	**343.74**	**18.90**	**6.30%**	**(ST. JOSEPH WIND) NDEX = 2080 Rugby wind off. Emergency = 429.5 MVA**
	LELAND OLDS XFORMER 1	250.00	157.13%	392.83	14.66	4.89%	(LELAND OLDS XFORM 2) Emergency = 300 MVA Below 5% OTDF threshold.
	66442 GARRISN7 to 67308 BEULAH 7	120.00	111.27%	133.52	9.40	3.13%	(CENTER to COYOTE 345) Emergency = 132 MVA Below 5% OTDF threshold.
	60302 COULEE 5 to 69523 GENOA 5	240.00	108.94%	261.46	7.18	2.39%	(ST. JOSEPH WIND) Emergency = 264 MVA
WTPK14 MHEX Import	**G82R**	**335.00**	**118.68%**	**397.58**	**23.25**	**7.75%**	**(ST. JOSEPH WIND) 150 MW Rugby Wind. Emergency = 429.5 MVA NDEX = 2080**
			104.20%	**349.07**	**18.24**	**6.08%**	**(ST. JOSEPH WIND) Rugby wind off. Emergency = 429.5 MVA NDEX = 2080**
			139.02%	**465.72**	**9.28**	**3.09%**	**(M602F) NDEX = 2080 150 MW Rugby Wind.**
			115.35%	**386.42**	**8.97**	**2.99%**	**(M602F) NDEX = 2080 Rugby wind off.**

Table 5.4: Post Contingency: Significantly Affected Facilities Category B (2014) Continued.

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
WTPK14 MHEX Import	61627 SHANNON4 to 66753 RUNNING4	477.00	94.48%	450.68	16.17	5.39%	(M602F) Emergency = 525 MVA NDEX = 0
	63050 WILLMAR to 66550 GRANITF	119.50	153.64%	183.60	6.87	2.29%	Y51L Rate C = 131.5 MVA
	61624 FORBES 4 to 61625 BLCKBRY4	372.00	113.65%	422.78	13.77	4.59%	(BOTH CHISAGO 345kV XFORMERS) Emergency = 409 MVA Below 5% OTDF threshold.
	63327 HANKSON to 63329 WAHPETN	320.00	100.91%	322.91	10.10	3.37%	(ST. JOSEPH WIND) Emergency = 352 MVA
	61676 HIBBARD to 61680 WNTR ST7	214.00	104.78%	224.23	37.57	12.52%	(ARROWHD to GARY 115) Emergency = 235 MVA
	Leland Olds Transformer 1	250.00	118.90%	297.25	12.44	4.15%	(ST. JOSEPH WIND) Rate C = 300 MVA
	Leland Olds Transformer 2	500.00	112.78%	563.90	23.60	7.87%	(ST. JOSEPH WIND) Rate C = 600 MVA

Table 5.5: Post Contingency: Significantly Affected Facilities Category C (2014).

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
SUOP14 MHEX Export	L20D	419.50	106.16%	445.34	95.65	31.88%	(BRK FAIL Y51L & BNK 2) Emergency = 460 MVA
			127.58%	534.56	44.73	14.91%	(RAMSEY to BALTA, RAMSEY to PRAIRIE, RAMSEY XFORMER)
	66752 DRAYTON4 to 66755 PRAIRIE4	389.00	108.71%	422.89	33.81	11.27%	(DONALDSON 115 STATION) Emergency = 428 MVA
	DRAYTON XFORMER 1	140.00	105.26%	147.36	10.73	3.58%	(DRAYTON XFORMER 2) Emergency = 161 MVA
	DRAYTON XFORMER 2	187.00	135.44%	253.27	17.95	5.98%	(BRK FAIL DRAYTON PRAIRIE & XFORMER 1) Emergency = 215 MVA Increase DCRED
	63255 DONALDS7 to 66705 DRAYTON7	198.00	103.31%	204.55	12.36	4.12%	(BRK FAIL DRAYTON PRAIRIE & XFORMER 1) Emergency = 200 MVA Increase DCRED
	63255 DONALDS7 to 66714 WARSAW 7	100.00	104.03%	104.03	7.29	2.43%	(BRK FAIL DRAYTON PRAIRIE & XFORMER 1) Emergency = 110 MVA
SUPK14 MHEX Export	L20D	419.50	101.81%	427.09	97.43	32.48%	(BRK FAIL Y51L & BNK 2) Emergency = 460 MVA
			126.40%	530.26	46.26	15.42%	(RAMSEY XFORMER & RAMSEY to BALTA & RAMSEY to PRAIRIE)
	66752 DRAYTON4 to 66755 PRAIRIE4	389.00	102.32%	398.02	34.06	11.35%	(DONALDSON 115 kV STATION) Emergency = 428 MVA
	DRAYTON XFORMER 1	140.00	108.55%	151.97	10.93	3.62%	(DRAYTON XFORMER 2) Emergency = 161 MVA

Table 5.5: Post Contingency: Significantly Affected Facilities Category C (2014) Continued.

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
SUPK14 MHEX Export	DRAYTON XFORMER 2	187.00	134.18%	250.91	18.00	6.00%	(BRK FAIL DRAYTON to PRAIRIE & XFORMER 1) Emergency = 215 MVA Increase DCRED.
	63255 DONALDS7 to 66705 DRAYTON7	198.00	103.44%	204.81	12.34	4.11%	(BRK FAIL DRAYTON to PRAIRIE & XFORMER 1) Emergency = 200 MVA Below 5% OTDF threshold.
	60203 COON CK to 60253 TWIN LK	371.00	100.13%	371.48	7.86	2.62%	(TERMINAL STATION XCEL) Emergency = 371 MVA Below 5% OTDF threshold.
SUPK14 MHEX Import	**G82R**	**335.00**	**109.80%**	**367.83**	**16.35**	**5.45%**	**(BRK FAIL S60L & ST. JOSEPH WIND) 150 MW Rugby wind. NDEX = 2080 Emergency = 429.4 MVA**
			100.76%	**337.24**	**17.73**	**5.91%**	**(BRK FAIL S60L & ST. JOSEPH WIND) Rugby wind off. NDEX = 2080**
			108.08%	**362.07**	**6.19**	**2.06%**	**(FORBES MULTI-CIRCUIT) 150 MW Rugby wind. NDEX = 2080**
			112.24%	**376.00**	**10.16**	**3.39%**	**(FORBES MULTI-CIRCUIT) Rugby wind off. NDEX = 2080**

Table 5.5: Post Contingency: Significantly Affected Facilities Category C (2014) Continued.

Scenario	Impacted Branch	Post-facility Post-contingency					Contingency/Comment
		Rate A	Overload	MVA	ΔMW	DF %	
SUPK14 MHEX Import	**G37C**	**279.70**	**111.73%**	**312.51**	**38.33**	**12.78%**	**(BRK FAIL Y51L & D55Y) 150 MW Rugby wind. NDEX = 2080**
			125.90%	**352.14**	**68.61**	**22.87%**	**(BRK FAIL Y51L & D55Y) Rugby wind off. NDEX = 2080**
WTPK14 MHEX Import	**G82R**	**335.00**	**115.82%**	**388.00**	**22.81**	**7.60%**	**(BRK FAIL S60L & ST. JOSEPH WIND) 150 MW Rugby wind. NDEX = 2080 Emergency = 429.4 MVA**
			103.26%	**345.92**	**18.94**	**6.31%**	**(BRK FAIL S60L & ST. JOSEPH WIND) Rugby wind off. NDEX = 2080**
			126.79%	**424.75**	**10.78**	**3.59%**	**(FORBES MULTI-CIRCUIT) 150 MW Rugby wind. NDEX = 2080**
			116.04%	**388.73**	**9.09**	**3.03%**	**(FORBES MULTI-CIRCUIT) Rugby wind off. NDEX = 2080**
	61627 SHANNON4 to 66753 RUNNING4	477.00	84.12%	401.25	8.73	2.91%	(FORBES MULTI-CIRCUIT) Emergency = 525 MVA NDEX = 0
	63327 HANKSON4 to 63329 WAHPETN4	320.00	100.04%	320.13	8.11	2.10%	(BRK FAIL S60L & ST. JOSEPH WIND) Emergency = 352 MVA
	Leland Olds Transformer 1	250.00	117.37%	293.43	10.35	3.45%	(BRK FAIL S60L & ST. JOSEPH WIND) Emergency = 300 MVA
	Leland Olds Transformer 2	500.00	111.33%	556.65	19.58	6.53%	(BRK FAIL S60L & ST. JOSEPH WIND) Emergency = 600 MVA

Appendix B

Impact of 150 MW Rugby Generation Injection on the MH System

Summer Peak MHEX = -700 NDEX = 2080
System Intact

	G82R	L20D	D602F	R50M	G37C	MHEX North
Pre-Rugby MW	328.90	264.00	147.00	-37.50	337.4	702.40
Post Rugby MW	358.10	256.50	131.90	-39.10	350.4	707.40
ΔMW	29.20	-7.50	-15.10	1.60	13	
DF%	19.47%	-5.00%	-10.07%	1.07%	8.67%	
Pre MVA	353.80	267.20	272.30	37.80	339.60	
Post MVA	385.20	259.50	219.10	39.40	353.00	
	Overload (335 MVA) Voltage 0.983 p.u.				(Overload 279 MVA)	

Summer Off-Peak MHEX = -700 NDEX = 2080
System Intact

	G82R	L20D	D602F	R50M	G37C	MHEX North
Pre-Rugby MW	278.80	206.00	244.70	-23.80	258.3	705.70
Post Rugby MW	309.60	197.90	225.90	-25.60	272.5	707.80
ΔMW	30.80	-8.10	-18.80	1.80	14.2	
DF%	20.53%	-5.40%	-12.53%	1.20%	9.47%	
Pre MVA	303.60	209.30	289.10	24.40	265.70	
Post MVA	335.20	201.10	275.60	26.10	280.10	
	Overload (335 MVA) Voltage 0.976 p.u.				(Overload 279 MVA)	

Summer Peak MHEX = -700 NDEX = 2080
Loss of L20D

	G82R	L20D	D602F	R50M	G37C	MHEX North
Pre-Rugby MW	331.70	0.00	384.00	-9.90	258.2	705.80
Post Rugby MW	358.40	0.00	360.50	-12.10	271.3	706.80
ΔMW	26.70	0.00	-23.50	2.20	13.1	
DF%	17.80%	0.00%	-15.67%	1.47%	8.73%	
Pre MVA	366.50	0.00	405.60	13.30	268.90	
Post MVA	394.50	0.00	385.40	14.40	282.40	
	Overload (350 MVA) Voltage 0.962 p.u.				(Overload 279 MVA)	

Summer Off-Peak MHEX = -700 NDEX = 2080
Loss of D602F

	G82R	L20D	D602F	R50M	G37C	MHEX North
Pre-Rugby MW	338.20	316.50	0.00	57.30	299.3	712.00
Post Rugby MW	359.90	305.20	0.00	50.20	308.5	715.30
ΔMW	21.70	-11.30	0.00	-7.10	9.2	
DF%	14.47%	-7.53%	0.00%	-4.73%	6.13%	
Pre MVA	370.20	322.20	0.00	60.60	309.60	
Post MVA	396.10	310.20	0.00	53.20	319.80	
	Overload (350 MVA) Voltage 0.947 p.u.				(Overload 279 MVA)	

Appendix C

Sensitivity of 199.5 MW Langdon Wind Tables

Table 5.9: Post Contingency: Sensitivity of 199.5 MW Langdon Wind Farm (2009)
Following a contingency which includes the loss of the Drayton to Prairie 230 kV line.

Scenario	Facility	Langdon 46 MW				Langdon 199 MW			
		System Intact Loading (% Rate A)	PTDF%	Post Contingency Loading (% Rate A)	OTDF (%)	System Intact Loading (% Rate A)	PTDF%	Post Contingency Loading (% Rate A)	OTDF (%)
SUPK09 MHEX Export	L20D	94	19.22	103.26	19.54	90	21.29	101.15	22.00
	66752 DRAYTON4 to 66755 PRAIRIE4	66	13.15	-	-	76	14.68	101.86	17.60
	DRAYTON XFORMER 2	42	2.80	113.36	7.91	26	3.12	-	-
	63255 DONALDS7 to 66705 DRAYTON7	60	3.28	-	-	69	3.88	112.09	6.17
	63255 DONALDS7 to 66714 WARSAW 7	47	1.90	-	-	58	2.24	112.91	3.75
SUOP09 MHEX Export	L20D	103	19.10	110.27	30.63	100.88	20.77	107.67	22.73
	66752 DRAYTON4 to 66755 PRAIRIE4	74	12.89	-	-	85	14.21	107.75	16.44
	DRAYTON XFORMER 2	45	2.81	120.19	8.99	26	3.07	-	-
	63255 DONALDS7 to 66705 DRAYTON7	66	3.25	108.88	6.48	77	3.77	106.58	6.83
	63255 DONALDS7 to 66714 WARSAW 7	45	1.93	-	-	55	2.17	107.28	3.38

Table 5.10: Post Contingency: Sensitivity of 199.5 MW Langdon Wind Farm (2014)
Following a contingency which includes the loss of the Drayton to Prairie 230 kV line.

Scenario	Facility	Langdon 46 MW				Langdon 199 MW			
		System Intact Loading (% Rate A)	PTDF%	Post Contingency Loading (% Rate A)	OTDF (%)	System Intact Loading (% Rate A)	PTDF%	Post Contingency Loading (% Rate A)	OTDF (%)
SUPK14 MHEX Export	L20D	115	15.20	129.84	31.87	107	14.60	104.26	21.33
	66752 DRAYTON4 to 66755 PRAIRIE4	81	10.15	109.49	11.38	89	9.88	114.38	11.15
	DRAYTON XFORMER 2	53	2.32	134.18	6.00	35	2.08	110.65	5.54
	63255 DONALDS7 to 66705 DRAYTON7	69	2.74	108.72	4.21	77	2.38	114.96	3.43
	63255 DONALDS7 to 66714 WARSAW 7	54	1.57	110.56	2.59	63	1.37	113.80	2.15
SUOP14 MHEX Export	L20D	120	13.91	129.84	31.87	113	14.18	115.85	22.46
	66752 DRAYTON4 to 66755 PRAIRIE4	87	9.52	103.49	11.42	94	9.41	100.35	12.22
	DRAYTON XFORMER 2	52	2.10	135.44	5.98	34	2.09	112.81	5.17
	63255 DONALDS7 to 66705 DRAYTON7	66	2.52	108.67	4.73	73	2.45	120.07	5.26
	63255 DONALDS7 to 66714 WARSAW 7	56	1.57	105.68	2.96	64	1.33	124.28	3.38
	66709 LANGDON7 to 66720 SWEETWA7	26	1.37	-	-	84	1.37	107.83	2.10