Report R164-08

MHEB Group TSR System Impact Study Executive Summary

Prepared for

Midwest ISO

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Executive Summary

Several requests for long term firm transmission service have been made under the Midwest ISO's Open Access Transmission and Energy Markets Tariff. Analysis of these requests is summarized in the study reports listed below; this document provides a summary of the System Impact Study conclusions.

- "MHEB Group TSR System Impact Study, Near-Term Requests," Siemens PTI Report R164-08, Jan. 12, 2009
- "MHEB Group TSR System Impact Study, Out-Year Power Flow Analysis, MH to US Requests, Summer Peak / South Flow," Siemens PTI Report R164-08, July 17, 2009
- "MHEB Group TSR System Impact Study, Out-Year Power Flow Analysis, US to MH Requests, Winter Peak / North Flow," Siemens PTI Report R164-08, July 17, 2009
- "MHEB Group TSR System Impact Study, Stability Analysis, US to MH Requests," Siemens PTI Report R164-08, July 17, 2009

This study was performed by Siemens PTI under the direction of Midwest ISO and an Ad Hoc Study Group consisting of American Transmission Company (ATC LLC), Basin Electric Power Cooperative (BEPC), Dairyland Power Cooperative (DPC), Great River Energy (GRE), Manitoba Hydro (MHEB), Minnesota Power (MP), Minnkota Power Cooperative (MPC), Otter Tail Power (OTP), Western Area Power Administration (WAPA) and Xcel Energy (XEL).

Near-Term Requests

Near-term requests for transmission service are shown in Table E-1, which seek to reserve 440 MW of transmission service from Manitoba Hydro to various sinks in the United States.

Table E-1: MH-US South Bound Near-Term Requests

Oasis Ref No	Service Type	Start Time	Stop Time	POR	POD	Requested Capacity	Queue Date	Study Number
76703520	P-to-P	May 2007	May 2009	MHEB-MISO	CIN	80 MW	11/15/06	A339
76703521	P-to-P	May 2007	May 2009	MHEB-MISO	NSP	80 MW	11/15/06	A340
76703535	Network	April 2008	April 2013	MHEB-MISO	NSP	30 MW	01/26/07	A351
76703685	P-to-P	Nov. 2009	Nov. 2014	MHEB-MISO	NSP	250 MW	02/04/08	A406
					Total:	440 MW		

A power flow analysis was performed for summer peak conditions. Constraints identified for the near-term requests are summarized in Table E-2. Request A340 was approved by Midwest ISO for 7 MW of service. Requests A339 and A406 have been withdrawn. Request A351 will require upgrades and was included in the out-year studies.

Table E-2: Near-Term Constraints

Monitored Element	Rating (MVA)
MHEX_S flowgate	1972
BREWHEJEFROC flowgate	786
COOPER_S flowgate	670
FTCAL_S flowgate	451
Dorsey 500/230/46 kV xfmr #51	1200
Dorsey 500/230/46 kV xfmr #52	1200

Out-Year Requests

Out-year requests for transmission service are shown in Table E-2 and Table E-3. The South bound requests seek to reserve 1130 MW of transmission service from Manitoba Hydro to various sinks in the United States. The South bound requests seek to reserve 1100 MW of transmission service from various sources in the United State to Manitoba Hydro.

Table E-2: MH-US South bound Requests

Oasis Ref No	Service Type	Start Time	Stop Time	POR	POD	Requested Capacity	Queue Date	Study Number
76703536	Network	Nov-2014	Nov-2024	MHEB-MISO	GRE	200	12/7/2006	A388
76703535	Network	Apr-2008	Apr-2013	MHEB-MISO	NSP	30	1/26/2007	A351
76703671	Network	Jun-2017	Jun-2027	MHEB-MISO	WPS	500	6/12/2007	A380
76703672	Network	Jun-2017	Jun-2037	MHEB-MISO	MP	250	7/6/2007	A383
76703686	Network	Jun-2017	Jun-2027	MHEB-MISO	NSP	50	4/17/2008	A416
76703687	Network	Jun-2017	Jun-2027	MHEB-MISO	WEC	100	4/17/2008	A417
					Total (MW)	1130		

Table E-3: US-MH North bound Requests

Oasis Ref No	Service Type	Start time	Stop Time	POR	POD	Requested Capacity	Queue Date	Study Number
76537582	Network	Jun-2009	Jun-2027	WPS	MHEB	500	06/13/07	A380
76544699	Network	Jun-2009	Jun-2037	MP	MHEB	250	07/06/07	A383
76637089	P-to-P	Nov-2014	Nov-2024	GRE	MHEB	100	04/17/08	A415
76637091	P-to-P	Nov-2014	Nov-2024	GRE	MHEB	100	04/17/08	A415
76637257	P-to-P	Jun-2009	Jun-2027	WEC	MHEB	50	04/17/08	A414
76637259	P-to-P	Jun-2009	Jun-2027	ALTE	MHEB	50	04/17/08	A413
76637260	P-to-P	Jun-2009	Jun-2027	ALTE	MHEB	50	04/17/08	A413
					Total (MW)	1100		

Power flow and stability analyses were performed on two 500 kV AC transmission options to determine a transmission plan for the TSRs along with a planning level cost estimate.

Proposed Transmission Options

The transmission upgrade options proposed by the ad hoc study group are summarized in Table E-4 along with their cost estimates. The cost estimates are for the new 500 kV transmission lines only and are based on $/mile costs taken from the JCSP 2008 Interim Stakeholder Meeting Introduction Presentation[1] and adjusted down from 2024 dollars to 2018 dollars using a 3% escalation factor. The costs for series compensation, transformers, line terminations and other required substation equipment are not included in this preliminary estimate. These costs will be further developed and refined in the Facilities study.

Table E-4: Proposed Transmission Options

Option No.	Project	Cost in 2018[1]
1	Dorsey – Maple River 50% series compensated 500 kV line with one 500/345 kV, 1200 MVA transformer at Maple River. Maple River – Helena 50% series compensated 500 kV line terminated with two 500/345 kV, 1200 MVA transformers at Helena.	$1.035 B
3	Dorsey – King 50% series compensated 500 kV line terminated via two 500/345 kV, 1200 MVA transformers at King.	$955 M

Note 1: Cost estimates are for transmission lines only

[1] http://www.midwestmarket.org/publish/Document/81d7e_11b6e66e758_-795e0a48324a/Interim%20Presentation.pdf?action=download&_property=Attachment

The transmission upgrade options evaluated in this study do not include shunt reactors to compensate for capacitive generation on the new 500 kV lines. Both Option 1 and Option 3 will require shunt reactors on the 500 kV line to control voltage when the line is open-ended. In Option 3, the steady-state voltage is around 1.2 per unit at the series capacitor on the Dorsey-King 500 kV line and the series capacitors will need to be designed accordingly.

Outage of new 500 kV facilities associated with upgrade Option 1 or Option 3 were modeled without HVDC reduction. Existing 500 kV and 230 kV triggers to the Manitoba Hydro HVDC power order reduction scheme were simulated in both the power flow and stability analyses.

Power Flow Analysis

A power flow analysis was performed for summer peak south flow and winter peak north flow scenarios. Constraints and required mitigation are listed in Table E-5 and Table E-6. No constraints were identified for outage of new 500 kV facilities associated with upgrade Option 1 or Option 3 without HVDC reduction.

Table E-5: Summer Peak Constraints

Monitored Element	Owner	Rating (MVA)	Mitigation Required	Option 1	Option 3
Saratoga-Petenwell 138 kV line	ATC	72.2	Reconductor 22.7 mi of the line	X	X
East Krok-Kewaunee 138 kV line	ATC	272.6	Replacing substation equipment at E. Krok	X	X
Jackson 161/69 kV transformer	NSP	47	Replace with larger 161/69 kV transformer	X	X

Table E-6: Winter Peak Constraints

Monitored Element	Owner	Rating (MVA)	Mitigation Required	Option 1	Option 3
Stanton – Coal Creek 230 kV (FG: SONCCTCOCSON)	MISO	478	Replace terminal equipment at Stanton and Coal Creek	X	X
Rugby – Rugby CPC 115 kV line	WAPA & BEPC	144.4	Reconductor 0.1 miles of the line	X	X
Cass Lake – Nary 115 kV line	OTP & MPC	105.6	Reconductor 11 miles of the line	X	

In the summer peak case, the total system losses within the study area increase by 11.5% (Option 3) to 12.1% (Option 1) compared to the benchmark case. Option 3 is 14 MW more efficient than Option 1. In the winter peak case, losses decrease slightly (5 MW) with Option 1 and increase by 30 MW with Option 3.

Stability Analysis

A transient stability analysis was performed for a summer off-peak scenario. Simulation results indicate unacceptable transmission system performance for disturbances involving the following outages:

- Dorsey-Maple River 500 kV line in Option 1 without directly triggering HVDC reduction,
- Maple River-Helena 500 kV line in Option 1,
- Dorsey-King 500 kV line in Option 3 without directly triggering HVDC reduction, or
- Faults at King with delayed clearing that result in outage of the King-Eau Claire 345 kV line in Option 3.

Minong Voltage Violations

In Option 3, faults at King with delayed clearing that result in outage of the King-Eau Claire 345 kV line cause a transient voltage violation at the Minong 161 kV bus. A second 75 MVAR shunt capacitor at the Stone Lake 345 kV bus increases the minimum transient voltage to 0.82 per unit and eliminates the violation. If the Stone Lake 345 kV capacitors are switched sequentially, the insertion time for each capacitor needs to be less than 12 cycles so that both capacitors are on before the violation occurs.

Outage of Dorsey-Maple River or Dorsey-King

In both options, several of the simulated disturbances cause the relay on the Manitoba-Ontario tie or the DCAR DC reduction relay at Forbes to operate. These relays are intended to operate for severe disturbances that could lead to voltage collapse and are not intended to operate for category B or category C disturbances. Simulations were repeated with the relays blocked to determine what happens if the settings of the relays could be changed so that the relays do not operate for the Dorsey-Maple River or Dorsey-King outage.

After blocking the MH-OH and/or DCAR relays with Option 1, the out-of-step relays on the Riel-Forbes 500 kV line (M602F) violate the minimum transient-period relay margin. With Option 3, three-phase faults on the Dorsey-King 500 kV line cause stability problems with an electrical center in northern Minnesota around Forbes. Voltage oscillations are poorly damped with either option because the Forbes SVC is at its capacitive limit following the disturbance and is not able to provide damping.

Two options were evaluated to address these violations:

- Additional reactive support at Forbes
- HVDC Reduction

Additional Reactive Support

Critical disturbances were repeated with additional dynamic reactive support added at the Forbes 500 kV bus. With Option 1, the analysis indicates that tripping Dorsey-Maple River without a corresponding HVDC reduction requires the installation of more than 400 MVAr of additional dynamic (fast-switched capacitors) reactive support at Forbes; a total of

approximately 600 MVAR is required to reduce the Forbes SVC output below the 110 MVAr continuous rating within 10 seconds. With Option 3, the analysis indicates that tripping Dorsey-King without a corresponding reduction to the HVDC power order requires the installation of more than 600 MVAr of additional dynamic reactive support at Forbes; a total of approximately 900 MVAR is required to reduce the Forbes SVC output below the 110 MVAr continuous rating.

Simulation results indicate that overcurrent relays will initiate a bypass of the Roseau series capacitors during the post-disturbance swing with option 3, which triggers the existing HVDC reduction scheme. Either option requires additional analysis of protection on the Monitoba-Ontario ties, M602F line and Roseau series capacitors to make sure the system is secure during the power swing and voltage dip that occurs following trip of Dorsey-Maple River in Option 1 or Dorsey-King in Option 3.

HVDC Reduction

Critical disturbances were repeated with the existing HVDC reduction scheme triggered by outage of the new Dorsey-Maple River 500 kV tie line in Option 1 and by outage of the new Dorsey-King 500 kV tie line in Option 3. Reduction was assumed equal to 100% of the pre-disturbance flow on the line. There are no criteria violations with either Option 1 or with Option 3. Depending on the final design of the transmission upgrades, the required amount of reduction may be less than 100%.

Reduction amounts for the new and existing triggers are lower in the Option 1 and Option 3 study cases than in the benchmark case because flows on the existing Manitoba-US tie lines are lower in the study cases as shown in Table E-7.

Table E-7: MH-US Tie Line Loading

Tie Line	Pre-Benchmark	Benchmark	Study Option 1	Study Option 3
M602F @ Riel	1855 MW	1777 MW	1545 MW	1583 MW
Dorsey-Maple River	-	-	1459 MW	-
Dorsey-King	-	-	-	1361 MW
L20D @ Letellier	238 MW	287 MW	236 MW	268 MW
R50M @Richer	142 MW	139 MW	128 MW	134 MW
G82R @Glenboro	-62 MW	-28 MW	-61 MW	-36 MW

Outage of Maple River-Helena

When simulating outage of the Maple River-Helena 500 kV line with Option 1, the output of the Forbes SVC exceeds the continuous rating at the end of the simulation. Either option described above for outage of Dorsey-Maple River or Dorsey-King will address this issue; additional reactive support at Forbes or a cross-trip of Dorsey-Maple River combined with HVDC reduction.

Constraint Mitigation Costs

Estimated costs for resolving each of the TSR constraints are summarized in Table E-8. The costs are good faith estimates and will be further developed and refined in the Facility Study. The total estimated cost of each transmission upgrade option is shown in Table E-9.

Table E-8: Constraint Mitigation Costs

Mitigation	Option 1	Option 3
Fast-switched capacitors at Forbes 500 kV (400-600 MVAr)	$20,000,000	$32,000,000
A new 75 MVAr capacitor at Stone Lake 345 kV	--	$930,000
Stanton - Coal Creek 230 kV (FG: SONCCTCOCSON)	$500,000	$500,000
Saratoga - Petenwell 138 kV	$2,927,167	$2,927,167
East Krok - Kewaunee 138 kV	$1,000,000	$1,000,000
Rugby - Rugby CPC 115 kV	$69,652	$69,652
Cass Lake - Nary 115 kV	$7,661,692	--
Jackson 161/69 kV transformer	$900,000	$900,000
Total	$33,058,511	$38,326,819

Table E-9: Total Estimated Cost of System Upgrades

	Option 1	Option 3
Cost of proposed transmission options	$1,035,000,000	$955,000,000
Cost of constraint mitigation	$33,058,511	$38,326,819
Total	$1,068,058,511	$993,326,819

Further Study

The next step in the study process is for the transmission customers to decide whether to proceed to a Facility Study. The Facility Study will specify in more detail the schedule and cost to design, procure and construct the system upgrades identified in this SIS report. Transmission upgrade Options 1 and 3 will both be carried forward into the Facilities Study as the Minnesota Public Utilities Commission and the Public Service Commission of Wisconsin will require study information for more than one option before granting a Certificate of Need.

Through the course of the System Impact Study, the Study Group identified a need for studying additional scenarios, beyond the scope of the SIS as originally defined. The need for supplemental study work primarily resulted from considerations such as physical build-outs, the impact of the proposed transmission on reserve requirements, and operating

situations. The magnitude of the TSRs and the proposed transmission warrants this analysis. Some of the items identified by the Study Group are listed below.

- Transfer capability for the prior-outage of new and existing MH-US tie-lines.
- Benefits and costs of tying Option 3 into the 500 kV system at Forbes.
- Impact of moving the 500 kV line terminal to a new substation east of King in Option 3 due to physical constraints at King
- Size and location of shunt reactors on the new 500 kV lines to control voltage when the line is open-ended.
- Determine if the double-circuited CapX facilities (Maple River-Monticello) can be used as an alternative to the south 500 kV line in Option 1
- Determine if the LaCrosse-W. Middleton 345 kV line being considered by ATC mitigates the transient voltage violation at Minong in Option 3.
- Determine if TSRs can be accommodated while respecting TRM
- Additional analyses required should HVDC reduction not be utilized as a mitigation measure

After the scope of the supplemental impact study has been finalized, the study will proceed with concurrence from the customers and Transmission Owners. The supplemental impact study is proposed to be performed in parallel with the Facility Study.

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MHEB Group TSR System Impact Study Near-Term Requests

Prepared for

Midwest ISO

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Executive Summary

Long term firm transmission service requests have been requested under the Midwest ISO's Open Access Transmission and Energy Markets Tariff. This report presents the results of a system impact study performed to evaluate the requests for transmission service shown in Table E-1, which seek to reserve 440 MW of transmission service from Manitoba Hydro. These near-term requests are four of sixteen requests being evaluated in the MHEB Group TSR System Impact Study. The requests are evaluated based on 2009 system conditions. Rollover rights, if any, will be evaluated along with the remaining twelve (out-year) requests.

Table E-1: MHEB Group TSR Near-Term Requests

Oasis Ref No	Service Type	Start Time	Stop Time	POR	POD	Requested Capacity	Queue Date	Study Number
76703520	P-to-P	May 2007	May 2009	MHEB-MISO	CIN	80 MW	11/15/06	A339
76703521	P-to-P	May 2007	May 2009	MHEB-MISO	NSP	80 MW	11/15/06	A340
76703535	Network	April 2008	April 2013	MHEB-MISO	NSP	30 MW	01/26/07	A351
76703685	P-to-P	Nov. 2009	Nov. 2014	MHEB-MISO	NSP	250 MW	02/04/08	A406
					Total:	440 MW		

Analyses have been performed for the near term period to assess the impacts the proposed transfers would have on the transmission system.

A339 (80 MW MHEB-MISO to CIN)

A339 is a request for 80 MW of point-to-point transmission service from MHEB-MISO to CIN. For A339, the following flowgates have been identified as constraints to the transfer in the flow-based analysis. Note that minimum posted available transfer capacity on the MHEX_S flowgate is 100 MW, of which 57 MW corresponds to the Midwest ISO allocation.

Table E-2: A339 Flow-Based Constraints

Flowgate Name	Limiting Constraint	Contingency	Rating (MVA)	Lowest Available Flowgate Capacity (pre-transfer)	TDF
MHEX_S	Letellier - Drayton 230 kV Dorsey - Roseau 500 kV Richer - Roseau 230 kV Glenboro - Rugby 230 kV	Base Case	1972	57 out of 100	100.00%
BREWHEJEFROC	Breed - Wheatland 345 kV	Jefferson-Rockport 765 kV	786	-150	26.39%
COOPER_S	Cooper - St. Joe 345 kV Cooper - Fairport 345 kV	Base Case	670	-472	17.62%
FTCAL_S	Fort Calhoun South	Base Case	451	-101	11.18%

A340 (80 MW MHEB-MISO to NSP)

A340 is a request for 80 MW of point-to-point transmission service from MHEB-MISO to NSP. The MHEX_S flowgate has been identified as a constraint to the transfer in both the network analysis and the flow-based analysis. Note that if A339 proceeds, then there is no available transfer capability along this flowgate for A340 and thus service could not be granted without transmission improvements.

Table E-3: A340 Flow-Based Analysis Constraints

Flowgate Name	Limiting Constraint	Contingency	Rating (MVA)	Lowest Available Flowgate Capacity (pre-transfer)	TDF
MHEX_S	Letellier - Drayton 230 kV Dorsey - Roseau 500 kV Richer - Roseau 230 kV Glenboro - Rugby 230 kV	Base Case	1972	-23 [1]	100.00%

Note 1: AFC assuming A339 proceeds

A351 (30 MW MHEB-MISO to NSP)

A351 is a request for 30 MW of network transmission service from MHEB-MISO to NSP. The The MHEX_S flowgate has been identified as a constraint to the transfer in both the network analysis and the flow-based analysis. Note that if A339 or A340 proceeds, then there is no available transfer capability along this flowgate for A351 and thus service could not be granted without transmission improvements.

Table E-4: A351 Flow-Based Analysis Constraints

Flowgate Name	Limiting Constraint	Contingency	Rating (MVA)	Lowest Available Flowgate Capacity (pre-transfer)	TDF
MHEX_S	Letellier - Drayton 230 kV Dorsey - Roseau 500 kV Richer - Roseau 230 kV Glenboro - Rugby 230 kV	Base Case	1972	-103 [1]	100.00%

Note 1: AFC assuming A339 and A340 proceed

A406 (250 MW MHEB-MISO to NSP)

A406 is a request for 250 MW of point-to-point transmission service from MHEB-MISO to NSP. Request A406 can not be accepted without system improvements. Constraints identified in the network analysis and flow-based analysis are shown in Table E-5 and Table E-6, respectively. Note that if A339, A340 or A351 proceeds, then there is no available transfer capability along the MHEX_S flowgate for A406.

Table E-5: A406 Network Analysis Thermal Constraints

Date Upgrade Needed	Facility to be upgraded/built	Minimum Capacity Required (MVA)
Before Service can commence	Dorsey 500/230/46 kV xfmr #52	1274.4
	Dorsey 500/230/46 kV xfmr #51	1274.4

Table E-6: A406 Flow-Based Analysis Constraints

Flowgate Name	Limiting Constraint	Contingency	Rating (MVA)	Lowest Available Flowgate Capacity (pre-transfer)	TDF
MHEX_S	Letellier - Drayton 230 kV Dorsey - Roseau 500 kV Richer - Roseau 230 kV Glenboro - Rugby 230 kV	Base Case	1972	-133 [1]	100.00%

Note 1: AFC assuming A339, A340 and A351 proceed

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Section

1

Introduction

This report presents the results of a system impact study performed to evaluate the requests for transmission service shown in Table 1-1. These requests are four of 16 requests being evaluated in the MHEB Group TSR System Impact Study. These near-term requests are evaluated based on 2009 system conditions. Rollover rights, if any, will be evaluated along with the remaining twelve (out-year) requests.

Table 1-1: MHEB Group TSR Near-Term Requests

Oasis Ref No	Service Type	Start time	Stop Time	POR	POD	Requested Capacity	Queue Date	Study Number
76703520	P-to-P	May 2007	May 2009	MHEB-MISO	CIN	80 MW	11/15/06	A339
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Section
2

Steady-State Analysis

2.1 Methodology

A benchmark power flow model representing system conditions in 2009 was created without the requested transmission service. A study case was created by modeling the requested transmission service in the benchmark case. A nonlinear (ac) contingency analysis was performed on both the benchmark and study case and the incremental impact of the requested transmission service was evaluated by comparing flows and voltages without and with the service.

Linear (dc) analysis was used to calculate distribution factors for each TSR. These distribution factors and the results of the nonlinear contingency analysis were used to calculate the loading of impacted facilities before and after each TSR.

2.2 Computer Programs

Analysis was performed using PSS®E version 30.3 and PSS®MUST version 8.3.2.

2.3 Model Development

2.3.1 Near-term Benchmark Case

A near-term benchmark case without the study TSRs was developed from a summer peak case provided by Midwest ISO. This case represents 2009 summer peak conditions and was developed from the MRO 2007 series models as described herein.

2.3.1.1 Midwest ISO Transmission Expansion Plan 2008 (MTEP08) Projects

Table 2-1 shows the MTEP08 projects that were added to the near-term benchmark case using response files provided by Midwest ISO.

Table 2-1: MTEP Projects Added to the Near-term Case

TO	PrjID	Project Name
ATC LLC	352	Cranberry-Conover 115 kV
ATC LLC	345	Clintonville-Werner West 138
ATC LLC	177	Gardner Park-Highway 22 345 kV line projects
ITCM	1761	Readlyn-Tripoli 69kV Rebuild
ITCM	1757	Cambridge REC-Maxwell 69kV Rebuild
ITCM	1753	Winnebago Jct south 161/69kV
ITCM	1739	Arnold-Vinton-Dysart-Washburn 161kV Reconductor
ITCM	1619	Grnd Mnd 161-69kV 2nd Xfmr & 161kV loop
ITCM	1618	Hrn Lk-Lkfld 161kV Ckt 1 Rbld
ITCM	1342	Lewis Fields 161 kV substation which taps the SwampFX - Coggon 115 kV line
ITCM	1289	Marshalltown - Toledo - Belle Plaine - Stoney Point 115 kV line rebuild
ITCM	1287	Replace Salem 345/161 kV transformer with 448 MVA unit
MP/GRE	1021	Embarass to Tower 115 kV Line
XEL	1959	Yankee Doodle interconnection
XEL	1956	Blue Lake - Wilmarth 345 kV line capacity upgrade
XEL	1549	Eau Claire - Hydro Lane 161 kV Conversion
XEL	1548	La Crosse Area Capacitor banks
XEL	1489	Woodbury - Tanners Lake upgrade
XEL	1457	G287, 37642-03. Upgrades for G287
XEL	1373	Ft. Ridgeley - Searles Jct 115 new line and Searles Jct - New Ulm 69 Reconductor
XEL	1370	Convert/Relocate the 69 kV Rush River substation to existing 161 kV line from Pine Lake - Crystal Cave
XEL	1369	Osceola - Sand Lake 69 Reconductor
XEL	1368	Three Lakes 115/69 kV substation
XEL/GRE	1545	Mankato 115 kV loop

2.3.1.2 Midwest ISO TSRs and Confirmed Requests

Table 2-2 shows Midwest ISO TSRs and confirmed requests that were added to the near-term benchmark case using sources and sinks provided by Midwest ISO. The near-term benchmark case includes all existing firm commitments on the MHEX_S interface.

Table 2-2: Midwest ISO TSRs Added to the Near-term Case

OASIS	OASIS #	STUDY	POR	POD	CAPACITY REQUESTED (MW)	START	STOP
MISO	75690165	A168	MP	NSP	20	6/1/2006	6/1/2026
MISO	75690167	A168	MP	NSP	15	6/1/2006	6/1/2026
MISO	75884042	A201	NSP	NSP	19	12/1/2007	11/1/2029
MISO	75884044	A201	NSP	NSP	19	1/1/2008	1/1/2033
MISO	76541075	A204	MP	MP	25	2/1/2008	2/1/2009
MISO	76109095	A230	WAUE	GRE	18 (Note 1)	1/1/2008	1/1/2036
MISO	76198084	A259	GRE	GRE	13	9/1/2005	9/1/2025
MISO	76703518	A304	MHEB	MP	50	5/1/2009	5/1/2015
MISO	76463020	A329	OTP	OTP	21	2/1/2007	1/1/2028
MISO	76480654	A335	GRE	GRE	80 (Note 2)	4/1/2009	4/1/2029
MISO	76659803	-	MP-ONT	MP	150	11/01/2008	11/01/2013
MISO	76414212	-	MP	GRE	100	06/01/2006	06/01/2010

Note 1: The transfer size has been increased to 61 MW

Note 2: The transfer size has been reduced to 68 MW

2.3.1.3 WAPA TSRs

The following proposed generating facilities have TSRs in study on the WAPA OASIS and are modeled in the near-term case.

- Culbertson Project (130 MW)
- GI-0704 (240 MW)
- GI-0714 (100 MW)

The generating facilities are dispatched against generation at Big Bend and Ft. Randall. Groton Unit 1 and Unit 2 are dispatched at 125 MW each.

2.3.1.4 Miscellaneous Updates and Corrections

Table 2-3 shows other miscellaneous model updates.

Table 2-3: Miscellaneous Updates and Corrections

Area	Description
ATC LLC	Update system topology, load forecast, and generation dispatch for ATC LLC companies
MH	Net flow on MH-SPC ties reduced to 0 MW
MH	Brandon 5 turned off; Kelsey uprate and Wuskwatim generating facility added
MH	Flow on the MH dc line set at 2910 MW in preparation for sourcing the 440 MW study transfer at Dorsey.

The power flow case was solved with transformer tap adjustment enabled, area interchange enabled (ties and load), phase shifter adjustment enabled before contingency and locked after contingency, and switched shunt adjustment enabled.

2.3.2 Near-term Study Case

A near-term TSR study case was developed by adding the near-term requests shown in Table 1-1 to the benchmark case described in Section 2.3.1. The TSR sources and sinks are masked.

Table 2-4: Near Term TSR sink

Bus #	Bus Name	MW
Masked		

2.4 Contingency Criteria

A variety of system conditions are considered for the steady-state analysis.

- NERC Category A with system intact (no contingencies)
- NERC Category B contingencies
  - Outage of single element (B.2 and B.3) associated with single contingency event in the following areas: ATCLLC (WEC, ALTE, WPS, MGE, UPPC), DPC, GRE, ITC Midwest, MH, MP, OTP, SMMPA, WAPA, XEL
  - Outage of multiple-elements (B.2 and B.3) associated with single contingency event in the Dakotas, Manitoba, Minnesota, Wisconsin

2.5 Monitored Facilities

Monitored facilities and associated thermal and voltage limits are shown in Table 2-5.

Table 2-5: Monitored Facilities and Limits

Owner/ Area	Monitored Facilities	Thermal Limits [1]		Voltage Limits
		Pre-Disturbance	Post-Disturbance	
ATC LLC	69 kV and above	95% of Rate A	95% of Rate B	1.10/0.90
BEPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
DPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
GRE	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.92/0.90 [2]
ITCMW	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
MDU	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
MEC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
MH	69 kV and above	100% of Rate A	100% of Rate A	1.15/1.10/0.94/0.90 [3]
MP	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
MPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
MRES	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
NWPS	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
OTP	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
RPU	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
SMMPA	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
SPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
WAPA	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
XEL	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90

Note 1: PSSE Rate A, Rate B or Rate C
Note 2: 0.92 limit applies to load serving buses
Note 3: Limits dependent on nominal bus voltage

2.6 Reliability Margins

Capacity benefit margin (CBM) and transmission reliability margin (TRM) are accounted for in the flowgate definitions. All other system elements were monitored as shown in Table 2-5.

2.7 Performance Criteria

A branch or flowgate is considered a significantly affected facility if both of the following conditions are met:

1) the branch is loaded above its applicable normal or emergency rating for the post-change case, and
2) the power transfer distribution factor (PTDF) is greater than 5% or the outage transfer distribution factor (OTDF) is greater than 3%.

Distribution factors for each TSR are calculated using linear (dc) analysis.

A voltage impact is considered significant if both of the following conditions are met:

1) the bus voltage is outside of applicable normal or emergency limits for the post-disturbance case,
2) the impact of the service on bus voltage is greater than 0.01 per unit.

2.8 Network Analysis Results

Facilities on which one or more TSR have a significant thermal impact are shown in Appendix A, Table A-1. A thermal impact is considered significant if the facility loading exceeds the limit shown in Table 2-5 and the impact has a PTDF greater than 5% or an OTDF greater than 3%. There are no significant voltage impacts.

The power flow solution converges in the benchmark case following outage of the Tioga-Boundary Dam 230 kV line but does not converge in the study case. The solution in the study case converges if the fictitious capacitor added at Dorsey in the study case is increased from 200 Mvar to 300 Mvar and no significant thermal or voltage impacts are identified. This issue is related to the ultimate TSR source and is not considered a constraint to the MISO service.

2.8.1 A339 (80 MW MHEB-MISO to CIN)

A339 is a request for 80 MW of point-to-point transmission service from MHEB-MISO to CIN. For A339, the Blackberry-Boswell 230 kV line is the only significantly affected facility as shown in Table 2-6. Blackberry-Boswell is not a constraint because the Boswell special protection system will automatically reduce generation at the Clay Boswell plant to mitigate this contingent overload.

2.8.2 A340 (80 MW MHEB-MISO to NSP)

A340 is a request for 80 MW of point-to-point transmission service from MHEB-MISO to NSP. For A340, the Blackberry-Boswell 230 kV line and MHEX_S flowgate have been identified as

significantly affected facilities as shown in Table 2-7. Blackberry-Boswell is not a constraint because the Boswell special protection system will automatically reduce generation at the Clay Boswell plant to mitigate this contingent overload. The MHEX_S flowgate is a constraint to the transfer.

2.8.3 A351 (30 MW MHEB-MISO to NSP)

A351 is a request for 30 MW of network transmission service from MHEB-MISO to NSP. For A351, the Blackberry-Boswell 230 kV line and MHEX_S flowgate have been identified as significantly affected facilities as shown in

Table 2-8. Blackberry-Boswell is not a constraint because the Boswell special protection system will automatically reduce generation at the Clay Boswell plant to mitigate this contingent overload. The MHEX_S flowgate is a constraint to the transfer.

2.8.4 A406 (250 MW MHEB-MISO to NSP)

A406 is a request for 250 MW of point-to-point transmission service from MHEB-MISO to NSP. Multiple constraints have been identified for request A406 as shown in Table 2-9. The MHEX_S flowgate and contingent overloads of the Dorsey transformers are constraints to the transfer.

Table 2-6: A339 Thermal Constraints (80 MW; MHEB-MISO to CIN)

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency	Category
61625 BLCKBRY4 230 61626 BOSWELL4 230 2[1]	MP	438.0	138.8	139.5	3.7	BLCKBRY4 230 - BOSWELL4 230 1	B

Note 1: Boswell special protection system will automatically reduce generation at the Clay Boswell plant to mitigate this contingent overload

Table 2-7: A340 Thermal Constraints (80 MW MHEB-MISO to NSP)

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency	Category
61625 BLCKBRY4 230 61626 BOSWELL4 230 2 [1]	MP	438.0	139.5	140.1	3.4	BLCKBRY4 230 - BOSWELL4 230 1	B
6002:MHEX_S		1972.0	97.7	101.8	100.0	Base Case	A

Note 1: Boswell special protection system will automatically reduce generation at the Clay Boswell plant to mitigate this contingent overload

Table 2-8: A351 Thermal Constraints (30 MW MHEB-MISO to NSP)

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency	Category
61625 BLCKBRY4 230 61626 BOSWELL4 230 2 [1]	MP	438.0	140.1	140.3	3.6	BLCKBRY4 230 - BOSWELL4 230 1	B
6002:MHEX_S		1972.0	101.8	103.3	100.0	Base Case	A

Note 1: Boswell special protection system will automatically reduce generation at the Clay Boswell plant to mitigate this contingent overload

Table 2-9: A406 Thermal Constraints (250 MW MHEB-MISO to NSP)

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency	Category
61625 BLCKBRY4 230 61626 BOSWELL4 230 2 [1]	MP	438.0	140.3	142.6	3.4	BLCKBRY4 230 - BOSWELL4 230 1	B
67564 DORSEY 2 500 67566 DORSEYM4 230 52	MH	1200.0	93.4	106.2	47.5	DSY BK51 DORSEY 4 230 - DORSY2M4 230 51 DORSEY 2 500 - DORSY2M4 230 51 DORSY2T9 46.0 - DORSY2M4 230 51 Change bus 67503 DORSEY 4 230 load by 882.0 MW dispatch	B
67564 DORSEY 2 500 67598 DORSY2M4 230 51	MH	1200.0	94.1	106.2	47.9	DSY BK52 DORSEY 4 230 - DORSEYM4 230 52 DORSEY 2 500 - DORSEYM4 230 52 DORSEYT9 46.0 - DORSEYM4 230 52 Change bus 67503 DORSEY 4 230 load by 882.0 MW dispatch	B
6002:MHEX_S		1972.0	103.3	115.8	100.0	Base Case	A

Note 1: Boswell special protection system will automatically reduce generation at the Clay Boswell plant to mitigate this contingent overload

2.9 AFC Analysis

The AFC values for Midwest ISO and MAPP flowgates are posted for the next 36 months. For any flowgate impacted by the study transfers, the AFC values of those flowgates are considered. Note that minimum posted available transfer capacity on the MHEX_S flowgate is 100 MW, of which 57 MW corresponds to the Midwest ISO allocation. If A339 proceeds, the MHEX_S flowgate will not have sufficient transfer capability available for A340, and likewise if A340 proceeds, there would be no available capacity on the MHEX_S flowgate for A351 and A406.

2.9.1 A339 (80 MW MHEB-MISO to CIN)

For A339, the following flowgates have been identified as constraints to the transfer in the flow-based analysis. Note that minimum posted available transfer capacity on the MHEX_S flowgate is 100 MW, of which 57 MW corresponds to the Midwest ISO allocation.

Table 2-10: A339 Flow-Based Constraints

Flowgate Name	Limiting Constraint	Contingency	Rating (MVA)	Lowest Available Flowgate Capacity (pre-transfer)	TDF
MHEX_S	Letellier - Drayton 230 kV Dorsey - Roseau 500 kV Richer - Roseau 230 kV Glenboro - Rugby 230 kV	Base Case	1972	57 out of 100	100.00%
BREWHEJEFROC	Breed - Wheatland 345 kV	Jefferson-Rockport 765 kV	786	-150	26.39%
COOPER_S	Cooper - St. Joe 345 kV Cooper - Fairport 345 kV	Base Case	670	-472	17.62%
FTCAL_S	Fort Calhoun South	Base Case	451	-101	11.18%

2.9.2 A340 (80 MW MHEB-MISO to NSP)

For A340 the following flowgates are constraints to the transfer. Note that if A339 proceeds, then there is no available transfer capability along this flowgate for A340 and thus service could not be granted without transmission improvements.

Table 2-11: A340 Flow-Based Analysis Constraints

Flowgate Name	Limiting Constraint	Contingency	Rating (MVA)	Lowest Available Flowgate Capacity (pre-transfer)	TDF
MHEX_S	Letellier - Drayton 230 kV Dorsey - Roseau 500 kV Richer - Roseau 230 kV Glenboro - Rugby 230 kV	Base Case	1972	-23 [1]	100.00%

Note 1: AFC assuming A339 proceeds

2.9.3 A351 (30 MW MHEB-MISO to NSP)

For A351 the following flowgates are constraints to the transfer. Note that if A339 or A340 proceeds, then there is no available transfer capability along this flowgate for A351 and thus service could not be granted without transmission improvements.

Table 2-12: A351 Flow-Based Analysis Constraints

Flowgate Name	Limiting Constraint	Contingency	Rating (MVA)	Lowest Available Flowgate Capacity (pre-transfer)	TDF
MHEX_S	Letellier - Drayton 230 kV Dorsey - Roseau 500 kV Richer - Roseau 230 kV Glenboro - Rugby 230 kV	Base Case	1972	-103 [1]	100.00%

Note 1: AFC assuming A339 and A340 proceed

2.9.4 A406 (250 MW MHEB-MISO to NSP)

For A406 the following flowgates are constraints to the transfer. Note that if A339 or A340 proceeds, then there is no available transfer capability along this flowgate for A406 and thus service could not be granted without transmission improvements.

Table 2-13: A406 Flow-Based Analysis Constraints

Flowgate Name	Limiting Constraint	Contingency	Rating (MVA)	Lowest Available Flowgate Capacity (pre-transfer)	TDF
MHEX_S	Letellier - Drayton 230 kV Dorsey - Roseau 500 kV Richer - Roseau 230 kV Glenboro - Rugby 230 kV	Base Case	1972	-133	100.00%

Note 1: AFC assuming A339, A340 and A351 proceed

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Appendix

A

Network Analysis Results

Table A-1: Significantly Impacted Facilities

Monitored Branches	Owner	Rating	Benchmark Loading (%)	Post TSR Loading (%)	Contingency	Category
6002:MHEX_S		1972.0	93.7	115.8	Base Case	A
61625 BLCKBRY4 230 61626 BOSWELL4 230 2	MP	438.0	138.8	142.6	BLCKBRY4 230 - BOSWELL4 230 1	B
67564 DORSEY 2 500 67566 DORSEYM4 230 52	MH	1200.0	86.0	106.2	DSY BK51 DORSEY 4 230 - DORSY2M4 230 51 DORSEY 2 500 - DORSY2M4 230 51 DORSY2T9 46.0 - DORSY2M4 230 51 Change bus 67503 DORSEY 4 230 load by 882.0 MW dispatch	B
67564 DORSEY 2 500 67598 DORSY2M4 230 51	MH	1200.0	86.7	106.2	DSY BK52 DORSEY 4 230 - DORSEYM4 230 52 DORSEY 2 500 - DORSEYM4 230 52 DORSEYT9 46.0 - DORSEYM4 230 52 Change bus 67503 DORSEY 4 230 load by 882.0 MW dispatch	B

Benchmark loading is loading in the benchmark case without study TSRs. Post TSR loading includes impact of all four near-term requests

Report R164-08

MHEB Group TSR System Impact Study
Out-Year Power Flow Analysis
MH to US Requests
Summer Peak / South Flow

Prepared for

Midwest ISO

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Revision History

Date	Description
3/11/2009	Original
6/26/2009	General revisions, removed Option 2, requests A339 and A406 have withdrawn; request A340 approved for 7 MW of service
7/17/2009	Incorporated study group comments

Contents

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Executive Summary

Several requests for long term firm transmission service have been made under the Midwest ISO's Open Access Transmission and Energy Markets Tariff. This report presents the results of a steady-state power flow analysis performed on a summer peak scenario to evaluate the requests for transmission service shown in Table E-1. These requests seek to reserve 1130 MW of transmission service from Manitoba Hydro to various sinks in US.

Table E-1: MHEB Group TSR MH to US Requests

Oasis Ref No	Service Type	Start Time	Stop Time	POR	POD	Requested Capacity	Queue Date	Study Number
76703536	Network	Nov-2014	Nov-2024	MHEB-MISO	GRE	200	12/7/2006	A388
76703535	Network	Apr-2008	Apr-2013	MHEB-MISO	NSP	30	1/26/2007	A351
76703671	Network	Jun-2017	Jun-2027	MHEB-MISO	WPS	500	6/12/2007	A380
76703672	Network	Jun-2017	Jun-2037	MHEB-MISO	MP	250	7/6/2007	A383
76703686	Network	Jun-2017	Jun-2027	MHEB-MISO	NSP	50	4/17/2008	A416
76703687	Network	Jun-2017	Jun-2027	MHEB-MISO	WEC	100	4/17/2008	A417
					Total (MW)	1130		

This study was performed by Siemens PTI under the direction of Midwest ISO and an Ad Hoc Study Group consisting of American Transmission Company (ATC LLC), Basin Electric Power Cooperative (BEPC), Dairyland Power Cooperative (DPC), Great River Energy (GRE), Manitoba Hydro (MHEB), Minnesota Power (MP), Minnkota Power Cooperative (MPC), Otter Tail Power (OTP), Western Area Power Administration (WAPA) and Xcel Energy (XEL).

Transmission Upgrade Options

The transmission upgrade options proposed by the ad hoc study group are summarized in Table E-2 along with their cost estimates. The cost estimates are for the new 500 kV transmission lines only and are based on $/mile costs taken from the JCSP 2008 Interim Stakeholder Meeting Introduction Presentation[1] and adjusted down from 2024 dollars to 2018 dollars using a 3% escalation factor. The costs for series compensation, transformers, line terminations and other required substation equipment are not included in this preliminary estimate. These costs will be further developed and refined in the Facilities study.

System diagrams depicting the two proposed upgrade options are included in Appendix B.

Table E-2:-Transmission Upgrade Options

Option No.	Project	Cost in 2018[1]
1	Dorsey – Maple River 50% series compensated 500 kV line with one 500/345 kV, 1200 MVA transformer at Maple River. Maple River – Helena 50% series compensated 500 kV line terminated with two 500/345 kV, 1200 MVA transformers at Helena.	$1.035 B
3	Dorsey – King 50% series compensated 500 kV line terminated via two 500/345 kV, 1200 MVA transformers at King.	$955 M

Note 1: Cost estimates are for transmission lines only

The transmission upgrade options evaluated in this study do not include shunt reactors to compensate for capacitive generation on the new 500 kV lines. Both Option 1 and Option 3 will require shunt reactors on the 500 kV line to control voltage when the line is open-ended. In option 3, the steady-state voltage is around 1.2 per unit at the series capacitor on the Dorsey-King 500 kV line and the series capacitors will need to be designed accordingly.

Contingencies that simulate the outage of new 500 kV facilities associated with upgrade Option 1 or Option 3 were not modeled with HVDC reduction. Existing 500 kV and 230 kV triggers to the Manitoba Hydro HVDC power order reduction scheme were simulated in the contingency analysis.

Transmission Service Impacts

A benchmark power flow model representing 2017 summer peak system conditions was created without the requested transmission service. TSR study cases were created by adding the requested transmission service to the benchmark case along with one of two transmission upgrade options. Using the benchmark case as a reference, the total system losses within the study area increase by 11.5% (Option 3) to 12.1% (Option 1). Option 3 is 14 MW more efficient compared with Option 1.

A nonlinear (ac) contingency analysis was performed and the combined impact of the transmission upgrades and the 1130 MW aggregate study TSRs were evaluated by comparing flows and voltages in the benchmark and study cases. Linear (dc) analysis was

[1] http://www.midwestmarket.org/publish/Document/81d7e_11b6e66e758_-795e0a48324a/Interim%20Presentation.pdf?action=download&_property=Attachment

used to calculate distribution factors for each TSR and the distribution factors were used to identify the incremental impact of adding each TSR sequentially in queue date order.

Facilities that are constraints to one or more TSRs are summarized in Table E-3. Constraints to individual TSRs are described below the table.

Table E-3: Thermal Constraints

Monitored Element	Owner	Rating (MVA)	Option 1 Study Case	Option 3 Study Case	Contingency
Saratoga-Petenwell 138 kV line	ATC	72.2	X	X	Multiple Contingencies: C:ATC-ARP-OG1 C:ATC-ARP-OG2 C:ATC-ZN1-2
East Krok-Kewaunee 138 kV line	ATC	272.6	X	X	C:North Appleton-Kewaunee 345 kV line
Jackson 161/69 kV transformer	NSP	47	X	X	Base Case and Multiple Contingences*: C:605292 MONROCO8 605298 SPARTA28 C:605322 TREMVAL8 605328 BLAIR 8 C:602029 TREMVAL5 605322 TREMVAL8

* Only worst 3 contingencies are listed

A388 (200 MW MHEB-MISO to GRE)

A388 is a request for 200 MW of network transmission service from MHEB-MISO to GRE. No constraints were identified for A388 for either of the transmission upgrade option.

A351 (30 MW MHEB-MISO to NSP)

A351 is a request for 30 MW of network transmission service from MHEB-MISO to NSP. No constraints were identified for A351 for either of the transmission upgrade option.

A380 (500 MW MHEB-MISO to WPS)

A380 is a request for 500 MW of network transmission service from MHEB-MISO to WPS. A380 constraints are summarized in Table E-4.

Table E-4: A380 Thermal Constraints

Study	Constraint	Rating (MVA)	Loading	
			Option 1	Option 3
A380	Saratoga-Petenwell 138 kV line	72.2	137.3%	136.7%
	East Krok-Kewaunee 138 kV line	272.6	101.2%	100.8%

A383 (250 MW MHEB-MISO to MP)

A383 is a request for 250 MW of network transmission service from MHEB-MISO to MP. No constraints were identified for A383 for either of the transmission upgrade option.

A416 (50 MW MHEB-MISO to NSP)

A416 is a request for 50 MW of network transmission service from MHEB-MISO to NSP. A416 constraints are summarized in Table E-5.

Table E-5: A416 Thermal Constraints

Study	Constraint	Rating (MVA)	Loading	
			Option 1	Option 3
A416	Jackson 161/69 kV transformer	47	160.8%	160.2%

A417 (100 MW MHEB-MISO to WEC)

A417 is a request for 100 MW of network transmission service from MHEB-MISO to WEC. A417 constraints are summarized in Table E-6.

Table E-6: A417 Thermal Constraints

Study	Constraint	Rating (MVA)	Loading	
			Option 1	Option 3
A417	Saratoga-Petenwell 138 kV line	72.2	143.6%	142.8%

Constraint Mitigation Costs

Estimated costs for resolving each of the TSR constraints during Summer Peak conditions are summarized in Table E-7. Impacted facilities are common to both Option 1 and Option 3. The costs are good faith estimates provided by the affected Transmission Owners and will be further developed and refined in the Facility Study.

Table E-7: Mitigation costs for constraints during Summer Peak conditions

Thermal Constraint	Mitigation required	Costs
Saratoga-Petenwell 138 kV line	Reconductor 22.7 mi of the line	$2,927,167
East Krok-Kewaunee 138 kV line	Replacing substation equipment at E. Krok	$1,000,000
Jackson 161/69 kV transformer	Replace with larger 161/69 kV transformer	$900,000
	Total	$4,827,167

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Section

1

Steady-State Analysis

1.1 Methodology

A benchmark power flow model representing 2017 Summer Peak system conditions was created without the requested transmission service. TSR study cases were created by taking the benchmark case and modeling the requested transmission service along with one of the transmission upgrade options. A nonlinear (ac) contingency analysis was performed and the combined impacts of the transmission upgrade options and the 1130 MW aggregate study TSRs were evaluated by comparing flows and voltages in the benchmark and study cases.

Linear (dc) analysis was used to calculate distribution factors for each TSR and the distribution factors were used to identify the incremental impact of adding each TSR sequentially in queue date order.

1.2 Computer Programs

Analysis was performed using PSS®E version 30.3 and PSS®MUST version 8.3.2.

1.3 Model Development

1.3.1 Summer Peak Benchmark Case

A summer peak benchmark case without the study TSRs and associated transmission upgrades was developed. The source was a 2017 summer peak MTEP08 case that includes the future transmission upgrades from MTEP 08 Appendices A and B listed in Appendix A of this report. Projects in MTEP 08 Appendix B have not yet been studied through the MTEP cost-allocation process. If any of the projects in MTEP 08 Appendix B do not get developed, as per the identified need (in MTEP), the study TSRs would be reevaluated to determine if they are potentially responsible for the cost of those projects or appropriate alternatives. In addition to future transmission upgrades, the benchmark case was updated to include all existing MH to US firm transmission service commitments, prior-queued transmission service requests (confirmed and study status) not already included in the MTEP case, network resource generation and miscellaneous updates and corrections as described in the following sections.

The benchmark power flow case was solved with transformer tap adjustment enabled, switched shunt adjustment enabled, area interchange enabled (ties only), phase shifter adjustment enabled and dc tap adjustment enabled.

1.3.1.1 Existing MH to US Firm Transmission Service

The summer peak benchmark case includes all existing firm transmission service commitments on the MHEX_S (Manitoba Hydro Export South) interface, as listed in Table 1-1 below.

Table 1-1: Existing Firm Transmission Service on MHEX_S Interface

TSR Ref# (MH OASIS)	POR	POD	Capacity (MW)	Start Time	End Time	Service
76703190	MH	NSP	30	11/1/2008	12/1/2009	YEARLY FIRM PTP
76703232	MH	NSP	30	5/1/2009	5/1/2012	YEARLY FIRM PTP
76703181	MH	MP	50	5/1/2009	5/1/2015	YEARLY FIRM PTP
76703231	MH	GRE	50	11/1/2008	11/1/2014	YEARLY FIRM PTP
76703238	MH	OTP	55	11/1/2008	5/1/2010	YEARLY FIRM PTP
76703207	MH	NSP	64	5/1/2009	5/1/2013	YEARLY FIRM PTP
76703187	MH	NSP	70	11/1/2008	5/1/2011	YEARLY FIRM PTP
76737070	MH	WPS	100	6/1/2009	6/1/2014	YEARLY FIRM PTP
76703186	MH	NSP	100	11/1/2008	5/1/2010	YEARLY FIRM PTP
76703221	MH	NSP	150	5/1/2009	11/1/2009	YEARLY FIRM PTP
76703222	MH	GRE	150	5/1/2009	11/1/2009	YEARLY FIRM PTP
76703218	MH	NSP	200	5/1/2009	11/1/2009	YEARLY FIRM PTP
76703237	MH	NSP	213	11/1/2008	11/1/2009	YEARLY FIRM PTP
76703234	MH	NSP	529	11/1/2008	5/1/2015	YEARLY FIRM PTP
76735261	MH	OTP	50	5/1/2009	5/1/2014	YEARLY FIRM PTP
76739827	MH	NSP	7	5/1/2009	5/1/2014	YEARLY FIRM PTP
		Total	1848 MW			

The resulting MHEX_S interface flow in the summer peak benchmark case is 1844.5 MW.

1.3.1.2 Prior-Queued WAPA TSRs

The following proposed generating facilities have TSRs under study on the WAPA OASIS and were added to the summer peak benchmark case.

- Culbertson Project GI-0708 + GI-0614a (120+10 MW)
- GI-0704 (240 MW)
- Minot (aka Mallard) Project GI-0503 + GI-0720 (100+25 MW)
- GI-0714 (100 MW)

Table 1-2: Firm TSRs on WAPA OASIS

TSR Ref# (WAPA OASIS)	Capacity (MW)	Start Time	End Time	Service
941998	100	10/1/2006	1/1/2015	YEARLY FIRM NITS
70992013	10	1/1/2008	1/1/2029	YEARLY FIRM NITS
71283528	240	6/1/2009	6/1/2034	YEARLY FIRM NITS
71372179	120	1/1/2009	1/1/2035	YEARLY FIRM NITS
71689351	25	6/1/2009	6/1/2029	YEARLY FIRM NITS
942047	100	10/1/2006	1/1/2015	YEARLY FIRM NITS
Total	595 MW			

The aggregate output of these generating facilities (595 MW) is dispatched against generation at Big Bend and Ft. Randall. Groton Unit 1 and Unit 2 are dispatched at 125 MW each.

1.3.1.3 Prior-Queued Midwest ISO TSRs

Table 1-3 shows prior-queued Midwest ISO TSRs and confirmed requests that were added to the summer peak benchmark case using sources and sinks provided by Midwest ISO.

Table 1-3: Midwest ISO TSRs Added to the SUPK Case

OASIS	OASIS #	STUDY	POR	POD	CAPACITY REQUESTED (MW)	START	STOP
MISO	75690167 75690165	A168	MP	NSP	35 (20+15)	6/1/2006 6/1/2006	6/1/2026 6/1/2026
MISO	76541075 76541076	A204	MP	MP	50 (25+25)	2/1/2008 2/1/2011	2/1/2009 2/1/2012
MISO	76109095	A230	WAUE	GRE	108	1/1/2008	1/1/2036
MISO	76414212	A301B	MP	GRE	100	6/1/2006	6/1/2008
MISO	76403280	A304	MHEB	MP	50	5/1/2009	5/1/2015
MISO	76434677	A316	OTP	OTP	50	2/1/2010	11/1/2028
MISO	76463020	A329	OTP	OTP	21	2/1/2007	1/1/2028
MISO	76480654	A335	GRE	GRE	68	4/1/2009	4/1/2029
MISO	76484129 76484130	A338	OTP	OTP	40 (20+20)	4/1/2014	1/1/2028
MISO	76488162	A341	WAUE	GRE	68	1/1/2008	1/1/2036
MISO	76463020	A345	WAUE	NSP	61	6/1/2009	6/1/2029
MISO	76515390	A365	WAUE	GRE	30	1/1/2009	1/1/2022
MISO	76526766	A374	OTP	OTP	49	11/1/2008	11/1/2028
MISO	76484129 76484130	A411	OTP	OTP	98 (50+48)	6/1/2009 10/1/2008	6/1/2069 10/1/2068
MISO	76659803	-	MP-ONT	MP	150	11/01/2008	11/01/2013
MISO	76668811	A373	MP	MP	100	7/1/2010	8/1/2015
MISO	76668831	A373	NSP	MP	100	7/1/2010	8/1/2015
MISO	76668843	A381	GRE	MP	200	7/1/2011	8/1/2016
MISO	76668850	A393	OTP	MP	100	7/1/2010	8/1/2015

1.3.1.4 Midwest ISO Network Resource Generation

The NR generating facilities listed in Table 1-4 were added to the summer peak benchmark case.

Table 1-4: Midwest ISO NR Generation Added to the SUPK Case

MISO Project Number	MISO Queue Number	MISO Queue Date	Control Area	County	Point of Interconnection	Max Output (MW)	Dispatch (MW)
G519	38491-01	19-May-05	MP	Itasca, MN	Blackberry 230/115kV Substation	600	600
G555	38649-02	24-Oct-05	OTP	Stevens, MN	2 miles north of the Morris substation on the Morris - Grand Co. 115 kV line	100	20
G586	38716-02	30-Dec-05	XEL	Lincoln, MN	Xcel New Yankee Sub 34.5 kV	30	6
G593	38755-01	07-Feb-06	ALTW	Jackson, MN	Lakefield Junct. - Triboji 161 kV line	100	20
G602	38771-01	23-Feb-06	XEL	Nobles, MN	Nobles County Sub along 161 kV NSP trans line	31.5	6.3
G618	38818-02	11-Apr-06	OTP	Yellow Medicine, MN	Burr Jct to Toronto 115 kV line located 5 miles from Camby	138	27.6
G619	38821-01	14-Apr-06	OTP	Otter Tail, MN	41 kV at Tamarac Sub (GRE)	50	10
G626	38832-02	25-Apr-06	XEL	Brown, MN	Morgan to Sleepy Eye line #0719 69 kV	31.5	6.3
G691	39006-02	16-Oct-06	XEL	Vernon, WI	Westby - Cashton tap 69 kV line	50	10
G767	39161-01	20-Mar-07	WAPA	Fallon, MT	Baker 60 kV	30	6
G843	39318-01	24-Aug-07	OTP	Otter Tail, MN	R37T131 Sec 3 Parkers Prairie Twp near the junction of State Highway 29 and Co Rd 138	100	20
G858	39329-01	04-Sep-07	XEL	Stearns, MN	Xcel Black Oak Switching Station on County Road 186 in Section 6 of Grove Township	38	7.6
G875	39364-03	09-Oct-07	OTP	Kittson/ Marshall, MN	115 kV line between Donaldson and Warsaw	80	16
G904	39388-01	02-Nov-07	OTP	Rolette, ND	Rugby-Glenboro 230kV Line	150	30
G930	39426-03	10-Dec-07	XEL	Sherburne, MN	Sherco Substation	120	120

1.3.1.5 Manitoba Hydro (MH) System Updates

The following transmission and generation facilities were added to the summer peak benchmark case to update the MH system representation and to facilitate high export at peak summer load:

- Bipole 3 and associated facilities at Riel
- Dorsey-Riel 500 kV circuit #2
- Dorsey-Portage 230 kV line
- Laverendrye-St Vital 230 kV line
- Letellier-St Vital 230 kV line
- Pointe du Bois rebuilt generating plant at 120 MW
- St Joseph wind farm (2 x 150 MW)
- Keeyask generating plant (7 x 90 MW)
- Conawapa generating plant (10 x 130 MW)

The aggregate injection from the three HVDC bipoles was set at 3400 MW in the benchmark case as follows:

- Bipole 1 = 800 MW
- Bipole 2 = 940 MW
- Bipole 3 = 1660 MW

1.3.1.6 Miscellaneous Updates and Corrections

Table 1-5 shows other miscellaneous model updates.

Table 1-5: Miscellaneous Updates and Corrections

Area	Description
ATC	Redispatched generation in control areas ALTE and WEC so that area slack generator output is within limits
MH, SPC	Reduced net flow on MH-SPC ties to 0 MW
MH	Add 3x73.4 MVar shunt capacitors on 46-kV tertiary of Riel 500/230-kV transformer.
WAPA	Topology corrections at Penn 115 kV and Hilken 230 kV buses
WAPA	Purged extraneous 230/115/13.2 kV transformer at Winger and Canby 345 kV-Granite Falls 230 kV line.
WAPA	Dispatched Leland Olds Unit #1 at 225 MW
XEL/ WAPA	Turned on Forbes SVC and adjust SVC output at Forbes, Fargo and Watertown
XEL	Removed extraneous BRIGO facilities
XEL	Dispatched River Falls generation
XEL	Updated facility ratings for M602F, F601C and Coon Creek – Kolman Lake
XEL	Changed Forbes SVC rating from +400/-450 Mvar (10 second capability) to +110/-149 Mvar (continuous).

1.3.2 Summer Peak Study Cases

TSR study cases were created by taking the benchmark case and modeling the requested transmission service along with one of the transmission upgrade options. Losses for each TSR study case are summarized in Appendix C.

1.3.2.1 Source and Sinks for Study TSRs

The TSR source is the Dorsey inverter station and the 1130 MW aggregate study TSRs were sunk by increasing the injection from the existing two HVDC bipoles at Dorsey from 1740 MW in the benchmark case to 2870 MW in the study case. The study TSRs were sunk at the generators shown in Table 1-6.

Table 1-6: MH to US TSR Sinks

Bus #	Generator Name	MW
	REMOVED	

1.3.2.2 Transmission Upgrade Options

The transmission upgrade options proposed by the ad hoc study group are summarized in Table 1-7.

System diagrams depicting the proposed upgrade options are included in Appendix B.

Table 1-7: Transmission Upgrade Options

Option No.	Project
1	Dorsey – Maple River 50% series compensated 500 kV line with one 500/345 kV, 1200 MVA transformer at Maple River. Maple River – Helena 50% series compensated 500 kV line terminated with two 500/345 kV, 1200 MVA transformers at Helena.
3	Dorsey – King 50% series compensated 500 kV line terminated via two 500/345 kV, 1200 MVA transformers at King.

The transmission upgrade options evaluated in this study do not include shunt reactors to compensate for capacitive generation on the new 500 kV lines. Both Option 1 and Option 3 will require shunt reactors on the 500 kV line to control voltage when the line is open-ended. In option 3, steady-state voltage is around 1.2 per unit at the series capacitor on the Dorsey-King 500 kV line and the series capacitors will need to be designed accordingly.

```
OPTION 3 BUSES WITH VOLTAGE GREATER THAN 1.1000:

   BUS#  X-- NAME --X  BASKV   V(PU)   V(KV)
 601061  MIDCOMP-N    500.00  1.1900  595.01
 601062  MIDCOMP-S    500.00  1.1415  570.74
```

1.4 Contingency Criteria

A variety of system conditions are considered for the steady-state analysis.

- NERC Category A with system intact (no contingencies)
- NERC Category B contingencies
  - Outage of single element 100 kV or higher (B.2 and B.3) associated with single contingency event in the following areas: ATCLLC (WEC, ALTE, WPS, MGE, UPPC), DPC, GRE, ITC Midwest, MH, MP, OTP, SMMPA, WAPA, XEL
  - Outage of multiple-elements 100 kV or higher (B.2 and B.3) associated with single contingency event in the Dakotas, Manitoba, Minnesota, Wisconsin

Contingencies that simulate the outage of new 500 kV facilities associated with upgrade Option 1 or Option 3 do not trigger HVDC reduction. Existing 500 kV and 230 kV triggers to the Manitoba Hydro HVDC power order reduction scheme were simulated in the contingency analysis.

For all contingency and post-disturbance analyses, the power flow cases are solved with transformer tap adjustment and switched shunt adjustment enabled, area interchange adjustment disabled, and phase shifter adjustment plus dc tap adjustment disabled.

1.5 Monitored Facilities

Monitored facilities and associated thermal and voltage limits are shown in Table 1-8.

Table 1-8: Monitored Facilities and Limits

Owner/ Area	Monitored Facilities	Thermal Limits [1]		Voltage Limits
		Pre-Disturbance	Post-Disturbance	
ATC LLC	69 kV and above	95% of Rate A	95% of Rate B	1.10/0.90
BEPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
DPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
GRE	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.92/0.90 [2]
ITCMW	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
MDU	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
MEC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
MH	69 kV and above	100% of Rate A	100% of Rate B	1.15/1.10/0.94/0.90 [3]
MP	69 kV and above	100% of Rate A	100% of Rate B	1.05/0.95
MPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
MRES	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
NWPS	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
OTP	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90

Owner/ Area	Monitored Facilities	Thermal Limits [1]		Voltage Limits
		Pre-Disturbance	Post-Disturbance	
RPU	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
SMMPA	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
SPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
WAPA	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
XEL	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90

Note 1: PSSE Rate A or Rate B
Note 2: 0.92 limit applies to load serving buses
Note 3: Limits dependent on nominal bus voltage

1.6 Reliability Margins

Flowgate ratings for this out-year analysis are based on facility ratings and do not consider capacity benefit margin (CBM) or transmission reliability margin (TRM). All other system elements were monitored as shown in Table 1-8.

1.7 Performance Criteria

A branch or flowgate is considered a significantly affected facility if both of the following conditions are met for the transmission service under study:

1) the facility is loaded above its applicable normal or emergency rating in the study case, and
2) the power transfer distribution factor (PTDF) is greater than 5% or the outage transfer distribution factor (OTDF) is greater than 3% for the overloaded facility.

Distribution factors for each TSR are calculated using linear (dc) analysis.

A voltage impact is considered significant if both of the following conditions are met for the transmission service under study:

1) the bus voltage is outside of applicable normal or emergency limits in the study case, and
2) the impact of the requested service on bus voltage is greater than 0.01 per unit.

1.8 Network Analysis Results

1.8.1 Impact on System Losses

The combined impact of the transmission upgrades and the aggregate TSRs (1130 MW) on system losses is shown in Appendix C, Table C-1. For each upgrade option, the change in system losses within the study area is tabulated. Although the real power losses occurring in the upgrade facilities comprising Option 1 are lower than in Option 3, the net change in system real power losses (compared to the benchmark case) is higher for Option 1 (237 MW increase) compared to Option 3 (223 MW increase).

1.8.2 Transmission Service Impacts

Table C-2 in Appendix C shows the combined impact of the transmission upgrades and the aggregate TSRs (1130 MW) on facilities impacted by one or more TSR. A thermal impact is considered significant if the facility loading exceeds the limit shown in Table 1-8 and the distribution factor exceeds the threshold given in Section 1.7. There are no significant voltage impacts attributable to any TSR.

1.8.2.1 A388 (200 MW MHEB-MISO to GRE)

A388 is a request for 200 MW of network transmission service from MHEB-MISO to GRE. With respect to request A388, no significantly affected facilities were identified for either of the transmission upgrade options.

1.8.2.2 A351 (30 MW MHEB-MISO to NSP)

A351 is a request for 30 MW of network transmission service from MHEB-MISO to NSP. With respect to request A351, no significantly affected facilities were identified for either of the transmission upgrade options.

1.8.2.3 A380 (500 MW MHEB-MISO to WPS)

A380 is a request for 500 MW of network transmission service from MHEB-MISO to WPS. Request A380 has a significant thermal impact on the facilities shown in Table 1-11.

With respect to request A380, two significantly affected facilities are common to both transmission upgrade options: the Saratoga-Petenwel 138 kV line, and the East Krok-Kewaunee 138 kV line. Both facilities are constraints with either option.

1.8.2.4 A383 (250 MW MHEB-MISO to MP)

A383 is a request for 250 MW of network transmission service from MHEB-MISO to MP. With respect to request A388, no significantly affected facilities were identified for either of the transmission upgrade options.

1.8.2.5 A416 (50 MW MHEB-MISO to NSP)

A416 is a request for 50 MW of network transmission service from MHEB-MISO to NSP. Request A416 has a significant thermal impact on the facilities shown in Table 1-13.

With respect to request A416, the Jackson 161/69 kV transformer is a constraint with either option.

1.8.2.6 A417 (100 MW MHEB-MISO to WEC)

A417 is a request for 100 MW of network transmission service from MHEB-MISO to WEC. Request A417 has a significant thermal impact on the facilities shown in Table 1-14.

With respect to request A417, the Saratoga-Petenwel 138 kV line is a constraint with either option.

With upgrade Option 1, the Letellier-Drayton 230 kV line loading is just under (99.9%) the 460.5 MVA emergency rating with the Dorsey-King 500 kV line out of service without HVDC reduction. This is not a constraint because the loading does not exceed the emergency rating.

Table 1-9: A388 Thermal Violations (200 MW MHEB-MISO to GRE)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
No significantly affected facilities						

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
No significantly affected facilities						

Table 1-10: A351 Thermal Violations (30 MW MHEB-MISO to NSP)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
No significantly affected facilities						

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
No significantly affected facilities						

Table 1-11: A380 Thermal Violations (500 MW MHEB-MISO to WPS)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	98.3	137.3	5.6	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	90.5	127.9	5.4	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	94.5	132.2	5.4	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699619 EAST KRK 138 699620 KEWAUNEE 138 1	ATC	272.6	87.8	101.2	7.3	C:699359 N APP 1 345 699630 KEWAUNEE 345 1

Table 1-11 (continued): A380 Thermal Violations (500 MW MHEB-MISO to WPS)

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	97.9	136.7	5.6	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	90.2	127.3	5.4	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	94.7	132.2	5.4	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699619 EAST KRK 138 699620 KEWAUNEE 138 1	ATC	272.6	87.5	100.8	7.2	C:699359 N APP 1 345 699630 KEWAUNEE 345 1

Table 1-12: A383 Thermal Violations (250 MW MHEB-MISO to MP)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
No significantly affected facilities						

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
No significantly affected facilities						

Table 1-13: A416 Thermal Violations (50 MW MHEB-MISO to NSP)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
602022 JACKSON5 161 605309 JACKCO 8 69.0 1	XEL	47.0	153.3	160.8	7.1	C:605292 MONROCO8 69.0 605298 SPARTA28 69.0 1
602022 JACKSON5 161 605309 JACKCO 8 69.0 1	XEL	47.0	131.0	137.5	6.2	C:605322 TREMVAL8 69.0 605328 BLAIR 8 69.0 1
602022 JACKSON5 161 605309 JACKCO 8 69.0 1	XEL	47.0	127.7	133.8	5.7	C:602029 TREMVAL5 161 605322 TREMVAL8 69.0 1
602022 JACKSON5 161 605309 JACKCO 8 69.0 1 [1]	XEL	47.0	101.2	107.0	5.5	** Base Case **

Note: Jackson 161-69 kV transformer overloads above 115% for several contingencies (worst three overloads listed)

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
602022 JACKSON5 161 605309 JACKCO 8 69.0 1	XEL	47.0	152.7	160.2	7.1	C:605292 MONROCO8 69.0 605298 SPARTA28 69.0 1
602022 JACKSON5 161 605309 JACKCO 8 69.0 1	XEL	47.0	130.8	137.3	6.2	C:605322 TREMVAL8 69.0 605328 BLAIR 8 69.0 1
602022 JACKSON5 161 605309 JACKCO 8 69.0 1	XEL	47.0	127.7	133.8	5.7	C:602029 TREMVAL5 161 605322 TREMVAL8 69.0 1
602022 JACKSON5 161 605309 JACKCO 8 69.0 1	XEL	47.0	101.4	107.2	5.5	** Base Case **

Note: Jackson 161-69 kV transformer overloads above 115% for several contingencies (worst three overloads listed)

Table 1-14: A417 Thermal Violations (100 MW MHEB-MISO to WEC)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	138.5	143.6	3.6	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	129.1	133.8	3.4	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	133.5	138.3	3.4	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1

Table 1-14 (continued): A417 Thermal Violations (100 MW MHEB-MISO to WEC)

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	137.9	142.8	3.6	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	128.4	133.1	3.4	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	133.5	138.2	3.4	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1

Appendix

A

MTEP Projects Applied from MOD

Transmission Owner	MTEP Project ID	Project Name	MTEP Appendix
ATC LLC	345	Morgan - Werner West 345 kV line (includes Clintonville-Werner West 138)	A
XEL	1486	Mary Lake - City of Buffalo 69 kV line 116 MVA	A
XEL/SMP		SMP-GRANDMEADOW-WF	B
XEL	2119	G417	A
ITC	905	Marysville Decommissioning	A
ITCM	1758	Beaver Channel-2nd Ave 69kV	A
ITCM	1755	Washington-Hills 69kV Rebuild	A
ITCM	1752	Jefferson Co 69kV Cap banks	A
ITCM	1751	Jefferson Co 161/69kV	A
ITCM	1289	Marshalltown - Toledo - Belle Plaine - Stoney Point 115 kV line rebuild	A
SMP	1367	Lake City load serving upgrades	A
ATC LLC	352	Cranberry-Conover 115 kV and Conover-Plains conversion to 138 kV	A
ITCM	1522	6th Street - Beverly	A
ATC LLC	570	Rock River-Bristol-Elkhorn conversion to 138 kV	A
ATC LLC	177	Gardner Park-Highway 22 345 kV line projects	A
ATC LLC	345	Morgan - Werner West 345 kV line (includes Clintonville-Werner West 138)	A
ATC LLC	1268	Cap banks at Artesian and Kilbourn	A
ATC LLC	1677	Uprate Chandler-Cornell 69 kV line	A
XEL	1371	Black Dog - Wilson 115 kV #2 Reconductor	A
XEL	1457	G287, 37642-03. Upgrades for G287	A
XEL	1548	La Crosse Area Capacitor banks	A
XEL	385	Xcel Energy Wind 425-825 MW project	A
XEL	1489	Woodbury - Tanners Lake upgrade	A
ITCM	1341	Replace two Hazleton 161/69 kV transformers	A
ITCM	1287	Replace Salem 345/161 kV transformer with 448 MVA unit	A
XEL	1487	Somerset - Stanton 69 kV line 84 MVA	A
XEL	1368	Three Lakes 115/69 kV substation	A
XEL	1548	La Crosse Area Capacitor banks	A
XEL	1455	G238, 37642-02, Increase of generating capacity at Riverside Generating Plant	A
XEL	1373	Ft. Ridgeley - Searles Jct 115 new line and Searles Jct - New Ulm 69 Reconductor	A
XEL	1457	G287, 37642-03. Upgrades for G287	A
ATC LLC	1279	North Beaver Dam 49 MVAR cap bank	A

Transmission Owner	MTEP Project ID	Project Name	MTEP Appendix
ITC	1488	Break up 3-ended Prizm-Proud-Placid 120 kV line	A
ATC LLC	345	Morgan - Werner West 345 kV line (includes Clintonville-Werner West 138)	A
XEL	552	Ironwood 92/34.5 kV transformer #2	A
ATC LLC	1681	Uprate North Lake Geneva-Lake Geneva 69 kV line	A
ATC LLC	1944	G550 Uprate Concord generators #3 & #4	C
ATC LLC	1682	Rebuild Crivitz-High Falls Dbl Ckt 69 kV line	A
ATC LLC	1679	Richland Center Olson sub and Brewer Sub Capacitor banks	A
OTP/MPC	2091	Cass Lake 115/69/41.6 kV sub	A
OTP	2092	South Cascade 115 kV Addition	A
MP/GRE	1022	Badoura-Long Lake 115 kV line	A
ATC LLC	1555	Perkins Capacitor Banks	A
ITC	1871	Hurst	A
XEL/GRE	1545	Mankato 115 kV loop	A
ATC LLC	1676	L'Anse Capicitor Bank	A
ATC LLC	1553	Hiawatha 138kV Capacitor Bank	A
ATC LLC	352	Cranberry-Conover 115 kV and Conover-Plains conversion to 138 kV	A
ATC LLC	339	Lake Mills Transmission-Distribution interconnection	A
ATC LLC	339	Lake Mills Transmission-Distribution interconnection	A
ATC LLC	345	Morgan - Werner West 345 kV line (includes Clintonville-Werner West 138)	A
OTP	1792	Mapleton - Buffalo 115 kV line addition	A
ATC LLC	1667	Pine River substation Upgrades	A
ATC LLC	177	Gardner Park-Highway 22 345 kV line projects	A
GRE	599	Crooked Lake - Enterprise Park 115 kV line	A
XEL	1956	Blue Lake - Wilmarth 345 kV line capacity upgrade	A
ITC	1870	Clyde	A
ATC LLC	345	Morgan - Werner West 345 kV line (includes Clintonville-Werner West 138)	A
ITCM	1644	Grand Junction 24 MVAR Cap Bank	A
ITCM	1643	Anita 24 MVAR Cap Bank	A
ITCM	1739	Arnold-Vinton-Dysart-Washburn 161kV Reconductor	A
ITCM	1641	OGS 50 MVAR Cap Bank	A
ITCM	1619	Grnd Mnd 161-69kV 2nd Xfmr & 161kV loop	A
MP	277	Badoura Project: Pine River - Pequot Lakes 115 kV line	A
MP/GRE	1021	Embarass to Tower 115 kV Line	A
ATC LLC	1268	Cap banks at Artesian and Kilbourn	A
ATC LLC	1938	G366, 37909-02 Randolph Wind Farm	C
ATC LLC	1143	G282, 37628-02	C
ATC LLC	2057	Warrens T-D	A
ATC LLC	1945	Upgrade Sheekskin Capacitor 69-kV Bank	A
ATC LLC	1680	Uprate Walworth-North Lake Geneva 69 kV line	A
XEL	1959	Yankee Doodle interconnection	A
ATC LLC	1939	G588, Marshfield CT	C
MP/GRE	1022	Badoura-Long Lake 115 kV line	A

Transmission Owner	MTEP Project ID	Project Name	MTEP Appendix
ATC LLC	352	Cranberry-Conover 115 kV and Conover-Plains conversion to 138 kV	A
XEL	1368	Three Lakes 115/69 kV substation	A
ATC LLC	352	Cranberry-Conover 115 kV and Conover-Plains conversion to 138 kV	A
ATC LLC	1683	Rebuild Sunset Point-Pearl Ave 69 kV line	A
ITC	1873	Tahoe	A
Midwest ISO	2194	MTEP08 Reference Future EHV Overlay - Toledo to Montgomery	A
ITCM	1342	Lewis Fields 161 kV substation which taps the SwampFX - Coggon 115 kV line	A
ATC LLC	1267	New Oak Ridge-Verona 138-kV line and a 138/69-kV transformer at Verona	A
XEL	56	Chisago - Apple River	A
OTP	973	Big Stone II Generation Project	B
XEL	1953	St. Cloud - Sauk River 115 kV line upgrade	A
XEL	1961	Lake Emily Capacitor bank	A
MP	1482	Pepin Lake 115/34.5 - Transformer 115/34.5 kV 39 MVA	A
OTP/MPC	971	Winger 230/115 kV Transformer Upgrade	A
ITCM	1288	Replace Hazleton 345/161 kV transformer #1 with 335 MVA unit	A
ITCM	1289	Marshalltown - Toledo - Belle Plaine - Stoney Point 115 kV line rebuild	A
ITCM	1618	Hrn Lk-Lkfld 161kV Ckt 1 Rbld	A
XEL	1960	Traverse - St. Peter upgrade	A
XEL	675	Rebuild Westgate to Scott County 69 kV to 115 kV	A
XEL	1285	Build 18 miles 115 kV line from Glencoe - West Waconia	A
XEL	2109	G609	A
XEL	1954	Cherry Creek - Split Rock 115 kV line saperation	A
GRE/OTP	1033	Silver Lake 230/41.6 kV transformer	A
OTP	973	Big Stone II Generation Project	B
ITC	907	Goodison Station (Oakland)	A
ITCM	1345	Replace the limiting facility of CTs and conductor inside the substations for Quad Cities-Rock Creek-Salem 345 kV line	A
ITCM	1340	Hazleton - Salem 345 kV line with a 2nd Salem 345/161 kV 448 MVA transformer.	A
ITC	692	Bismark-Troy 345 kV line	A
OTP	973	Big Stone II Generation Project	B
ATC LLC	1470	G483	A
XEL	1957	New 161/69 kV Sub SW of Eau Claire where Alma – Elk Mound 161 kV intersects Shawtown – Naples 69 kV line. Rebuild 69 kV London/Madison to new substation. New 69 kV from new substation - DPC Union Sub. New 69 kV to DPC Brunswick Sub	A
OTP	973	Big Stone II Generation Project	B
MPC/XEL/OTP/MP	279	Bemidji-Grand Rapids 230 kV Line	A
XEL	1958	Stone Lake-Edgewater 161 kV line. A new radial 161 kV line and substation in Sawyer County, Wisconsin	A
ATC LLC	1617	G527	A
ATC LLC	574	Monroe County - Council Creek 161 kV line projects	A
ATC LLC	574	Monroe County - Council Creek 161 kV line projects	A
ATC LLC	356	Rockdale-West Middleton 345 kV	A

Transmission Owner	MTEP Project ID	Project Name	MTEP Appendix
OTP	973	Big Stone II Generation Project	B
GRE, XEL, OTP, MP, MRES	286	Fargo, ND - St Cloud/Monticello, MN area 345 kV project	A
XEL	1957	New 161/69 kV Sub SW of Eau Claire where Alma – Elk Mound 161 kV intersects Shawtown – Naples 69 kV line. Rebuild 69 kV London/Madison to new substation. New 69 kV from new substation - DPC Union Sub. New 69 kV to DPC Brunswick Sub	A
XEL/GRE	1203	Brookings, SD - SE Twin Cities 345 kV project	B
OTP	973	Big Stone II Generation Project	B
XEL, DPC, RPU, SMP, WPPI	1024	SE Twin Cities - Rochester, MN - LaCrosse, WI 345 kV project	A
OTP	585	Pelican Rapids 115 kV Line Uprate	B
ATC LLC	1463	Twin_Creeks-G384	N/A
ITCM	1645	Leon-1645_69kV_7MVAR	N/A
ITCM	1772	N_Cntrville_69kV-1772_7MVA	N/A
WAPA, BEPC	Correction	Su2009+-SplitWess	N/A
GRE	Network	KRMRLK(53801)	N/A
XEL	1380	WWACONIA-SCOTT	N/A

N/A – These projects have been withdrawn and no longer appear in MTEP Appendix A/B.

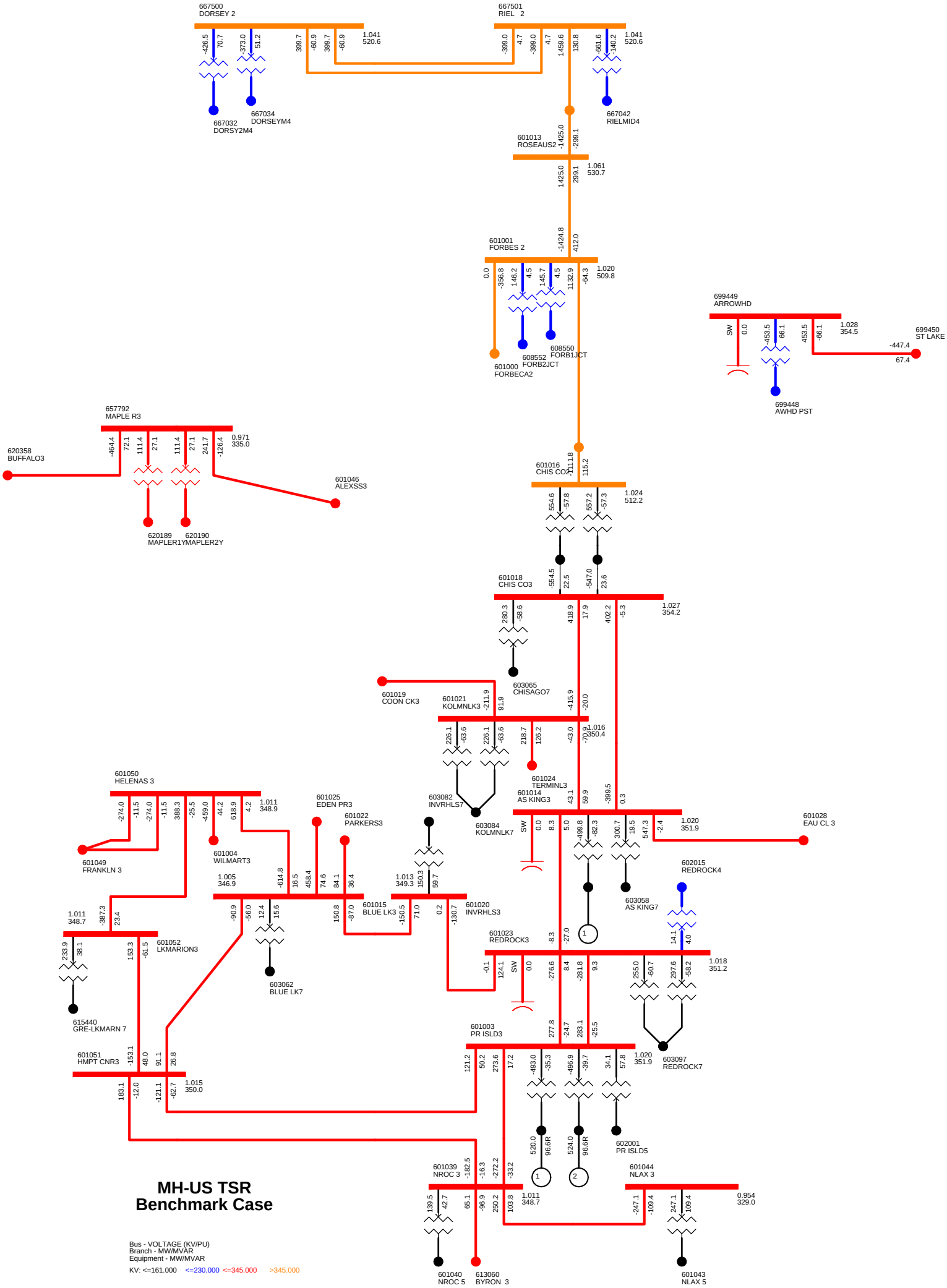
Appendix

B

Transmission Upgrade Options

Table B-1: Modeling Parameters

Facility	R (pu)	X (pu)	B (pu)	Rate A (MVA)	Rate B (MVA)
Dorsey – Maple River 500 kV line with 50% series compensation	0.00290	0.04830 -0.02415	4.30	1732 1732	1905 2165
Maple River – Helena 500 kV line with 50% series compensation	0.00252	0.04200 -0.02100	3.74	1732 1732	1905 2165
Dorsey – King 500 kV line with 50% series compensation	0.00600	0.10700 -0.05350	10.00	1732 1732	1905 2165
500/345 kV, 1200 MVA Transformer One at Maple River (Option1) Two at Helena (Option 1) Two at King (Option 3)	0.000050	0.004700		1200	1200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601001
FORBES 2
601000
FORBECA2
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FORB2JCT
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FORB1JCT
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ARROWHD
699450
ST LAKE
699448
AWHD PST
657792
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BUFFALO3
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MAPLER1Y
620190
MAPLER2Y
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ALEXSS3
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CHIS CO2
601018
CHIS CO3
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CHISAGO7
601019
COON CK3
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KOLMNLK3
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TERMINL3
603082
INVRHLS7
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AS KING3
603084
KOLMNLK7
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EAU CL 3
602015
REDROCK4
603058
AS KING7
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HELENAS 3
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FRANKLN 3
601004
WILMART3
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EDEN PR3
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PARKERS3
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BLUE LK3
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INVRHLS3
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LKMARION3
603062
BLUE LK7
615440
GRE-LKMARN 7
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REDROCK3
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PR ISLD3
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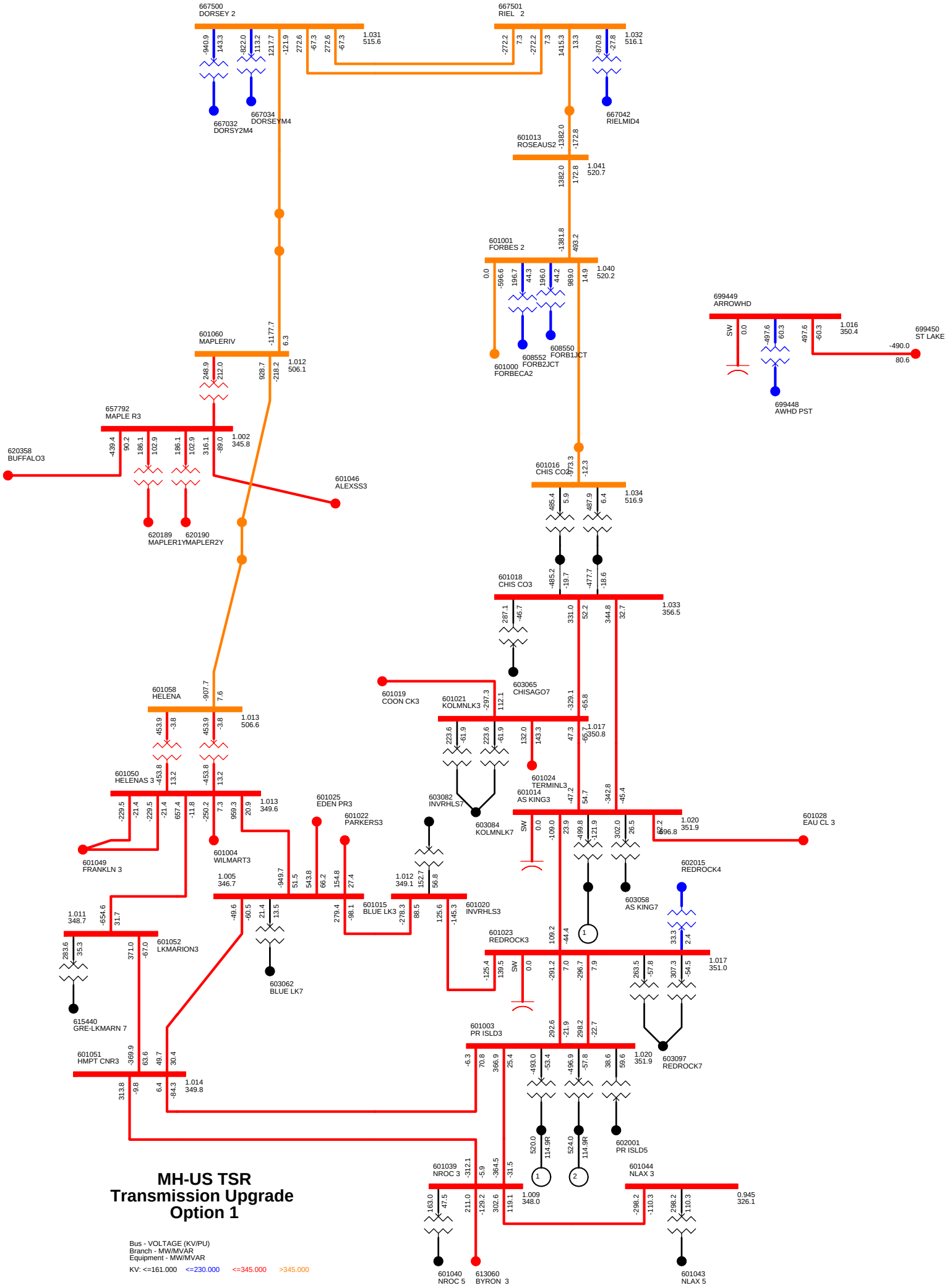
REDROCK7
601051
HMPT CNR3
602001
PR ISLD5
601039
NROC 3
601044
NLAX 3
601040
NROC 5
613060
BYRON 3
601043
NLAX 5
MH-US TSR
Benchmark Case
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000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REDROCK3
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351.0
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1.020
351.9
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REDROCK7
601051
HMPT CNR3
1.014
349.8
602001
PR ISLD5
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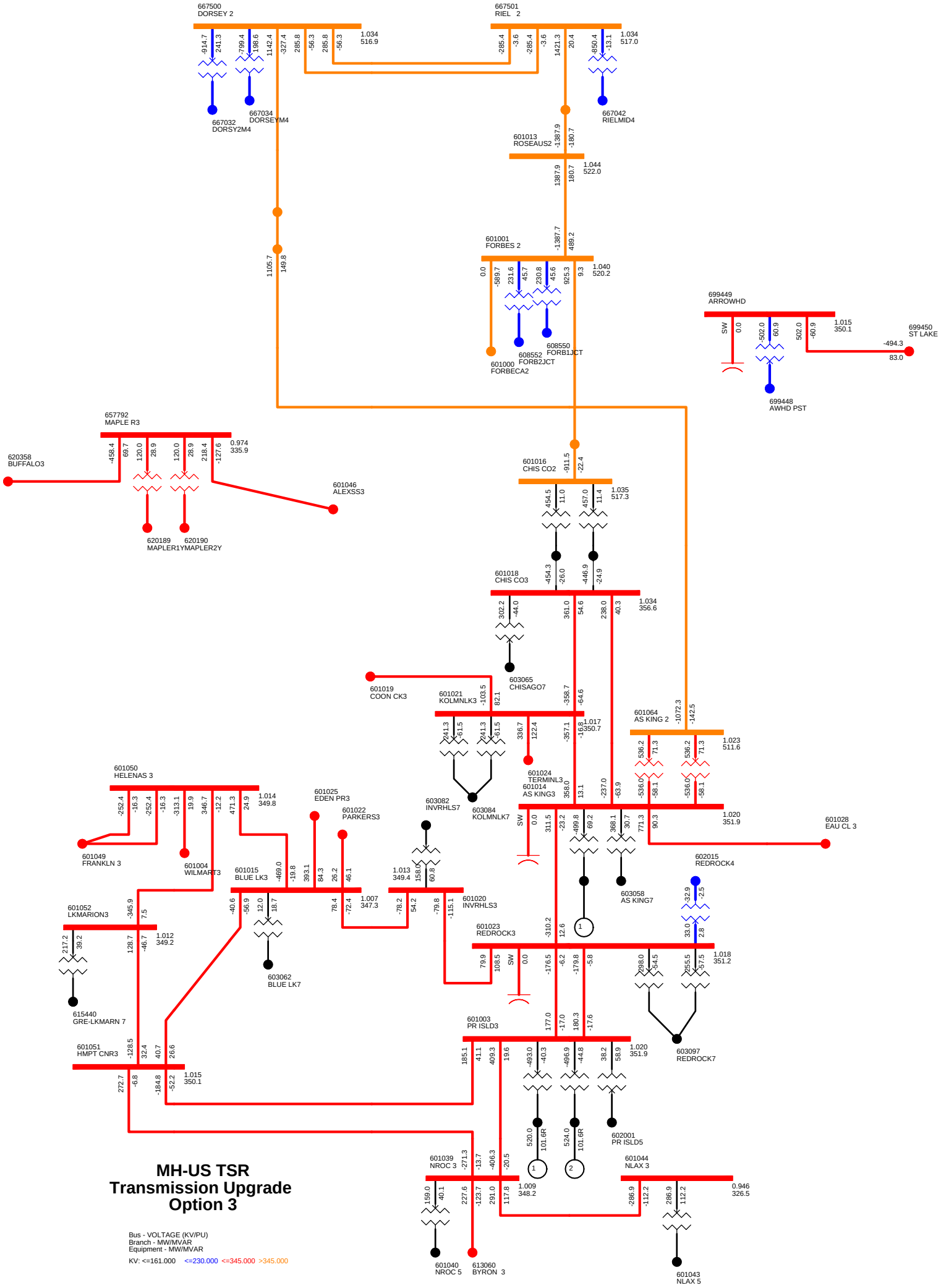
NROC 3
1.009
348.0
601044
NLAX 3
0.945
326.1
601040
NROC 5
613060
BYRON 3
601043
NLAX 5
MH-US TSR
Transmission Upgrade
Option 1
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000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ROSEAUS2
601001
FORBES 2
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ARROWHD
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601018
CHIS CO3
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CHISAGO7
601019
COON CK3
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KOLMNLK3
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601024
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601051
HMPT CNR3
601023
REDROCK3
603097
REDROCK7
601003
PR ISLD3
602001
PR ISLD5
601039
NROC 3
601040
NROC 5
613060
BYRON 3
601044
NLAX 3
601043
NLAX 5
MH-US TSR
Transmission Upgrade
Option 3
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000

Appendix

C

Network Analysis Results

Table C-1: Network Loss Analysis Results

Area	Benchmark Case Losses	Option 1 Study Case		Option 3 Study Case	
		Losses	Difference	Losses	Difference
295 WEC	158.6 MW 2663.1 MVAR	162.8 MW 2705.7 MVAR	4.2 MW 42.6 MVAR	163.2 MW 2711.1 MVAR	4.6 MW 48.0 MVAR
600 XEL	413.5 MW 4297.5 MVAR	442.2 MW 4498.2 MVAR	28.7 MW 200.7 MVAR	427.7 MW 4388.7 MVAR	14.2 MW 91.2 MVAR
608 MP	105.7 MW 1342.9 MVAR	105.5 MW 1366.2 MVAR	-0.2 MW 23.3 MVAR	106.2 MW 1372.8 MVAR	0.5 MW 29.9 MVAR
613 SMMPA	1.6 MW 16.8 MVAR	2.1 MW 21.6 MVAR	0.5 MW 4.8 MVAR	2.0 MW 20.2 MVAR	0.4 MW 3.4 MVAR
615 GRE	95.2 MW 1840.8 MVAR	95.9 MW 1824.9 MVAR	0.7 MW -15.9 MVAR	93.8 MW 1776.4 MVAR	-1.4 MW -64.4 MVAR
620 OTP	114.4 MW 1175.1 MVAR	115.0 MW 1161.6 MVAR	0.6 MW -13.5 MVAR	113.9 MW 1169.0 MVAR	-0.5 MW -6.1 MVAR
627 ALTW	99.5 MW 1026.6 MVAR	102.0 MW 1031.6 MVAR	2.5 MW 5.0 MVAR	100.2 MW 1023.3 MVAR	0.7 MW -3.3 MVAR
635 MEC	115.2 MW 1319.4 MVAR	118.4 MW 1336.5 MVAR	3.2 MW 17.1 MVAR	116.4 MW 1322.9 MVAR	1.2 MW 3.5 MVAR
652 WAPA	225.0 MW 2560.5 MVAR	229.6 MW 2605.2 MVAR	4.6 MW 44.7 MVAR	228.4 MW 2600.8 MVAR	3.4 MW 40.3 MVAR
667 MH	335.8 MW 5214.6 MVAR	433.8 MW 7173.7 MVAR	98.0 MW 1959.1 MVAR	436.1 MW 7184.0 MVAR	100.3 MW 1969.4 MVAR
680 DPC	76.1 MW 443.4 MVAR	85.7 MW 500.0 MVAR	9.6 MW 56.6 MVAR	82.2 MW 483.0 MVAR	6.1 MW 39.6 MVAR

Area	Benchmark Case Losses	Option 1 Study Case		Option 3 Study Case	
		Losses	Difference	Losses	Difference
694 ALTE	118.3 MW 1123.3 MVAR	129.1 MW 1198.4 MVAR	10.8 MW 75.1 MVAR	128.5 MW 1194.0 MVAR	10.2 MW 70.7 MVAR
696 WPS	77.2 MW 807.5 MVAR	89.8 MW 884.2 MVAR	12.6 MW 76.7 MVAR	90.2 MW 895.2 MVAR	13.0 MW 87.7 MVAR
697 MGE	14.0 MW 215.5 MVAR	13.9 MW 214.6 MVAR	-0.1 MW -0.9 MVAR	13.9 MW 214.5 MVAR	-0.1 MW -1.0 MVAR
698 UPPC	8.0 MW 27.9 MVAR	7.9 MW 28.0 MVAR	-0.1 MW 0.1 MVAR	7.9 MW 27.9 MVAR	-0.1 MW 0.0 MVAR
Network Upgrade Facilities	0.0 MW 0.0 MVAR	61.3 MW 549.2 MVAR	61.3 MW 549.2 MVAR	70.4 MW 765.1 MVAR	70.4 MW 765.1 MVAR
TOTALS	1958.1 MW 24076.1 MVAR	2195.1 MW 27100.8 MVAR	237.0 MW 3024.7 MVAR	2181.1 MW 27150.3 MVAR	223.0 MW 3074.2 MVAR

Table C-2: Combined Impact of TSRs and Transmission Upgrade Options on SUPK Case
Thermal Violations, Significantly Affected Facilities

** From bus **	** To bus **	CKT	Owner	Rating (MVA)	Benchmark Case Loading (%)	Option 1 Study Case Loading (%)	Option 1 Study Case DF (%)	Option 3 Study Case Loading (%)	Option 3 Study Case DF (%)	Contingency
699240 SAR 138	699808 PETENWEL 138	1	ATC	72	97.4	143.6	3.0	142.8	2.9	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1
699240 SAR 138	699808 PETENWEL 138	1	ATC	72.2	88.9	133.8	2.9	133.1	2.8	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699240 SAR 138	699808 PETENWEL 138	1	ATC	72.2	91.7	138.3	3.0	138.2	3.0	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699619 EAST KRK	699620 KEWAUNEE 138	1	ATC	273	87.6	100.9	3.2	100.5	3.1	699359 N APP 1 345 699630 KEWAUNEE 345 1
602022 JACKSON5	605309 JACKCO 8 69.0	1	XEL	47	96.0	107.6	0.5	107.8	0.5	** Base Case **
602022 JACKSON5	605309 JACKCO 8 69.0	1	XEL	47.0	149.4	161.1	0.5	160.5	0.5	605292 MONROCO8 69.0 605298 SPARTA28 69.0 1
602022 JACKSON5	605309 JACKCO 8 69.0	1	XEL	47.0	125.0	138.3	0.6	138.1	0.5	605322 TREMVAL8 69.0 605328 BLAIR 8 69.0 1
602022 JACKSON5	605309 JACKCO 8 69.0	1	XEL	47.0	122.1	134.4	0.5	134.4	0.5	602029 TREMVAL5 161 605322 TREMVAL8 69.0 1

Note: Jackson 161-69 kV transformer overloads above 115% for several contingencies (worst three overloads listed)

Report R164-08

MHEB Group TSR System Impact Study
Out-Year Power Flow Analysis
US to MH Requests
Winter Peak / North Flow

Prepared for

Midwest ISO

Submitted by:
Douglas R. Brown
Lengcheng Huang
Harinderpal Singh

Revised July 17, 2009

Siemens PTI Project P/21-113318

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SIEMENS

Revision History

Date	Description
3/20/2009	Original
6/26/2009	General revision for model updates and removed option 2
7/17/2009	Incorporated study group comments

Contents

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Executive Summary

Several requests for long term firm transmission service have been made under the Midwest ISO's Open Access Transmission and Energy Markets Tariff. This report presents the results of a steady-state power flow analysis performed on a winter peak scenario to evaluate the requests for transmission service shown in Table E-1. These requests seek to reserve 1100 MW of transmission service from various sources in the US to Manitoba Hydro.

Table E-1: MHEB Group TSR US to MH Requests

Oasis Ref No	Service Type	Start Time	Stop Time	POR	POD	Requested Capacity	Queue Date	Study Number
76537582	Network	Jun-2009	Jun-2027	WPS	MHEB	500	06/13/07	A380
76544699	Network	Jun-2009	Jun-2037	MP	MHEB	250	07/06/07	A383
76637089	P-to-P	Nov-2014	Nov-2024	GRE	MHEB	100	04/17/08	A415
76637091	P-to-P	Nov-2014	Nov-2024	GRE	MHEB	100	04/17/08	A415
76637257	P-to-P	Jun-2009	Jun-2027	WEC	MHEB	50	04/17/08	A414
76637259	P-to-P	Jun-2009	Jun-2027	ALTE	MHEB	50	04/17/08	A413
76637260	P-to-P	Jun-2009	Jun-2027	ALTE	MHEB	50	04/17/08	A413
					Total (MW)	1100		

This study was performed by Siemens PTI under the direction of Midwest ISO and an Ad Hoc Study Group consisting of American Transmission Company (ATC LLC), Basin Electric Power Cooperative (BEPC), Dairyland Power Cooperative (DPC), Great River Energy (GRE), Manitoba Hydro (MHEB), Minnesota Power (MP), Minnkota Power Cooperative (MPC), Otter Tail Power (OTP), Western Area Power Administration (WAPA) and Xcel Energy (XEL).

Transmission Upgrade Options

The transmission upgrade options proposed by the ad hoc study group are summarized in Table E-2. The cost estimates are for the new 500 kV transmission lines only and are based on $/mile costs taken from the JCSP 2008 Interim Stakeholder Meeting Introduction Presentation[1] and adjusted down from 2024 dollars to 2018 dollars using a 3% escalation factor. The costs for series compensation, transformers, line terminations and other required substation equipment are not included in this preliminary estimate. These costs will be further developed and refined during the Facilities study.

System diagrams depicting the proposed upgrade options are included in Appendix B.

Table E-2: Transmission Upgrade Options

Option No.	Project	Cost in 2018[1]
1	Dorsey – Maple River 50% series compensated 500 kV line with one 500/345 kV, 1200 MVA transformer at Maple River. Maple River – Helena 50% series compensated 500 kV line terminated with two 500/345 kV, 1200 MVA transformers at Helena.	$1.035 B
3	Dorsey – King 50% series compensated 500 kV line terminated via two 500/345 kV, 1200 MVA transformers at King.	$955 M

Note 1: Cost estimates are for transmission lines only

The transmission upgrade options evaluated in this study do not include shunt reactors to compensate for capacitive generation on the new 500 kV lines. Both Option 1 and Option 3 will require shunt reactors on the 500 kV line to control voltage when the line is open-ended. In Option 3, the steady-state voltage is around 1.2 per unit at the series capacitor on the Dorsey-King 500 kV line and the series capacitors will need to be designed accordingly.

Contingencies that simulate the outage of new 500 kV facilities associated with upgrade Option 1 or Option 3 were not modeled with HVDC reduction. Existing 500 kV and 230 kV triggers to the Manitoba Hydro HVDC power order reduction scheme were simulated in the contingency analysis.

Transmission Service Impacts

A benchmark power flow model representing 2019 winter peak system conditions was created without the requested transmission service. TSR study cases were created by adding the requested transmission service to the benchmark case along with one of two transmission upgrade options. Using the benchmark case as a reference, the total system losses within the study area decrease slightly with Option 1 and increase by 1.8% with Option 3. Option 1 is 35 MW more efficient compared with Option 3.

A nonlinear (ac) contingency analysis was performed and the combined impacts of the transmission upgrade options and the 1100 MW aggregate study TSRs were evaluated by comparing flows and voltages in the benchmark and study cases. Linear (dc) analysis was

[1] http://www.midwestmarket.org/publish/Document/81d7e_11b6e66e758_-795e0a48324a/Interim%20Presentation.pdf?action=download&_property=Attachment

used to calculate distribution factors for each TSR and the distribution factors were used to identify the incremental impact of adding each TSR sequentially in queue date order.

Facilities that are constraints to one or more TSRs are summarized in Table E-3. Constraints to individual TSRs are described below the table.

Table E-3: Thermal Constraints

Monitored Element	Owner	Rating (MVA)	Option 1 Study Case	Option 3 Study Case	Contingency
Flowgate 6174:SONCCTCOCSON	MISO	478	X	X	OTDF Flowgate
Rugby – Rugby CPC 115 kV line	WAPA /BEPC	144.4	X	X	C: Rugby – Balta 230 kV line
Cass Lake – Nary 115 kV line	OTP/ MPC	105.6	X		C: Wilton – Cass Lake 230 kV line

A380 (500 MW WPS to MHEB-MISO)

A380 is a request for 500 MW of network transmission service from WPS to MHEB-MISO. A380 constraints are summarized in Table E-4.

Table E-4: A380 Thermal Constraints

Study	Constraint	Rating (MVA)	Loading	
			Option 1	Option 3
A380	Flowgate 6174:SONCCTCOCSON	478	101.8	104.8%
	Rugby – Rugby CPC 115kV line	144.4	-	100.2%

Note 1: Blank cell indicates facility is not significantly affected

A383 (250 MW MP to MHEB-MISO)

A383 is a request for 250 MW of network transmission service from MP to MHEB-MISO. A383 constraints are summarized in Table E-5.

Table E-5: A383 Thermal Constraints

Study	Constraint	Rating (MVA)	Loading	
			Option 1	Option 3
A383	Flowgate 6174:SONCCTCOCSON	478	-	106.5
	Cass Lake – Nary 115 kV line	105.6	100.7%	-
	Rugby – Rugby CPC 115kV line	144.4	-	106.7%

Note 1: Blank cell indicates facility is not significantly affected

A415 (100+100 MW GRE to MHEB-MISO)

A415 consists of two 100 MW requests for point-to-point transmission service from GRE to MHEB-MISO. A415 constraints are summarized in Table E-6.

Table E-6: A415 Thermal Constraints

Study	Constraint	Rating (MVA)	Loading	
			Option 1	Option 3
A415	Flowgate 6174:SONCCTCOCSON	478	103.7% (a) 104.4% (b)	107.4% (a) 108.4% (b)
	Rugby – Rugby CPC 115kV line	144.4	100.6% (a) 102.9% (b)	109.9% (a) 113.1% (b)

Notes:
(a): For 100 MW transmission service
(b): For 200 MW transmission service

A414 (50 MW WEC to MHEB-MISO)

A414 is a request for 50 MW of point-to-point transmission service from WEC to MHEB-MISO. A414 constraints are summarized in Table E-7.

Table E-7: A414 Thermal Constraints

Study	Constraint	Rating (MVA)	Loading	
			Option 1	Option 3
A414	Flowgate 6174:SONCCTCOCSON	478	104.8%	108.9%
	Rugby – Rugby CPC 115kV line	144.4	104.2%	114.7%

Note 1: Blank cell indicates facility is not significantly affected

A413 (50+50 MW ALTE to MHEB-MISO)

A383 consists of two 50 MW requests for point-to-point transmission service from ALTE to MHEB-MISO. A383 constraints are summarized in Table E-8.

Table E-8: A383 Thermal Constraints

Study	Constraint	Rating (MVA)	Loading	
			Option 1	Option 3
A413	Flowgate 6174:SONCCTCOCSON	478	105.2% (a) 105.6% (b)	109.4% (a) 109.9% (b)
	Rugby – Rugby CPC 115kV line	144.4	105.6% (a) 106.9% (b)	116.3% (a) 117.9% (b)

Notes:
(a): For 100 MW transmission service
(b): For 200 MW transmission service

Constraint Mitigation Costs

Estimated costs for resolving each of the TSR constraints during Winter Peak conditions are summarized in Table E-9. The costs are good faith estimates provided by the affected Transmission Owners and will be further developed and refined in the Facility Study.

Table E-9: Mitigation costs for constraints during Winter Peak conditions

Thermal Constraint	Mitigation required	Option 1	Option 3
Stanton - Coal Creek 230 kV (FG: SONCCTCOCSON)	Replace terminal equipment at Stanton and Coal Creek	$500,000	$500,000
Rugby - Rugby CPC 115 kV	Reconductor 0.1 miles of the line	$69,652	$69,652
Cass Lake - Nary 115 kV	Reconductor 11 miles of the line	$7,661,692	-
	Total	$8,231,344	$569,652

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Section

1

Steady-State Analysis

1.1 Methodology

A benchmark power flow model representing 2019 winter peak system conditions was created without the requested transmission service. TSR study cases were created by taking the benchmark case and modeling the requested transmission service along with one of the transmission upgrade options. A nonlinear (ac) contingency analysis was performed and the combined impacts of the transmission upgrade options and the 1100 MW aggregate study TSRs were evaluated by comparing flows and voltages in the benchmark and study cases.

Linear (dc) analysis was used to calculate distribution factors for each TSR and the distribution factors were used to identify the incremental impact of adding each TSR sequentially in queue date order.

1.2 Computer Programs

Analysis was performed using PSS®E version 30.3 and PSS®MUST version 8.3.2.

1.3 Model Development

1.3.1 Winter Peak Benchmark Case

A winter peak benchmark case without the study TSRs and associated transmission upgrades was developed. The source was a 2019 Winter Peak case from the MRO 2008 model series. The Winter Peak benchmark case was developed by adding transmission projects from MTEP 08 Appendices A and B, which are listed in Appendix A, Table A-1. Projects in MTEP 08 Appendix B have not yet been studied through the MTEP cost-allocation process. If any of the projects in MTEP 08 Appendix B do not get developed, as per the identified need (in MTEP), the study TSRs would be reevaluated to determine if they are potentially responsible for the cost of those projects or appropriate alternatives. In addition to future transmission upgrades, the benchmark case was updated to include all existing US to MH firm transmission service commitments, prior-queued transmission service requests (confirmed and study status) not already included in the MRO case, MISO network resource generation and miscellaneous updates and corrections as described in the following sections.

The benchmark power flow case was solved with transformer tap adjustment enabled, switched shunt adjustment enabled, area interchange enabled (ties only), phase shifter adjustment enabled and dc tap adjustment enabled.

1.3.1.1 Existing US to MH Firm Transmission Service

The winter peak benchmark case includes existing firm transmission service commitments on the MHEX_N (Manitoba Hydro Export North) interface, as listed in Table 1-1 below.

Table 1-1: Existing Firm Transmission Service on MHEX_N Interface

TSR Ref# (MH OASIS)	POR	POD	Capacity (MW)	Start Time	End Time	Service
76703255	NSP	MH	500	5/1/2009	5/1/2019	YEARLY FIRM NETWORK DES
76735261	OTP	MH	50	5/1/2009	5/1/2014	YEARLY FIRM PTP
76703241	NSP	MH	200	11/1/2008	5/1/2019	YEARLY FIRM NETWORK DES
76703240	NSP	MH	200	11/1/2008	11/1/2016	YEARLY FIRM NETWORK DES
76703244	GRE	MH	150	11/1/2008	5/1/2015	GFA CARVE OUT - FIRM
		Total	1100 MW			

These TSRs correspond to grandfathered agreements that correspond to energy guarantees. Not all of the energy guarantees can be scheduled simultaneously. The TSRs are conditioned so that the total firm schedule does not exceed 700 MW. The resulting MHEX_N interface flow in the winter peak benchmark case is 699 MW.

1.3.1.2 Prior-Queued WAPA TSRs

The following proposed generating facilities have TSRs under study on the WAPA OASIS and were added to the winter peak benchmark case.

- Culbertson Project GI-0708 + GI-0614a (120+10 MW)

Table 1-2: Firm TSRs on WAPA OASIS

TSR Ref# (WAPA OASIS)	Capacity (MW)	Start Time	End Time	Service
70992013	10	1/1/2008	1/1/2029	YEARLY FIRM NITS
71372179	120	1/1/2009	1/1/2035	YEARLY FIRM NITS

Groton Unit 1 and Unit 2 are dispatched at 120 MW each.

1.3.1.3 Prior-Queued Midwest ISO TSRs

Table 1-3 shows prior-queued Midwest ISO TSRs and confirmed requests that were added to the winter peak benchmark case using sources and sinks provided by Midwest ISO.

Table 1-3: Midwest ISO TSRs Added to the WIPK Case

OASIS	OASIS #	STUDY	POR	POD	CAPACITY REQUESTED (MW)	START	STOP
MISO	Multiple	A054, A101, A183, A234 and A237	NSP	NSP	52	8/1/2002	8/1/2028
MISO	75836490	A194	NSP	NSP	100	12/1/2008	12/1/2025
MISO	76434677	A316	OTP	OTP	50	2/1/2010	11/1/2028
MISO	76509135	A356	GRE	NSP	100	10/1/2008	1/1/2034
MISO	76517411	GFA	GRE	OTP	94	4/1/2007	1/1/2036
MISO	76517414	GFA	GRE	OTP	30	4/1/2007	11/20/2027
MISO	76517415	GFA	GRE	MP	275	4/1/2007	3/2/2010
MISO	76526766	A374	OTP	OTP	49	11/1/2008	11/1/2028
MISO	76541075	A204	MP	MP	25	2/1/2008	2/1/2009
MISO	76541076	A204	MP	MP	25	2/1/2011	2/1/2012
MISO	76561178	A390	SMP	NSP	45	11/1/2007	11/1/2037
MISO	76668811	A373	MP	MP	100	7/1/2010	8/1/2015
MISO	76668831	A373	NSP	MP	100	7/1/2010	8/1/2015
MISO	76668843	A381	GRE	MP	200	7/1/2011	8/1/2016
MISO	76668850	A393	OTP	MP	100	7/1/2010	8/1/2015

1.3.1.4 Midwest ISO Network Resource Generation

The NR generating facilities listed in Table 1-4 were added to the winter peak benchmark case.

Table 1-4: Midwest ISO NR Generation Added to the WIPK Case

MISO Project Number	MISO Queue Number	MISO Queue Date	Control Area	County	Point of Interconnection	Max Output (MW)	Dispatch (MW)
G519	38491-01	19-May-05	MP	Itasca, MN	Blackberry 230/115kV Substation	600	600
G691	39006-02	16-Oct-06	XEL	Vernon, WI	Westby - Cashton tap 69 kV line	50	10
G930	39426-03	10-Dec-07	XEL	Sherburne, MN	Sherco Substation	120	120

1.3.1.5 Miscellaneous Updates and Corrections

Table 1-5 shows other miscellaneous model updates.

Table 1-5: Miscellaneous Updates and Corrections

Area	Description
ATC	Update Ellington-Hintz 138-kV line rating to 381 MVA (WN), 461 MVA (WE)
ITCM	Redispatched Alliant Energy generation so that area slack bus is within limits
MEC	Redispatched MidAmerican generation so that area slack bus is within limits
MH	Added Dorsey – Riel 500 kV circuit #2
MH	Add 3x73.4 MVar shunt capacitors on 46-kV tertiary of Riel 500/230-kV transformer.
MP	Purge extra Blackberry-Wilton 230 kV line
OTP	Added TSRs 76517414 and 76517411 from GRE to OTP so that OTP area slack bus is within limits
SMMPA/XEL	Shifted 220 MW from SMMPA generation in XEL control area to Austin so that SMMPA area slack bus is within limits
WAPA	Purged superfluous zero-impedance branches: - Max-ND Prairie Wind 115-34.5 kV transformer - Ft Thomson-Leland Olds 345 kV line - Whitlock-Glenham 230 kV line
WAPA	Letcher-Wessington correction
WAPA	Purge Storla-Broadland 230 kV line
WAPA	Set Miles City DC tie at 150 MW east to west Set Boundary Dam at 165 MW south to north
WAPA	Remove Selby generator and associated topology changes to make WIPK model topology consistent with SUPK model. Selby 540 MW output compensated by dispatching BEPC and MDU peakers.
WAPA	Redispatched WAPA generation so that area slack bus is within limits.
XEL	Increased generator MW limits at Prairie Island and Monticello (A201)
XEL	Removed Chanarambie 115/34.5 kV #4 transformer
XEL	Change the control area of Tatanka Wind to XEL (600)
XEL	Lena Tap correction
XEL	Colville generator updates
XEL	Update facility ratings for M602F, F601C and Coon Creek-Kolman Lake
XEL	Change Forbes SVC rating from +400/-450 Mvar (10 second capability) to +110/-149 Mvar (continuous).

1.3.2 Winter Peak Study Cases

TSR study cases were created by taking the benchmark case and modeling the requested transmission service along with one of the transmission upgrade options. Losses for each TSR study case are summarized in Appendix B.

1.3.2.1 Sources and Sink for Study TSRs

The TSR sink is the Dorsey inverter station and the 1100 MW aggregate study TSRs were sunk by decreasing the injection of the existing two HVDC bipoles at Dorsey from 1950 MW in the benchmark case to 850 MW in the study case. The study TSRs were sourced at the generators shown in Table 1-6.

Table 1-6: US to MH TSR Sources

Bus #	Generator Name	MW
	REMOVED	

1.3.2.2 Transmission Upgrade Options

The transmission upgrade options proposed by the ad hoc study group are summarized in Table 1-7.

System diagrams depicting the proposed upgrade options are included in Appendix B.

Table 1-7: Transmission Upgrade Options

Option No.	Project
1	Dorsey – Maple River 50% series compensated 500 kV line with one 500/345 kV, 1200 MVA transformer at Maple River. Maple River – Helena 50% series compensated 500 kV line terminated with two 500/345 kV, 1200 MVA transformers at Helena.
3	Dorsey – King 50% series compensated 500 kV line terminated via two 500/345 kV, 1200 MVA transformers at King.

The transmission upgrade options evaluated in this study do not include shunt reactors to compensate for capacitive generation on the new 500 kV lines. Both Option 1 and Option 3 will require shunt reactors on the 500 kV line to control voltage when the line is open-ended. In Option 3, steady-state voltage is around 1.2 per unit at the series capacitor on the Dorsey-King 500 kV line and the series capacitors will need to be designed accordingly.

```
OPTION 3 BUSES WITH VOLTAGE GREATER THAN 1.1000:

   BUS#  X-- NAME --X  BASKV   V(PU)   V(KV)
 601061  MIDCOMP-N    500.00  1.1758  587.91
 601062  MIDCOMP-S    500.00  1.2041  602.04
```

1.4 Contingency Criteria

A variety of system conditions are considered for the steady-state analysis.

- NERC Category A with system intact (no contingencies)
- NERC Category B contingencies
  - Outage of single element 100 kV and above (B.2 and B.3) associated with single contingency event in the following areas: ATCLLC (WEC, ALTE, WPS, MGE, UPPC), DPC, GRE, ITC Midwest, MH, MP, OTP, SMMPA, WAPA, XEL
  - Outage of multiple-elements 100 kV and above (B.2 and B.3) associated with single contingency event in the Dakotas, Manitoba, Minnesota, Wisconsin

For all contingency and post-disturbance analyses, the power flow cases are solved with transformer tap adjustment and switched shunt adjustment enabled, area interchange adjustment disabled, and phase shifter adjustment plus dc tap adjustment disabled.

1.5 Monitored Facilities

Monitored facilities and associated thermal and voltage limits are shown in Table 1-8.

Table 1-8: Monitored Facilities and Limits

Owner/ Area	Monitored Facilities	Thermal Limits [1]		Voltage Limits
		Pre-Disturbance	Post-Disturbance	
ATC LLC	69 kV and above	95% of Rate A	95% of Rate B	1.10/0.90
BEPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
DPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
GRE	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.92/0.90 [2]
ITCMW	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
MDU	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
MEC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
MH	69 kV and above	100% of Rate A	100% of Rate B	1.15/1.10/0.94/0.90 [3]
MP	69 kV and above	100% of Rate A	100% of Rate B	1.05/0.95
MPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
MRES	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
NWPS	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
OTP	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
RPU	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
SMMPA	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90
SPC	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
WAPA	69 kV and above	100% of Rate A	100% of Rate A	1.10/0.90
XEL	69 kV and above	100% of Rate A	100% of Rate B	1.10/0.90

Note 1: PSSE Rate A, or Rate B
Note 2: 0.92 limit applies to load serving buses
Note 3: Limits dependent on nominal bus voltage

1.6 Reliability Margins

Flowgate ratings for this out-year analysis are based on facility ratings and do not consider capacity benefit margin (CBM) or transmission reliability margin (TRM). All other system elements were monitored as shown in Table 1-8.

1.7 Performance Criteria

A branch or flowgate is considered a significantly affected facility if both of the following conditions are met for the transmission service under study:

1) the facility is loaded above its applicable normal or emergency rating in the study case, and
2) the power transfer distribution factor (PTDF) is greater than 5% or the outage transfer distribution factor (OTDF) is greater than 3% for the overloaded facility.

Distribution factors for each TSR are calculated using linear (dc) analysis.

A voltage impact is considered significant if both of the following conditions are met for the transmission service under study:

1) the bus voltage is outside of applicable normal or emergency limits in the study case, and
2) the impact of the requested service on bus voltage is greater than 0.01 per unit.

1.8 Network Analysis Results

1.8.1 Impact on System Losses

The combined impact of the transmission upgrades and the aggregate TSRs (1100 MW) on system losses is shown in Appendix C, Table C-1. For each upgrade option, the change in system losses within the study area is tabulated. The net change in system real power losses (compared to the benchmark case) is lower for Option 1 (5 MW decrease) compared to Option 3 (30 MW increase).

1.8.2 Transmission Service Impacts

Table C-2 in Appendix C shows the combined impact of the transmission upgrades and the aggregate TSRs (1100 MW) on facilities impacted by one or more TSR. A thermal impact is considered significant if the facility loading exceeds the limit shown in Table 1-8 and the distribution factor exceeds the threshold given in Section 1.7. There are no significant voltage impacts attributable to any TSR.

1.8.2.1 A380 (500 MW WPS to MHEB-MISO)

A380 is a request for 500 MW of network transmission service from WPS to MHEB-MISO. Request A380 has a significant impact on the facilities shown in Table 1-9.

Two of the significantly affected facilities are common to both transmission upgrade options: the Leland Olds 345/230 kV transformer #2 and the Stanton-Coal Creek Tap flowgate (#6174). Of these, the Stanton-Coal Creek Tap flowgate is a constraint but the Leland Olds transformer is not a constraint because the post-contingency loading does not exceed the transformer's 700 MVA emergency rating.

With upgrade Option 1, the Tioga-Boundary Dam 230 kV line is a significantly affected facility; however, it is not a constraint because the post-contingency loading does not exceed the 250 MVA emergency rating and the B10T phase-shifting transformer can be used to reduce its flow within normal limits.

The Rugby-Rugby CPC 115kV line is a constraint with upgrade Option 3 only.

1.8.2.2 A383 (250 MW MP to MHEB-MISO)

A383 is a request for 250 MW of network transmission service from MP to MHEB-MISO. Request A383 has a significant impact on the facilities shown in Table 1-10.

The Cass Lake-Nary 115 kV line is a constraint with upgrade Option 1 only. The Rugby-Rugby CPC 115 kV line and the Stanton-Coal Creek Tap flowgate (#6174) are constraints with upgrade Option 3 only.

1.8.2.3 A415 (100+100 MW GRE to MHEB-MISO)

A415 consists of two 100 MW requests for total 200 MW of point-to-point transmission service from GRE to MHEB-MISO. Request A415 has a significant thermal impact on the facilities shown in Table 1-11 and Table 1-12.

Three of the significantly affected facilities are common to both transmission upgrade options: the Leland Olds 345/230 kV transformer #2, the Rugby-Rugby CPC 115kV line and the Stanton-Coal Creek Tap flowgate (#6174). The Leland Olds transformer is not a constraint because the post-contingency loading does not exceed the transformer's 700 MVA emergency rating. The other two facilities are constraints with either option.

With upgrade Option 1, the Tioga-Boundary Dam 230 kV line is a significantly affected facility; however, it is not a constraint because the post-contingency loading does not exceed the 250 MVA emergency rating and the B10T transformer can be used to reduce its flow within normal limits.

1.8.2.4 A414 (50 MW WEC to MHEB-MISO)

A414 is a request for 50 MW of point-to-point transmission service from WEC to MHEB-MISO. Request A414 has a significant thermal impact on the facilities shown in Table 1-13.

Three of the significantly affected facilities are common to all three transmission upgrade options: the Leland Olds 345/230 kV transformer #2, the Rugby-Rugby CPC 115kV line and the Stanton-Coal Creek Tap flowgate (#6174). The Leland Olds transformer is not a constraint because the post-contingency loading does not exceed the transformer's 700 MVA emergency rating. The other facilities are constraints with either option.

With upgrade Option 1, the Tioga-Boundary Dam 230 kV line is a significantly affected facility; however, it is not a constraint because the post-contingency loading does not exceed the 250 MVA emergency rating and the B10T transformer can be used to reduce its flow within normal limits.

1.8.2.5 A413 (50+50 MW ALTE to MHEB-MISO)

A413 consists of two 50 MW requests for total 100 MW of point-to-point transmission service from ALTE to MHEB-MISO. Request A417 has a significant thermal impact on the facilities shown in Table 1-14 and Table 1-15.

Three of the significantly affected facilities are common to all three transmission upgrade options: the Leland Olds 345/230 kV transformer #2, the Rugby-Rugby CPC 115kV line and the Stanton-Coal Creek Tap flowgate (#6174). The Leland Olds transformer is not a constraint because the post-contingency loading does not exceed the transformer's 700 MVA emergency rating. The other facilities are constraints with either option.

With upgrade Option 1, the Tioga-Boundary Dam 230 kV line is a significantly affected facility; however, it is not a constraint because the post-contingency loading does not exceed the 250 MVA emergency rating and the B10T transformer can be used to reduce its flow within normal limits.

Table 1-9: A380 Thermal Constraints (500 MW WPS to MHEB-MISO)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	98.1	101.8	3.5	C:Contingency of FlowGate 6174
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	116.8	122.0	5.2	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	113.6	117.4	3.8	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	97.6	101.2	3.6	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	97.7	101.2	3.6	C:GRE-COAL42G-GSU
661084 TIOGA4 4 230 672603 BDV 4 230 1 [1]	BEPC	200	109.9	117.7	3.1	C:MAPLERIV-DORSEY-500

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	100.0	104.8	4.5	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	84.7	100.2	4.5	C:GRE-BALTA-RUGBY-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	120.2	125.1	4.8	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	116.2	119.8	3.5	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	101.5	104.8	3.3	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	101.5	104.8	3.3	C:GRE-COAL42G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	97.4	100.7	3.3	C:CENTER2G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	97.4	100.7	3.3	C:CENTRDC-SQBUTTE-230

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Table 1-10: A383 Thermal Constraints (250 MW MP to MHEB-MISO)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
620247 CASS LK7 115 657710 NARY 7 115 1	OTP/ MPC	105.6	88.3	100.7	5.2	C:WILTON-CASSLK-230

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	104.8	106.5	3.3	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	100.2	106.7	3.8	C:GRE-BALTA-RUGBY-230

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Table 1-11: A415 (1st of 2) Thermal Constraints (100 MW GRE to MHEB-MISO)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	103.0	103.7	3.5	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	98.2	100.6	3.4	C:GRE-BALTA-RUGBY-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	123.2	124.2	4.7	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	118.3	119.0	3.5	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	102.0	102.7	3.2	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	102.0	102.7	3.2	C:GRE-COAL42G-GSU
661084 TIOGA4 4 230 672603 BDV 4 230 1	BEPC	200	120.8	122.4	3.3	C:MAPLERIV-DORSEY-500

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	106.5	107.4	4.6	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	106.7	109.9	4.6	C:GRE-BALTA-RUGBY-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	125.9	126.8	4.5	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	120.3	121.0	3.3	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	105.3	105.9	3.1	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	105.3	105.9	3.1	C:GRE-COAL42G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	101.3	101.9	3.1	C:CENTER2G-GSU

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	101.3	101.9	3.1	C:CENTRDC-SQBUTTE-230
659105 LELANDO3 345 659202 LELND2TY 345 1	BEPC	500	99.5	100.1	3.1	C:LELAN41G-GSU

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Table 1-12: A415 (2nd of 2) Thermal Constraints (100 MW GRE to MHEB-MISO)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	103.7	104.4	3.5	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	100.6	102.9	3.4	C:GRE-BALTA-RUGBY-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	124.2	125.1	4.7	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	119.0	119.7	3.5	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	102.7	103.3	3.2	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	102.7	103.3	3.2	C:GRE-COAL42G-GSU
661084 TIOGA4 4 230 672603 BDV 4 230 1 [1]	BEPC	200	122.4	124.0	3.3	C:MAPLERIV-DORSEY-500

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	107.4	108.4	4.6	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	109.9	113.1	4.6	C:GRE-BALTA-RUGBY-230
659105 LELANDO3 345 659202 LELND2TY 345 1	BEPC	500	126.8	127.6	4.5	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1	BEPC	500	121.0	121.7	3.3	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1	BEPC	500	105.9	106.5	3.1	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1	BEPC	500	105.9	106.5	3.1	C:GRE-COAL42G-GSU

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
659105 LELANDO3 345 659202 LELND2TY 345 1	BEPC	500	101.9	102.5	3.1	C:CENTER2G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1	BEPC	500	101.9	102.5	3.1	C:CENTRDC-SQBUTTE-230
659105 LELANDO3 345 659202 LELND2TY 345 1	BEPC	500	100.1	100.7	3.1	C:LELAN41G-GSU

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Table 1-13: A414 Thermal Constraints (50 MW WEC to MHEB-MISO)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	104.4	104.8	3.7	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	102.9	104.2	3.6	C:GRE-BALTA-RUGBY-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	125.1	125.7	5.7	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	119.7	120.1	4.2	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	103.3	103.7	3.9	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	103.3	103.7	3.9	C:GRE-COAL42G-GSU
661084 TIOGA4 4 230 672603 BDV 4 230 1 [1]	BEPC	200	124.0	124.8	3.2	C:MAPLERIV-DORSEY-500

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	108.4	108.9	4.8	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	113.1	114.7	4.6	C:GRE-BALTA-RUGBY-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	127.6	128.2	5.3	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	121.7	122.1	3.9	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	106.5	106.9	3.6	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	106.5	106.9	3.6	C:GRE-COAL42G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	102.5	102.8	3.6	C:CENTER2G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	102.5	102.8	3.6	C:CENTRDC-SQBUTTE-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	100.7	101.1	3.6	C:LELAN41G-GSU

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Table 1-14: A413 (1st of 2) Thermal Constraints (50 MW ALTE to MHEB-MISO)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	104.8	105.2	3.7	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	104.2	105.4	3.6	C:GRE-BALTA-RUGBY-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	125.7	126.3	5.8	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	120.1	120.6	4.2	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	103.7	104.1	3.9	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	103.7	104.1	3.9	C:GRE-COAL42G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	99.8	100.2	3.9	C:CENTER2G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	99.8	100.2	3.9	C:CENTRDC-SQBUTTE-230
661084 TIOGA4 4 230 672603 BDV 4 230 1	BEPC	200	124.8	125.6	3.2	C:MAPLERIV-DORSEY-500

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	108.9	109.4	4.8	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	114.7	116.3	4.7	C:GRE-BALTA-RUGBY-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	128.2	128.7	5.4	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	122.1	122.4	3.9	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	106.9	107.3	3.7	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	106.9	107.3	3.7	C:GRE-COAL42G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	102.8	103.2	3.7	C:CENTER2G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	102.8	103.2	3.7	C:CENTRDC-SQBUTTE-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	101.1	101.5	3.7	C:LELAN41G-GSU

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Table 1-15: A413 (2nd of 2) Thermal Constraints (50 MW ALTE to MHEB-MISO)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	105.2	105.6	3.7	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	105.4	106.6	3.6	C:GRE-BALTA-RUGBY-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	126.3	126.8	5.8	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	120.6	121.0	4.2	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	104.1	104.5	3.9	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	104.1	104.5	3.9	C:GRE-COAL42G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	100.2	100.6	3.9	C:CENTER2G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	100.2	100.6	3.9	C:CENTRDC-SQBUTTE-230
661084 TIOGA4 4 230 672603 BDV 4 230 1 [1]	BEPC	200	125.6	126.4	3.2	C:MAPLERIV-DORSEY-500

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6174:SONCCTCOCSON	MISO	478	109.4	109.9	4.8	C:Contingency of FlowGate 6174
652452 RUGBY 7 115 659264 RUGBCPC7 115 1	WAPA/ BEPC	144.4	116.3	117.9	4.7	C:GRE-BALTA-RUGBY-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	128.7	129.3	5.4	C:LELND1T-XFMR
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	122.4	122.8	3.9	C:ANTELOP-CHAR.CK-345
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	107.3	107.6	3.7	C:GRE-COAL41G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	107.3	107.6	3.7	C:GRE-COAL42G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	103.2	103.6	3.7	C:CENTER2G-GSU
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	103.2	103.6	3.7	C:CENTRDC-SQBUTTE-230
659105 LELANDO3 345 659202 LELND2TY 345 1 [1]	BEPC	500	101.5	101.8	3.7	C:LELAN41G-GSU

Note 1: Post-contingency loading does not exceed the facility's emergency rating

Appendix

A

MTEP08 Projects

Table A-1 shows the MTEP08 projects that were added to the 2017 Winter Peak benchmark case using response files provided by Midwest ISO.

Table A-1: MTEP08 Projects added to the Winter Peak Case

Transmission Owner	MTEP Project ID	Project Name	MTEP Appendix
ITCM	1288	Replace Hazleton 345/161 kV transformer #1 with 335 MVA unit	A
ITCM	1341	Replace two Hazleton 161/69 kV transformers	A
ITCM	1473	Mason City Armor - Emery North 69 kV line	A
ITCM	1522	6th Street – Beverly	A
ITCM	1619	Grnd Mnd 161-69kV 2nd Xfmr & 161kV loop	A
ITCM	1641	OGS 50 MVAR Cap Bank	A
ITCM	1739	Arnold-Vinton-Dysart-Washburn 161kV Reconductor	A
ITCM	1755	Washington-Hills 69kV Rebuild	A
ITCM	1756	Dyersville-Peoasta 69kV Rebuild	A
ITCM	1758	Beaver Channel-2nd Ave 69kV	A
GRE	1361	Badoura - Birch Lake 115 lines	A
MP	277	Badoura Project: Pine River - Pequot Lakes 115 kV line	A
MP/GRE	1021	Embarass to Tower 115 kV Line	A
MP/GRE	1022	Badoura-Long Lake 115 kV line	A
OTP	973	Big Stone II Generation Project	B
SMP	1367	Lake City load serving upgrades	A
XEL/SMP		SMP-GRANDMEADOW-WF	B
XEL	675	Rebuild Westgate to Scott County 69 kV to 115 kV	A
XEL	1285	Build 18 miles 115 kV line from Glencoe - West Waconia	A
XEL	1457	G287, 37642-03. Upgrades for G287	A
XEL	1549	Eau Claire - Hydro Lane 161 kV Conversion	A
XEL	1953	St. Cloud - Sauk River 115 kV line upgrade	A
XEL	1954	Cherry Creek - Split Rock 115 kV line saperation	A
XEL	1956	Blue Lake - Wilmarth 345 kV line capacity upgrade	A
XEL	1957	New 161/69 kV Sub SW of Eau Claire where Alma – Elk Mound 161 kV intersects Shawtown – Naples 69 kV line. Rebuild 69 kV London/Madison to new substation. New 69 kV from new substation - DPC Union Sub. New 69 kV to DPC Brunswick Sub	A
XEL	1958	Stone Lake-Edgewater 161 kV line. A new radial 161 kV line and substation in Sawyer County, Wisconsin	A
XEL	1959	Yankee Doodle interconnection	A
XEL	1960	Traverse - St. Peter upgrade	A

Transmission Owner	MTEP Project ID	Project Name	MTEP Appendix
XEL	1961	Lake Emily Capacitor bank	A
XEL	2109	G609	A
XEL		G037	
ATC LLC	1463	Twin_Creeks-G384	N/A
ITCM	1645	Leon-1645_69kV_7MVAR	N/A
ITCM	1772	N_Cntrville_69kV-1772_7MVA	N/A
WAPA, BEPC	Correction	Su2009+-SplitWess	N/A
GRE	Network	KRMRLK(53801)	N/A
XEL	1380	WWACONIA-SCOTT	N/A

N/A – These projects have been withdrawn and no longer appear in MTEP Appendix A/B.

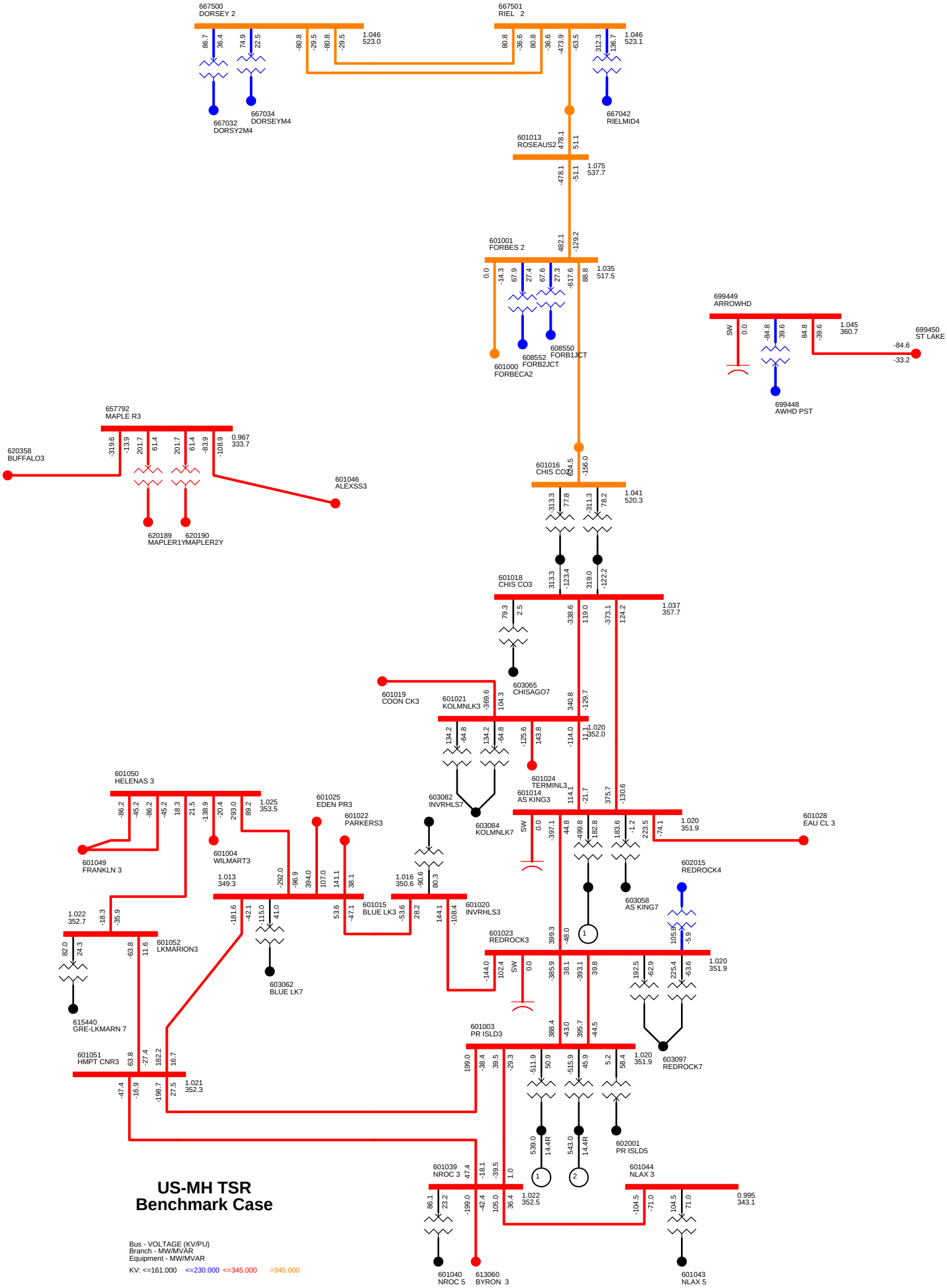
Appendix

B

Transmission Upgrade Options

Table B-1: Modeling Parameters

Facility	R (pu)	X (pu)	B (pu)	Rate A (MVA)	Rate B (MVA)
Dorsey – Maple River 500 kV line with 50% series compensation	0.00290	0.04830 -0.02415	4.30	1732 1732	1905 2165
Maple River – Helena 500 kV line with 50% series compensation	0.00252	0.04200 -0.02100	3.74	1732 1732	1905 2165
Dorsey – King 500 kV line with 50% series compensation	0.00600	0.10700 -0.05350	10.00	1732 1732	1905 2165
500/345 kV, 1200 MVA Transformer One at Maple River (option1) Two at Helena (Option 1) Two at King (Option 3)	0.000050	0.004700		1200	1200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699449
ARROWHD
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ST LAKE
699448
AWHD PST
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620358
BUFFALO3
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MAPLER1Y
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MAPLER2Y
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ALEXSS3
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CHIS CO2
601018
CHIS CO3
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CHISAGO7
601019
COON CK3
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KOLMNLK3
601024
TERMINL3
603082
INVRHLS7
601014
AS KING3
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KOLMNLK7
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EAU CL 3
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REDROCK4
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AS KING7
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HELENAS 3
601049
FRANKLN 3
601004
WILMART3
601025
EDEN PR3
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PARKERS3
601015
BLUE LK3
601020
INVRHLS3
601023
REDROCK3
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REDROCK7
601052
LKMARION3
615440
GRE-LKMARN 7
603062
BLUE LK7
601003
PR ISLD3
602001
PR ISLD5
601051
HMPT CNR3
601039
NROC 3
601044
NLAX 3
601040
NROC 5
613060
BYRON 3
601043
NLAX 5
US-MH TSR
Benchmark Case
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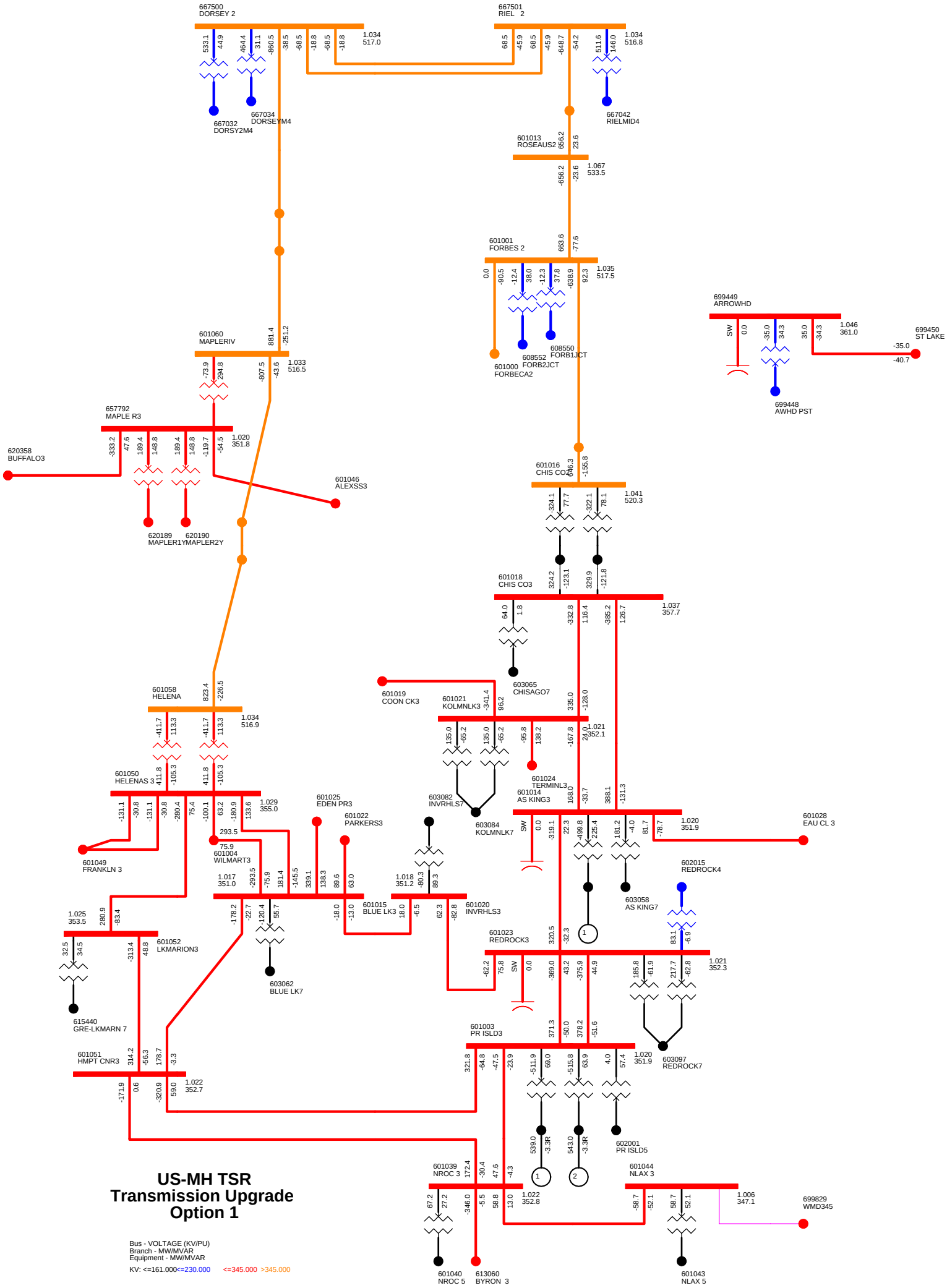
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000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ALEXSS3
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MAPLER1Y
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MAPLER2Y
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CHIS CO3
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CHISAGO7
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COON CK3
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KOLMNLK3
601024
TERMINL3
601014
AS KING3
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KOLMNLK7
601028
EAU CL 3
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REDROCK4
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AS KING7
603097
REDROCK7
601058
HELENA
601050
HELENAS 3
601049
FRANKLN 3
601004
WILMART3
601025
EDEN PR3
601022
PARKERS3
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INVRHLS7
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BLUE LK3
601020
INVRHLS3
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BLUE LK7
601023
REDROCK3
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PR ISLD3
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PR ISLD5
601052
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NROC 3
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NROC 5
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BYRON 3
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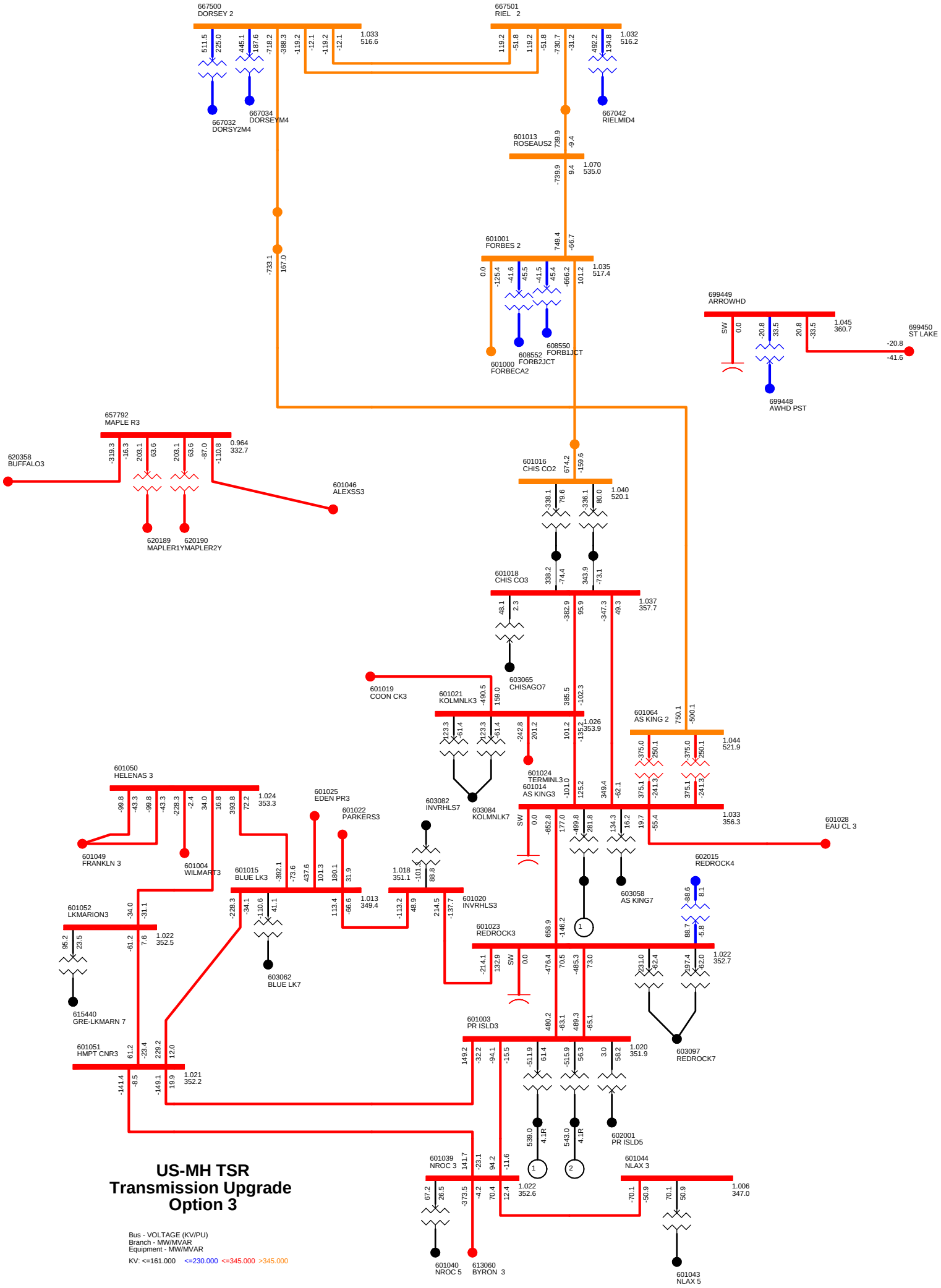
NLAX 3
601043
NLAX 5
699829
WMD345
US-MH TSR
Transmission Upgrade
Option 1
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000


667500
DORSEY 2
667501
RIEL 2
667032
DORSY2M4
667034
DORSEYM4
667042
RIELMID4
601013
ROSEAUS2
601001
FORBES 2
601000
FORBECA2
608552
FORB2JCT
608550
FORB1JCT
699449
ARROWHD
699450
ST LAKE
699448
AWHD PST
657792
MAPLE R3
620358
BUFFALO3
620189
620190
MAPLER1YMAPLER2Y
601046
ALEXSS3
601016
CHIS CO2
601018
CHIS CO3
603065
CHISAGO7
601019
COON CK3
601021
KOLMNLK3
601064
AS KING 2
601024
TERMINL3
601014
AS KING3
603082
INVRHLS7
603084
KOLMNLK7
601028
EAU CL 3
602015
REDROCK4
603058
AS KING7
601050
HELENAS 3
601049
FRANKLN 3
601004
WILMART3
601025
EDEN PR3
601022
PARKERS3
601015
BLUE LK3
601020
INVRHLS3
601052
LKMARION3
615440
GRE-LKMARN 7
603062
BLUE LK7
601023
REDROCK3
603097
REDROCK7
601003
PR ISLD3
602001
PR ISLD5
601051
HMPT CNR3
601039
NROC 3
601044
NLAX 3
601040
NROC 5
613060
BYRON 3
601043
NLAX 5
US-MH TSR
Transmission Upgrade
Option 3
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000

Appendix

C

Network Analysis Results

Table C-1: Network Loss Analysis Results

Area	Benchmark Case Losses	Option 1 Study Case		Option 3 Study Case	
		Losses	Difference	Losses	Difference
295 WEC	139.5	137.4	-2.1	137.7	-1.8
	2277.4	2237.4	-40.0	2239.2	-38.2
600 XEL	257.3	257	-0.3	276.8	19.5
	2604	2648.9	44.9	2792.4	188.4
608 MP	96.7	104.1	7.4	105.2	8.5
	1332.5	1399.6	67.1	1413.7	81.2
613 SMMPA	1.2	1.1	-0.1	1.1	-0.1
	11.2	9.6	-1.6	10.1	-1.1
615 GRE	103.5	102.2	-1.3	104.5	1.0
	1783	1788.5	5.5	1806	23.0
620 OTP	118.9	125.5	6.6	133.3	14.4
	1003.2	1052	48.8	1099.8	96.6
627 ALTW	81.8	89.7	7.9	87.5	5.7
	908.9	957.2	48.3	945.6	36.7
635 MEC	107.5	112.1	4.6	110.1	2.6
	1267.7	1309.6	41.9	1292.6	24.9
652 WAPA	271.5	274.6	3.1	282.5	11.0
	2650.2	2682.4	32.2	2729.6	79.4
667 MH	210.7	154.8	-55.9	153.9	-56.8
	3634.9	2261.5	-1373.4	2266.4	-1368.5
680 DPC	62.8	60	-2.8	63	0.2
	340	324.5	-15.5	337.6	-2.4
694 ALTE	104.3	99.2	-5.1	100.7	-3.6
	1019.3	980.4	-38.9	991.9	-27.4

Area	Benchmark Case Losses	Option 1 Study Case		Option 3 Study Case	
		Losses	Difference	Losses	Difference
696 WPS	64.9	60.9	-4.0	61.7	-3.2
	610.6	632.3	21.7	637.6	27.0
697 MGE	9.9	9.9	0.0	10.1	0.2
	143.1	141.8	-1.3	144.2	1.1
698 UPPC	9.1	9.1	0.0	9.1	0.0
	29.8	29.6	-0.2	29.7	-0.1
Network Upgrade Facilities	0	36.9	36.9	32.0	32.0
	0	330.2	330.2	376.6	376.6
TOTALS	1639.5	1634.5	-5.0	1669.2	29.7
	19615.9	18785.7	-830.2	19112.9	-503.0

Table C-2: Combined Impact of TSRs and Transmission Upgrade Options on WIPK Case
Thermal Violations, Significantly Impacted Facilities

** From bus **	** To bus **	** CKT	Owner	Rating (MVA)	Benchmark Case Loading (%)	Option 1 Study Case Loading (%)	Option 1 Study Case DF (%)	Option 3 Study Case Loading (%)	Option 3 Study Case DF (%)	Contingency
6174:SONCCTCOCSON			MISO	430	114.6	117.4	1.1	122.2	3.0	C:Contingency of FlowGate 6174
620247 CASS LK7 115	657710 NARY 7 115	1	OTP/MPC	105.6	86.7	101.6	1.4			C:620345 WILTON 4 230 620447 CASS LK4 230 1
652452 RUGBY 7 115	659264 RUGBCPC7 115	1	WAPA/BEPC	144.4	98.1	106.6	1.1	117.9	2.6	C:615903 GRE-BALTA 4 230 620379 RUGBY 4 230 1
659105 LELANDO3 345	659202 LELND2TY 345	1	BEPC	500	118.4	121.0	1.2	122.8	2.0	C:659101 ANTELOP3 345 659183 CHAR.CK3 345 1
659105 LELANDO3 345	659202 LELND2TY 345	1	BEPC	500	99.4	100.6	0.5	103.6	1.9	C:608601 CENTRDC4 230 657748 CENTER2G 20.0 1
659105 LELANDO3 345	659202 LELND2TY 345	1	BEPC	500	99.4	100.6	0.5	103.6	1.9	C:608601 CENTRDC4 230 657756 SQBUTTE4 230 1
659105 LELANDO3 345	659202 LELND2TY 345	1	BEPC	500	103.5	104.5	0.5	107.6	1.9	C:615001 GRE-COAL 41G22.0 615600 GRE-COAL CR4 230 1
659105 LELANDO3 345	659202 LELND2TY 345	1	BEPC	500	103.5	104.5	0.5	107.6	1.9	C:615002 GRE-COAL 42G22.0 615600 GRE-COAL CR4 230 1
659105 LELANDO3 345	659202 LELND2TY 345	1	BEPC	500	97.5	99.8	1.0	101.8	2.0	C:659106 LELANDO4 230 659110 LELAN41G 22.0 1
659105 LELANDO3 345	659202 LELND2TY 345	1	BEPC	500	123.0	126.8	1.7	129.3	2.9	C:659105 LELANDO3 345 659201 LELND1TY 345 1
661084 TIOGA4 4 230	672603 BDV 4 230	1	BEPC	200		126.4				MAPLERIV-DORSEY-500
661084 TIOGA4 4 230	672603 BDV 4 230	1	BEPC	200	136.3	108.7	-5.0	117.0	-3.5	M602F

Report R164-08

MHEB Group TSR System Impact Study
Stability Analysis
MH to US Requests

Prepared for

Midwest ISO

Submitted by:
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Revised July 17, 2009

Siemens PTI Project P/21-113318

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Revision History

Date	Description
4/28/09	Original
6/18/09	General revision including addition of Option 3 and analysis of both options without SPS
7/17/2009	Incorporated study group comments

Contents

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Executive Summary

Several requests for long term firm transmission service have been made under the Midwest ISO's Open Access Transmission and Energy Markets Tariff. This report presents the results of a transient stability analysis performed on a summer off-peak scenario to evaluate the requests for transmission service shown in Table E-1. These requests seek to reserve 1130 MW of transmission service from Manitoba Hydro to various sinks in the US.

Table E-1: MHEB Group TSR MH to US Requests

Oasis Ref No	Service Type	Start Time	Stop Time	POR	POD	Requested Capacity	Queue Date	Study Number
76703536	Network	Nov-2014	Nov-2024	MHEB-MISO	GRE	200	12/7/2006	A388
76703535	Network	Apr-2008	Apr-2013	MHEB-MISO	NSP	30	1/26/2007	A351
76703671	Network	Jun-2017	Jun-2027	MHEB-MISO	WPS	500	6/12/2007	A380
76703672	Network	Jun-2017	Jun-2037	MHEB-MISO	MP	250	7/6/2007	A383
76703686	Network	Jun-2017	Jun-2027	MHEB-MISO	NSP	50	4/17/2008	A416
76703687	Network	Jun-2017	Jun-2027	MHEB-MISO	WEC	100	4/17/2008	A417
					Total (MW)	1130		

This study was performed by Siemens PTI under the direction of Midwest ISO and an Ad Hoc Study Group consisting of American Transmission Company (ATC LLC), Basin Electric Power Cooperative (BEPC), Dairyland Power Cooperative (DPC), Great River Energy (GRE), Manitoba Hydro (MHEB), Minnesota Power (MP), Minnkota Power Cooperative (MPC), Otter Tail Power (OTP), Western Area Power Administration (WAPA) and Xcel Energy (XEL).

Transient stability analyses have been performed using a model representing off-peak system conditions after Manitoba Hydro's third HVDC bipole goes into service. The analyses were performed using a UIP study package that was updated by the NMORWG in January 2009.

Transmission Upgrade Options

The transmission upgrade options proposed by the ad hoc study group are summarized in Table E-2. The cost estimates are for the new 500 kV transmission lines only and are based on $/mile costs taken from the JCSP 2008 Interim Stakeholder Meeting Introduction Presentation[1] and adjusted down from 2024 dollars to 2018 dollars using a 3% escalation factor. The costs for series compensation, transformers, line terminations and other required substation equipment are not included in this preliminary estimate. These costs will be further developed and refined during the Facilities study.

System diagrams depicting the proposed upgrade options are included in Appendix B.

Table E-2: Transmission Upgrade Options

Option No.	Project	Cost in 2018[1]
1	Dorsey – Maple River 50% series compensated 500 kV line with one 500/345 kV, 1200 MVA transformer at Maple River. Maple River – Helena 50% series compensated 500 kV line terminated with two 500/345 kV, 1200 MVA transformers at Helena.	$1.035 B
3	Dorsey – King 50% series compensated 500 kV line terminated via two 500/345 kV, 1200 MVA transformers at King.	$955 M

Note 1: Cost estimates are for transmission lines only

The transmission upgrade options evaluated in this study do not include shunt reactors to compensate for capacitive generation on the new 500 kV lines. Both Option 1 and Option 3 will require shunt reactors on the 500 kV line to control voltage when the line is open-ended. In Option 3, steady-state voltage is around 1.2 per unit at the series capacitor on the Dorsey-King 500 kV line and the series capacitors will need to be designed accordingly.

Pre-Benchmark Case

A pre-benchmark case without CapX projects, study TSRs or associated transmission upgrades was developed from the 2015 summer off-peak case in the UIP package. The pre-benchmark case includes future transmission upgrades from MTEP Appendices A and B (excluding CapX projects) and Manitoba Hydro system updates including the Riel station and bipole 3. Projects in MTEP 08 Appendix B have not yet been studied through the MTEP cost-allocation process. If any of the projects in MTEP 08 Appendix B do not get developed, as per the identified need (in MTEP), the study TSRs would be reevaluated to determine if they are potentially responsible for the cost of those projects or appropriate alternatives. Loading of the MHEX, MWEX and NDEX interfaces was adjusted in the pre-benchmark case as shown in Table E-3. A power flow summary and diagram for the pre-benchmark case is in Appendix B. Simulated disturbances are described in Table 1-8; all of the disturbances simulated using the pre-benchmark case result in acceptable system performance.

[1] http://www.midwestmarket.org/publish/Document/81d7e_11b6e66e758_-795e0a48324a/Interim%20Presentation.pdf?action=download&_property=Attachment

Benchmark Case

A benchmark case without study TSRs or associated transmission upgrades was developed by adding the CapX 2020 Group 1 projects to the pre-benchmark case. Interface loading was not adjusted after adding the CapX projects and the resulting interface flows are summarized in Table E-3. A power flow summary and diagram for the benchmark case is in Appendix B. Simulated disturbances are described in Table 1-8; all of the disturbances simulated using the benchmark case result in acceptable system performance.

TSR Study Cases

TSR study cases were created by taking the benchmark case and modeling the requested transmission service along with one of the transmission upgrade options. Interface loading was not reset in the study cases and the resulting interface flows are summarized in Table E-3. Power flow summaries and diagrams for each study case are in Appendix B.

Table E-3: Interface Loading

Interface	Pre-Benchmark	Benchmark	Study Option 1	Study Option 3
MHEX	2174 MW	2176 MW	1849 MW	1949 MW
Dorsey-Maple River	-	-	1459 MW	-
Dorsey-King	-	-	-	1361 MW
Total	2174 MW	2176 MW	3309 MW	3311 MW
MWEX	1519 MW	1497 MW	1645 MW	1724 MW
Rochester-LaCrosse	-	247 MW	308 MW	292 MW
NDEX	2451 MW	2271 MW	2287 MW	2300 MW

Simulated disturbances are described in Table 1-8; it was initially assumed that outage of new 500 kV facilities associated with upgrade Option 1 or Option 3 do not trigger reduction of the power order on Manitoba Hydro's HVDC lines (HVDC reduction). Simulation results for the disturbances listed in Table E-4 and Table E-5 indicate unacceptable transmission system performance as explained ahead. These disturbances involve outage of one of four facilities:

- Dorsey-Maple River 500 kV line in Option 1 without directly triggering HVDC reduction,
- Maple River-Helena 500 kV line in Option 1
- Dorsey-King 500 kV line in Option 3 without directly triggering HVDC reduction, or
- King-Eau Claire 345 kV line in Option 3.

In both options, several of the disturbances cause the relay on the Manitoba-Ontario tie or the Forbes DC reduction relay (DCAR) to operate. These relays are intended to operate for severe disturbances that could lead to voltage collapse and are not intended to operate for category B or category C disturbances. In Option 3, faults at King with delayed clearing that result in outage of the King-Eau Claire 345 kV line cause a transient voltage violation at the Minong 161 kV bus. Additional analyses were performed to address these violations.

Table E-4: Option 1 Simulation Results

ID	Description	MH-OH Relay Trip *	DCAR Relay Trip *	Transient Voltage Violations	M602F Relay Margin	Notes
h79	3PH fault at Dorsey 500 on Maple River line	X	-	-	52%	
h53	3PH fault at Helena 500 on Maple River line	-	-	-	154%	Forbes SVC exceeds continuous rating
hm9	3PH fault at Maple River 500 on Dorsey line	X	X	-	44%	M602F margin violation
hec	SLG fault at Dorsey 500 on Maple River line with breaker failure; trip 500-230 kV xfmr; xfmr outage triggers DC reduction	-	-	-	21%	M602F margin violation
hlc	SLG fault at Dorsey 500 on Maple River line, with breaker failure, trip Dorsey-Riel	X	-	-	21%	M602F margin violation
hoc	SLG fault at Maple River 500 on 500-345 kV xfmr with brkr failure, trip Maple River-Dorsey	X	X	-	52%	

* MH-OH relay is DPDARE relay. DCAR is delta current admittance relay at Forbes.

Table E-5: Option 3 Simulation Results

ID	Description	MH-OH Relay Trip *	DCAR Relay Trip *	Transient Voltage Violations	M602F Relay Margin	Notes
pc0	SLG fault at King 345 on Eau Claire line with breaker failure; trip Chisago line			X		Minong voltage = 0.80
pcs	SLG fault at King 345 on Eau Claire line with breaker failure; trip Chisago line; cross trip Eau Claire-Arpin			X		Minong voltage = 0.80
hc9	3PH fault at Dorsey 500 on King line	X	X		45%	M602F margin violation
hfs	SLG fault at Dorsey 500 on King line with breaker failure; trip Dorsey 500-230 kV xfmr; xfmr outage triggers DC reduction				11%	M602F margin violation
hna	SLG fault at Dorsey 500 on King line with breaker failure; trip Dorsey-Riel #2	X	X		11%	M602F margin violation
hd9	3PH fault at King 500 on Dorsey line	X	X	X	38%	M602F margin violation, MP voltage violations
his	SLG fault at King 345 on 500-345 kV xfmr with breaker failure; trip Eau Claire line			X		Minong voltage = 0.81

* MH-OH relay is DPDARE relay. DCAR is delta current admittance relay at Forbes.

Minong Voltage Violations

In Option 3, disturbances his, pc0 and pcs cause a transient voltage violation at the Minong 161 kV bus. A second 75 MVAR shunt capacitor at the Stone Lake 345 kV bus increases the minimum transient voltage to 0.82 per unit and eliminates the violation. In disturbances pc0 and pcs the voltage violation occurs approximately 0.52 seconds after the fault is applied at King. The existing capacitor at the Stone Lake 345 kV bus is modeled with a 15-cycle insertion time; if the capacitors are switched sequentially, the insertion time for each capacitor needs to be less than 12 cycles so that both capacitors are on before the violation occurs.

Outage of Dorsey-Maple River or Dorsey-King

In both options, several of the simulated disturbances cause the relay on the Manitoba-Ontario tie or the DCAR DC reduction relay at Forbes to operate. Simulations were repeated with the relays blocked to determine what happens if the settings of the relays could be changed so that the relays do not operate for the Dorsey-Maple River or Dorsey-King outage.

After blocking the MH-OH and/or DCAR relays with Option 1, the out-of-step relays on the Riel-Forbes 500 kV line (M602F) violate the minimum transient-period relay margin. With Option 3, three-phase faults on the Dorsey-King 500 kV line cause stability problems with an electrical center in northern Minnesota around Forbes. Voltage oscillations are poorly damped with either option because the Forbes SVC is at its capacitive limit following the disturbance and is not able to provide damping.

Two options were evaluated to address these violations:

- Additional reactive support at Forbes
- HVDC Reduction

Additional Reactive Support

Critical disturbances were repeated with additional dynamic reactive support added at the Forbes 500 kV bus. With Option 1, the analysis indicates that tripping Dorsey-Maple River without a corresponding HVDC reduction requires the installation of more than 400 MVAr of additional dynamic (fast-switched capacitors) reactive support at Forbes; a total of approximately 600 MVAR is required to reduce the Forbes SVC output below the 110 MVAr continuous rating within 10 seconds. With Option 3, the analysis indicates that tripping Dorsey-King without a corresponding reduction to the HVDC power order requires the installation of more than 600 MVAr of additional dynamic (fast-switched capacitors) reactive support at Forbes; approximately 900 MVAR are required to reduce the Forbes SVC output below the continuous rating within 10 seconds.

Simulation results indicate that overcurrent relays will initiate a bypass of the Roseau series capacitors during the post-disturbance swing with Option 3, which triggers the existing HVDC reduction scheme. Either option requires additional analysis of protection on the Monitoba-Ontario ties, M602F line and Roseau series capacitors to make sure the system is secure during the power swing and voltage dip that occurs following trip of Dorsey-Maple River in Option 1 or Dorsey-King in Option 3.

HVDC Reduction

Critical disturbances were repeated with the existing HVDC reduction scheme triggered by outage of the new Dorsey-Maple River 500 kV tie line in Option 1 and by outage of the new Dorsey-King 500 kV tie line in Option 3. Reduction is assumed equal to 100% of the pre-disturbance flow on the line. There are no criteria violations with either Option 1 or with Option 3. Depending on the final design of the transmission upgrades, the required amount of reduction may be less than 100%.

Reduction amounts for the new and existing triggers are lower in the Option 1 and Option 3 study cases than in the benchmark case because flows on the existing Manitoba-US ties lines are lower in the study cases as shown in Table E-6.

Table E-6: MH-US Tie Line Loading

Tie Line	Pre-Benchmark	Benchmark	Study Option 1	Study Option 3
M602F @ Riel	1855 MW	1777 MW	1545 MW	1583 MW
Dorsey-Maple River	-	-	1459 MW	-
Dorsey-King	-	-	-	1361 MW
L20D @ Letellier	238 MW	287 MW	236 MW	268 MW
R50M @Richer	142 MW	139 MW	128 MW	134 MW
G82R @Glenboro	-62 MW	-28 MW	-61 MW	-36 MW

Outage of Maple River-Helena

When simulating outage of the Maple River-Helena 500 kV line with Option 1, the output of the Forbes SVC exceeds the continuous rating at the end of the simulation. Either option described above for outage of Dorsey-Maple River or Dorsey-King will address this issue; additional reactive support at Forbes or a cross-trip of Dorsey-Maple River combined with HVDC reduction.

Constraint Mitigation Costs

Estimated costs for resolving each of the TSR stability constraints are summarized in Table E-7. The costs are good faith estimates and will be further developed and refined in the Facility Study.

Table E-7: Mitigation Costs for Stability Constraints

Mitigation	Option 1	Option 3
Fast-switched capacitors at Forbes 500 kV (400-600 MVAr)	$20,000,000	$32,000,000
or		
New trigger to existing HVDC power order reduction scheme	$3,000,000	$3,000,000
Additional switched capacitor at Stone Lake with insertion time less than 12 cycles	-	$930,000
Total	$20,000,000	$32,930,000

Section

1

Transient Stability Analysis

Stability analyses have been performed to evaluate transient stability performance with the Manitoba Hydro TSRs and corresponding transmission upgrade options. Analyses were also performed on two cases without the TSRs or associated transmission upgrades to benchmark the 2015 summer off-peak case from the UIP study package.

1.1 Stability Study Package

Midwest ISO provided a UIP study package that was updated by the NMORWG in January 2009. Manitoba Hydro provided updates required to incorporate the Riel Station Reliability Project and Bipole 3.

1.2 Power Flow Cases

The power flow cases utilized in the stability analysis are listed in Table 1-1. The cases were developed from the 2015 summer off-peak case ("urg-so15aa.sav") in the UIP package. Case development is summarized in the following sections; additional details are provided in Appendix A.

Loading of the MHEX, MWEX and NDEX interfaces was reset in the pre-benchmark case and allowed to float in the benchmark and study cases.

Table 1-1: Power Flow Cases

Case Description	Case ID	CapX Projects	Study TSRs and Associated Transmission Upgrades
Pre-Benchmark Case	moa-so15aa	-	-
Benchmark Case	mba-so15aa	Group 1 Projects	-
TSR Study Case with Option 1	m1a-so15aa	Group 1 Projects	1130 MW with Upgrade Option 1
TSR Study Case with Option 3	m3a-so15aa	Group 1 Projects	1130 MW with Upgrade Option 3

1.2.1 Pre-Benchmark Case "moa-so15aa"

A pre-benchmark case without CapX projects, study TSRs or associated transmission upgrades was developed from the 2015 summer off-peak case in the UIP package as follows:

1) Apply response file provided by ATC to update model
2) Add Big Stone II (generator and 230 kV outlet)
3) Add MTEP projects excluding CapX 2020 Group 1 projects
4) Apply miscellaneous updates and corrections
5) Add NR generating facilities
6) Reduce load in North Dakota to approximately 80% of summer peak and reduce generation west of NDEX by a corresponding amount
7) Turn on generation in the GRE and XEL control areas that will be used to sink A388 and A416
8) Manitoba Hydro system updates including the addition of Bipole 3. HVDC loading adjusted to maintain export level and prepare to source TSRs at Dorsey in the TSR study cases.
9) Dispatch wind generation in southwest Minnesota at 1083 MW; sink using Xcel Energy generation in the Twin Cities.
10) Apply iplan program setexports.ipl to adjust NDEX, MHEX and MWEX to their simultaneous maximum capability. MHEX = 2175 MW, MWEX = 1525 MW, NDEX=2450 MW

The power flow summary for the pre-benchmark case is in Appendix B.1.

1.2.1.1 Big Stone II

Big Stone II is dispatched at 600 MW (net) and is modeled in the pre-benchmark case with the 230 kV outlet facilities:

- Big Stone-Johnson Jct–Morris 230 kV line
- Big Stone-Canby-Granite Falls 230 kV line
- Johnson Jct 230-115 kV transformer
- Canby 230-115 kV transformer

1.2.1.2 Midwest ISO Transmission Expansion Plan 2008 (MTEP08) Projects

Table 1-2 shows the MTEP08 projects that were added to the pre-benchmark case using response files provided by Midwest ISO. Projects in MTEP 08 Appendix B have not yet been studied through the MTEP cost-allocation process. If any of the projects in MTEP 08 Appendix B do not get developed, as per the identified need (in MTEP), the study TSRs would be reevaluated to determine if they are potentially responsible for the cost of those projects or appropriate alternatives.

Table 1-2: MTEP Projects Added to the Stability Case

Transmission Owner	MTEP Project ID	Project Name	MTEP Appendix
ITCM	1289	Marshalltown - Toledo - Belle Plaine - Stoney Point 115 kV line rebuild	A
ITCM	1618	Hrn Lk-Lkfld 161kV Ckt 1 Rbld	A
ITCM	1753	Winnebago Jct south 161/69kV	A
ITCM	1761	Readlyn-Tripoli 69kV Rebuild	A
ITCM	1739	Arnold-Vinton-Dysart-Washburn 161kV Reconductor	A
ITCM	1619	Grnd Mnd 161-69kV 2nd Xfmr & 161kV loop	A
ITCM	1342	Lewis Fields 161 kV substation which taps the SwampFX - Coggon 115 kV line	A
ITCM	1287	Replace Salem 345/161 kV transformer with 448 MVA unit	A
ATC LLC	339	Lake Mills Transmission-Distribution interconnection	A
ATC LLC	1553	Hiawatha 138kV Capacitor Bank	A
XEL	1368	Three Lakes 115/69 kV substation	A
XEL	1373	Ft. Ridgeley - Searles Jct 115 new line and Searles Jct - New Ulm 69 Reconductor	A
XEL	1457	G287, 37642-03. Upgrades for G287	A
XEL	1489	Woodbury - Tanners Lake upgrade	A
XEL/GRE	1545	Mankato 115 kV loop	A
XEL	1548	La Crosse Area Capacitor banks	A
XEL	1548	La Crosse Area Capacitor banks	A
XEL	1549	Eau Claire - Hydro Lane 161 kV Conversion	A
XEL	1959	Yankee Doodle interconnection	A
ITCM	1758	Beaver Channel-2nd Ave 69kV	A
ITCM	1288	Replace Hazleton 345/161 kV transformer #1 with 335 MVA unit	A
ITCM	1755	Washington-Hills 69kV Rebuild	A
ITCM	1345	Replace the limiting facility of CTs and conductor inside the substations for Quad Cities-Rock Creek-Salem 345 kV line	A
ITCM	1340	Hazleton - Salem 345 kV line with a 2nd Salem 345/161 kV 448 MVA transformer.	A
ITCM	1289	Marshalltown - Toledo - Belle Plaine - Stoney Point 115 kV line rebuild	A
MP/GRE	1021	Embarass to Tower 115 kV Line	A

Transmission Owner	MTEP Project ID	Project Name	MTEP Appendix
MP/GRE	1022	Badoura-Long Lake 115 kV line	A
GRE	1361	Badoura - Birch Lake 115 lines	A
GRE	599	Crooked Lake - Enterprise Park 115 kV line	A
ITCM	1341	Replace two Hazleton 161/69 kV transformers	A
ITCM	1473	Mason City Armor - Emery North 69 kV line	A
ITCM	1522	6th Street - Beverly	A
ITCM	1618	Hrn Lk-Lkfld 161kV Ckt 1 Rbld	A
ITCM	1641	OGS 50 MVAR Cap Bank	A
ITCM	1739	Arnold-Vinton-Dysart-Washburn 161kV Reconductor	A
ITCM	1753	Winnebago Jct south 161/69kV	A
ITCM	1756	Dyersville-Peoasta 69kV Rebuild	A
MP	1482	Pepin Lake 115/34.5 - Transformer 115/34.5 kV 39 MVA	A
GRE/OTP	1033	Silver Lake 230/41.6 kV transformer	A
OTP/MPC	971	Winger 230/115 kV Transformer Upgrade	A
OTP/MPC	2091	Cass Lake 115/69/41.6 kV sub	A
OTP	2092	South Cascade 115 kV Addition	A
SMP	1367	Lake City load serving upgrades	A
XEL	1371	Black Dog - Wilson 115 kV #2 Reconductor	A
XEL	1455	G238, 37642-02, Increase of generating capacity at Riverside Generating Plant	A
XEL	1487	Somerset - Stanton 69 kV line 84 MVA	A
XEL	1953	St. Cloud - Sauk River 115 kV line upgrade	A
XEL	1954	Cherry Creek - Split Rock 115 kV line saperation	A
XEL	1960	Traverse - St. Peter upgrade	A
XEL	1961	Lake Emily Capacitor bank	A
XEL	552	Ironwood 92/34.5 kV transformer #2	A
XEL	56	Chisago - Apple River	A
XEL	675	Rebuild Westgate to Scott County 69 kV to 115 kV	A
XEL	1958	Stone Lake-Edgewater 161 kV line. A new radial 161 kV line and substation in Sawyer County, Wisconsin	A
GRE	2569	Shoal Lake (Lawrence Lake) 115 kV line for new load	C
MP	2761	Pollymet load	C
MP	277	Badoura Project: Pine River - Pequot Lakes 115 kV line	A
ATC LLC	1463	Twin_Creeks-G384	N/A
ITCM	1645	Leon-1645_69kV_7MVAR	N/A
ITCM	1772	N_Cntrville_69kV-1772_7MVA	N/A
WAPA, BEPC	Correction	Su2009+-SplitWess	N/A
GRE	Network	KRMRLK(53801)	N/A

Transmission Owner	MTEP Project ID	Project Name	MTEP Appendix
XEL	1380	WWACONIA-SCOTT	N/A

N/A – These projects have been withdrawn and no longer appear in MTEP Appendix A/B.

1.2.1.3 Miscellaneous Updates and Corrections

Table 1-3 shows miscellaneous model updates and corrections.

Table 1-3: Miscellaneous Updates and Corrections

Area	Description
ATC	ATC footprint updates
GRE	MISO-PROJECT-KRMRLK(53801)
GRE	MISO-PROJECT-LWRNCTP(20138)
MP	MISO-Dunka-Load
MP	MISO-PROJECT-LL-BAD-PINE-PEQ
MP	Add MN Steel load and transmission
MP	GNET Unit 3 at Cloquet (bus 61668)
OTP	Put Buffalo-CSLTNET 115 kV line in service
OTP	Put Running 230/69 kV xfmr 1 in service
OTP	Put Moranville 230/115 kV xfmr 1 in service
OTP	Purge Center-Harvey-Prairie 345 kV line, Center 345-230 kV xfmr #2 and Harvey 345-230 kV xfmr
XEL	GNET Unit 1 at Chandler (bus 62710)

1.2.1.4 Midwest ISO Network Resource Generation

The NR generating facilities listed in Table 1-4 were added to the pre-benchmark case.

Table 1-4: Midwest ISO NR Generation Added to the Stability Case

MISO Project Number	MISO Queue Number	MISO Queue Date	Control Area	County	Point of Interconnection	Max Output (MW)	Dispatch (MW)
G519	38491-01	19-May-05	MP	Itasca, MN	Blackberry 230/115kV Substation	600	600
G618	38818-02	4/11/2006	OTP	Yellow Medicine, MN	Burr Jct to Toronto 115 kV line located 5 miles from Camby	138	27.6
G904	39388-01	11/2/2007	Xcel	Rolette, ND	Rugby-Glenboro 230kV	150	30
G930	39426-03	10-Dec-07	XEL	Sherburne, MN	Sherco Substation	120	120

1.2.1.5 North Dakota Load

Load in North Dakota was reduced by 540 MW to bring it down to approximately 80% of summer peak (to simulate summer off-peak conditions). Generation west of NDEX was reduced by a corresponding amount:

- North Dakota coal field generation units dispatched above their limits specified in the case were reduced to their respective limits (90 MW reduction)
- Big Stone Unit 1 reduced to its limit specified in the case (20 MW reduction)
- Wind generation in eastern North Dakota turned off at Ashtabula, Edgley and Langdon (430 MW reduction)

1.2.1.6 Manitoba Hydro (MH) System Updates

The following transmission and generating facilities were added to the pre-benchmark case to update the MH system representation and to ensure adequate generation reserves are available for sourcing the study TSRs:

- Bipole 3 and associated facilities at Riel
- Dorsey-Riel 500 kV circuit #2
- Dorsey-Portage 230 kV 2nd line
- Laverendrye-St Vital 230 kV line
- Letellier-St Vital 230 kV line
- Keeyask generating plant (7 x 90 MW)
- Conawapa generating plant (10 x 130 MW)

1.2.2 Benchmark Case "mba-so15aa"

A benchmark case without study TSRs or associated transmission upgrades was developed from the pre-benchmark case described in Section 1 as follows:

1) Add Big Stone 345 kV outlet facilities
2) Add CapX 2020 Group 1 projects

Interface loading was not reset in the benchmark case. The power flow summary for the benchmark case is in Appendix B.2.

1.2.2.1 Big Stone 345 kV Outlet Facilities

Big Stone II is modeled in the benchmark case with 345 kV outlet facilities:

- Big Stone - Johnson Jct-Morris 230 kV line
- Big Stone 345- 230 kV transformers
- Big Stone-Canby 345 line
- Canby 345-115 kV xfmr
- Canby-Hazel Run 345 line
- 2 Hazel Run 345/230 kV xfmrs
- Hazel Run 230/115 kV xfmr
- Hazel Run-Granite Falls 230 kV line
- Hazel Run-Minn Valley 230 kV line
- Johnson Jct 230-115 kV transformer

1.2.2.2 CapX 2020 Group 1 Projects

Table 1-5 shows the CapX 2020 Group 1 projects that were added to the benchmark case using response files provided by Midwest ISO.

Table 1-5: CapX 2020 Group 1 Projects Added to the Benchmark Case

PrjID	TO	Project Name
279	MPC, XEL, OTP, MP	CapX Bemidji-Grand Rapids 230 kV Line
286	GRE, XEL, OTP, MP, MRES	CapX Fargo, ND - St Cloud/Monticello, MN area 345 kV project
1024	XEL, DPC, RPU, SMP, WPPI	CapX SE Twin Cities - Rochester, MN - LaCrosse, WI 345 kV project
1203	XEL, GRE	CapX Brookings, SD - SE Twin Cities 345 kV project

1.2.3 TSR Study Cases

TSR study cases were created by taking the benchmark case and modeling the requested transmission service along with one of the transmission upgrade options.

1) Increase loading on the MH HVDC system (Bipole 1-3) including generation adjustments at Kettle, Long Spruce, Limestone, Keeyask, and Conawapa plants.
2) Adjust US generation to sink study TSRs
3) Add transmission upgrade option

Power flow summaries and diagrams for each study case are in Appendix B.

1.2.3.1 Source and Sinks for Study TSRs

The TSR source is the Dorsey inverter station and the 1130 MW aggregate study TSRs were sourced by increasing the injection from bipoles 1 and 2 from approximately 1700 MW in the benchmark case to 3245 MW in the study case and reducing the injection from bipole 3 from 1540 MW to 1130 MW. The study TSRs were sunk using the generators shown in Table 1-6.

Table 1-6: MH to US TSR Sinks

Generator Bus	MW
REMOVED	

Generator Bus	MW

1.2.3.2 Transmission Upgrade Options

The transmission upgrade options proposed by the ad hoc study group are summarized in Table 1-7. Impedance data and substation configuration assumptions are documented in Appendix A.4. Substation diagrams document assumption made when disturbances were defined and do not necessarily reflect actual or proposed substation layouts.

Table 1-7: Transmission Upgrade Options

1	3	Project
X		Dorsey – Maple River 50% series compensated 500 kV line terminated via 500/345 kV transformer at Maple River.
X		Maple River – Helena 50% series compensated 500 kV line terminated via 500/345 kV transformers at Helena.
	X	Dorsey – King 50% series compensated 500 kV line terminated via 500/345 kV transformer at King.

The transmission upgrade options evaluated in this study do not include shunt reactors to compensate for capacitive generation on the new 500 kV lines. Both Option 1 and Option 3 will require shunt reactors on the 500 kV line to control voltage when the line is open-ended. In Option 3, steady-state voltage is around 1.2 per unit at the series capacitor on the Dorsey-King 500 kV line and the series capacitors will need to be designed accordingly.

```
OPTION 3 BUSES WITH VOLTAGE GREATER THAN 1.1000:

   BUS#  X-- NAME --X  BASKV   V(PU)   V(KV)
 63061  MIDCOMP-N    500.00  1.1822  591.08
 63062  MIDCOMP-S    500.00  1.1360  568.00
```

1.3 Contingency Criteria

The stability simulations performed as part of this study considered the contingencies listed in Table 1-8. Disturbances defined in the MAPP standard library were simulated using the switching sequence from the library; disturbances affected by the Riel substation were updated based on input provided by Manitoba Hydro. New switching sequence files were developed for disturbances not defined in the library (ID beginning with an "h"); admittances used to simulate single-line-to-ground faults in new switching sequences were estimated assuming that the impedance in the positive, negative and zero sequences at the fault point are equal.

Table 1-8: Simulated Stability Disturbances

Pre-Benchmark moa	Benchmark mba	TSR Study Option 1 m1a	TSR Study Option 3 m3a	Description
ag1	ag1	ag1	ag1	4 cycle SLG fault at Leland Olds 345 kV on Leland Olds-Ft Thompson line; breaker 2692 fails; clear at 11 cycles by tripping faulted line
ag3	ag3	ag3	ag3	4 cycle 3PH fault at Leland Olds 345 kV, trip Leland Olds-Ft Thompson line
		cts [1]	cts [1]	4 cycle SLG fault at Chisago 345 kV on TR10, breaker 9P20 fails, clear at 16 cycles by tripping Chisago-Forbes; cross-trip Forbes-Riel and trigger HVDC reduction
ei2	ei2	ei2	ei2	CU DC permanent bipole fault with tripping of both Coal Creek units
		em3	em3	5 cycle 3PH fault at Letellier 230, clear by tripping Letellier-Drayton line; trigger HVDC reduction
eq1	eq1	eq1	eq1	SLG fault with breaker failure at Coal Creek on CU DC pole 1 with cross-trip of Coal Creek unit #2
fds	fds	fds	fds	5 cycle 3PH fault at Square Butte 230 kV, clear by tripping Square Butte-Stanton line
		mc3	mc3	5 cycle 3PH fault at Richer 230 kV, clear by tripping Richer-Roseau line; trigger HVDC reduction
		md3	md3	5 cycle 3PH fault at Glenboro 230 kV, clear by tripping Glenboro-Rugby line
		mis	mis	Bipole 2 block in the Manitoba Hydro System, Cross trip Manitoba Ontario Ties @ t=0.35s; trigger HVDC reduction
		mjs	mjs	4 cycle SLG fault at Chisago 345 kV on Chisago-Kohlman Lake line, breaker

Pre-Benchmark moa	Benchmark mba	TSR Study Option 1 m1a	TSR Study Option 3 m3a	Description
				fails at Chisago, clear by tripping Chisago 500-345 kV xfmr
		mkd	mkd	4 cycle 3 phase fault at Chisago 345 kV, clear the Chisago-King line
		mks	mks	4.5 cycle SLG fault at Chisago 345 kV on Chisago-King line, King breaker fails, clear at 15 cycles by tripping Chisago 500-345 kV xfmr
nad [1]	nad [1]	nad [1]	nad [1]	4 cycle 3PH fault at Forbes 500 kV on M602F; trigger HVDC reduction
nmz [1]	nmz [1]	nmz [1]	nmz [1]	4 cycle 3PH fault at Chisago 500 kV on F601C, xtrip M602F, 100% reduction, leave SVC on MP system
pas [1]	pas [1]	pas [1]	pas [1]	5 cycle SLG fault at Forbes 500 kV on M602F, Forbes breaker fails, Forbes breakers operate at 16 cycles, clear at 17 cycles; trigger HVDC reduction
		pc0	pc0	4.5 cycle SLG fault at King 345 kV on King-Eau Claire line, King breaker fails, clear at 16 cycles by tripping King-Chisago
pcs	pcs	pcs	pcs	4.5 cycle SLG fault at King 345 kV on King-Eau Claire line, King breaker fails, clear at 16 cycles by tripping King-Chisago, cross trip Eau Claire-Arpin
pct	pct	pct	pct	Trip of King-Eau Claire-Arpin without a fault
pys	pzs [2]	pzs [2]	pzs [2]	4.5 cycle SLG fault Prairie Island 345 kV on Prairie Island-N Rochester, 8H9 fails, clear at 16 cycles by tripping Prairie Island xfmr #10
pyt	pzt [2]	pzt [2]	pzt [2]	Trip of Prairie Island-N Rochester without a fault
		ya3	ya3	4 cycle 3 phase fault at Arrowhead 230 kV, clear the Arrowhead-Gardner park 345 kV line
		yas	yas	4 cycle SLG fault at Arrowhead 345 on AHD-GDP ckt #1, AHD brkr stk, clear at 17 cycles by tripping AHD-GDP bus section
		yb3	yb3	4 cycle 3PH fault at Arrowhead 345 kV, trip the Arrowhead-Stone Lake line
		h13	h13	5 cycle 3PH fault at Dorsey, trip Dorsey-Riel 500 kV line #1
		h23	h23	5 cycle 3PH fault at Dorsey, trip Dorsey 500/230 kV transformer #1; trigger HVDC reduction
		h79		5 cycle 3PH fault at Dorsey 500 kV, trip the Dorsey-Maple River 500 kV line
			hc9	5 cycle 3PH fault at Dorsey 500 kV, trip Dorsey-King 500 kV line
		hec		5 cycle SLG fault at Dorsey 500 kV on Dorsey-Maple River line, Dorsey breaker fails, clear at 16 cycles by tripping Dorsey 500-230 kV xfmr, trigger HVDC reduction; block SUVC
			hfs	5 cycle SLG fault at Dorsey 500 kV on Dorsey-King line, Dorsey breaker fails, clear at 16 cycles by tripping Dorsey 500-230 kV xfmr, trigger HVDC reduction; block SUVC
		hlc		5 cycle SLG fault at Dorsey 500 kV on Dorsey-Maple River line, Dorsey breaker fails, clear at 16 cycles by tripping Dorsey-Riel 500 kV line #2; block SUVC

Pre-Benchmark moa	Benchmark mba	TSR Study Option 1 m1a	TSR Study Option 3 m3a	Description
			hna	5 cycle SLG fault at Dorsey 500 kV on Dorsey-King line, Dorsey breaker fails, clear at 16 cycles by tripping Dorsey-Riel 500 kV line #2; block SUVC
		h33	h33	5 cycle 3PH fault at Riel, trip Riel-Forbes 500 kV line; trigger HVDC reduction
		h43	h43	5 cycle 3PH fault at Riel, trip Riel 500/230 kV transformer
		h53		5 cycle 3PH fault at Helena 500 kV, trip the Helena-Maple River 500 kV line
		h63		5 cycle 3PH fault at Helena 345 kV, trip the Helena-Blue Lake 345 kV line
		he3		5 cycle 3PH fault at Helena 345 kV, trip the Helena-Lake Marion 345 kV line
		hgs		5 cycle SLG fault at Helena 345 kV on 500-345 kV xfmr, 345 kV breaker fails, clear at 16 cycles by tripping Helena-Blue Lake
		hjs		5 cycle SLG fault at Helena 345 kV on Helena-Blue Lake line, Helena breaker fails, clear at 16 cycles by tripping Helena-Wilmarth
		h83		5 cycle 3PH fault at Maple River 500 kV, trip the Maple River 500/345 kV transformer
		hm9		5 cycle 3PH fault at Maple River 500 kV, trip the Dorsey-Maple River line
		hoc		5 cycle SLG fault at Maple River 500 kV on 500-345 kV xfmr, 500 kV breaker fails, clear at 16 cycles by tripping Dorsey-Maple River
		h93		5 cycle 3PH fault at Maple River 345 kV, trip Maple River-Alexandria SS 345 kV line
		hhs		5 cycle SLG fault at Maple River 345 kV on 500-345 kV xfmr, 345 kV breaker fails, clear at 16 cycles by tripping Maple River-Alexandria SS
		hks		5 cycle SLG fault at Maple River 345 on Alexandria SS line, Maple River breaker fails, clear at 16 cycles by tripping Maple River 345-230 kV xfmr
			hd9	5 cycle 3PH fault at King 500 kV, trip Dorsey-King line
			his	5 cycle SLG fault at King 345 on 500-345 kV transformer, 345 kV breaker fails, clear at 16 cycles by tripping King-Eau Claire line

Note 1: Switching sequence updated to account for Riel
Note 2: Switching sequence updated to account for N Rochester

The disturbances listed in Table 1-8 assume that outage of new 500 kV facilities associated with upgrade Option 1 or Option 3 do not trigger HVDC reduction. Existing triggers to the HVDC reduction scheme were simulated and reduction amounts are summarized in Table 1-9. When an exporting tie line is lost the HVDC power order is reduced by the pre-contingent flow on the tie line. Reduction amounts in the study cases are lower than in the benchmark case because flow is reduced on the existing Manitoba-US ties lines in the Option 1 and Option 3 study cases.

Table 1-9: HVDC Reduction

ID	Description	Reduction	Pre-Benchmark moa	Benchmark mba	TSR Study Option 1 m1a	TSR Study Option 3 m3a
cts	SLG fault at Chisago 345 with breaker failure	100% M602F	1856 MW	1777 MW	1545 MW	1583 MW
em3	3PH fault at Letellier 230 on L20D	100% L20D	239 MW	288 MW	236 MW	268 MW
h23	3PH fault at Dorsey 500 on 500-230 xfmr	50% M602F	928 MW	888 MW	772 MW	791 MW
h33	3PH fault at Riel 500 on M602F	100% M602F	1856 MW	1777 MW	1545 MW	1583 MW
hec	SLG fault at Dorsey 500 with breaker failure; xfmr outage triggers HVDC reduction	50% M602F			772 MW	
hfs	SLG fault at Dorsey 500 with breaker failure; xfmr outage triggers HVDC reduction	50% M602F				791 MW
mc3	3PH fault at Richer 230 on R50M	100% R50M	142 MW	140 MW	129 MW	134 MW
mis	Bipole 2 block , cross trip MH-OH ties	100% (K21W+K22W)	200 MW	200 MW	199 MW	199 MW
nad	3PH fault at Forbes 500 on M602F	100% M602F	1856 MW	1777 MW	1545 MW	1583 MW
nmz	3PH fault at Chisago 500 on F601C	100% M602F	1856 MW	1777 MW	1545 MW	1583 MW
pas	SLG fault at Forbes 500 with breaker failure	100% M602F	1856 MW	1777 MW	1545 MW	1583 MW

1.4 Performance Criteria

Simulation results were evaluated using the criteria in the MAPP Members Reliability Criteria and Study Procedures Manual. Transient voltages must be within the MAPP default limits of 0.70-1.20 per unit with the exception of a few specific buses, areas or companies that have different requirements. All machine rotor angle oscillations must be positively damped with a minimum damping factor of 5% for disturbances with a fault or 10% for line trips without a fault.

1.5 Results for Benchmark Cases

Transient stability simulation results for the pre-benchmark and benchmark cases are summarized in Appendix C. All of the simulated disturbances result in acceptable system performance.

1.6 Results for Option 1 Study Case

Transient stability simulation results for the TSR study cases are summarized in Appendix C.

1.6.1 Option 1 Results

Significant results are summarized in Table 1-10. These disturbances involve outage of the Dorsey-Maple River 500 kV line without directly triggering HVDC reduction or outage of the Maple River-Helena 500 kV line.

Several of the disturbances cause the relay on the Manitoba-Ontario tie or the DCAR DC reduction relay at Forbes to operate. These relays are intended to operate for severe disturbances that could lead to voltage collapse and are not intended to operate for category B or category C disturbances. The analysis summarized in Section 1.6.2 was performed to document system response if the settings of the Manitoba-Ontario relay and DCAR relay could be changed so that neither relay operates for the Dorsey-Maple River outage.

Table 1-10: Option 1 Simulation Results

ID	Description	MH-OH Relay Trip *	DCAR Relay Trip *	Transient Voltage Violations	M602F Relay Margin	DCAR Relay Margin	Notes
h79	3PH fault at Dorsey 500 on Maple River line	X	-	-	52%	39%	
h53	3PH fault at Helena 500 on Maple River line	-	-	-	154%	347%	Forbes SVC exceeds continuous rating
hm9	3PH fault at Maple River 500 on Dorsey line	X	X	-	44%	<0%	M602F margin violation
hec	SLG fault at Dorsey 500 on Maple River line with breaker failure; trip 500-230 kV xfmr; xfmr outage triggers HVDC reduction	-	-	-	21%	170%	M602F margin violation - minimum margin occurs during backup clearing.
hlc	SLG fault at Dorsey 500 on Maple River line, with breaker failure, trip Dorsey-Riel	X	-	-	21%	55%	M602F margin violation - minimum margin occurs during backup clearing.
hoc	SLG fault at Maple River 500 on 500-345 kV xfmr with breaker failure, trip Maple River-Dorsey	X	X	-	52%	<0%	

* MH-OH relay is DPDARE relay. DCAR is delta current admittance relay at Forbes.

Neither the Manitoba-Ontario relay nor the DCAR relay operate in disturbance *hec* but the out-of-step relay on M602F violates the 50% minimum relay margin criterion. This disturbance is a fault at Dorsey on the Maple River line with delayed clearing. The margin violation occurs during the backup clearing time, which means that the violation is independent of the facility disconnected to clear the fault.

1.6.2 Option 1 Results with Relays Blocked

Disturbances *h79*, *hm9*, *hlc* and *hoc* were repeated with the Manitoba-Ontario, DCAR and M602F relays blocked as indicated in Table 1-11 to document system response if the settings of the relays could be changed so that the relays do not operate for the Dorsey-Maple River outage.

Results are summarized in Table 1-11. There are no transient voltage violations. The M602F relay margin violation in *hls* (originally *hlc*) occurs during backup clearing time as shown in Figure 1-1. M602F relay margin violations in *h73* (originally *h79*), *hm3* (originally *hm9*) and *hoa* (originally *hoc*) occur when voltage dips at Forbes following fault clearing. The voltage oscillation shown in Figure 1-3 is typical of all four disturbances; the Forbes SVC is at its capacitive limit and is not able to provide damping.

Table 1-11: Option 1 Results with Relays Blocked

ID	Description	MH-OH Blocked	DCAR Blocked	M602F OOS Blocked	Transient Voltage Violations	M602F Relay Margin	Forbes SVC Reaches Dynamic Limit	Notes
h73	3PH fault at Dorsey 500 on Maple River line	X	X	-	-	48%	X	M602F margin violation
hm3	3PH fault at Maple River 500 on Dorsey line	X	X	-	-	37%	X	M602F margin violation
hls	SLG fault at Dorsey 500 on Maple River line, with breaker failure, trip Dorsey-Riel	X	-	-	-	21%	X	Minimum relay margin occurs during backup clearing.
hoa	SLG fault at Maple River 500 on 500-345 kV xfmr with breaker failure, trip Maple River-Dorsey	X	X	X	-	<0%	X	M602F margin is around 10% on first swing; <0% for second swing

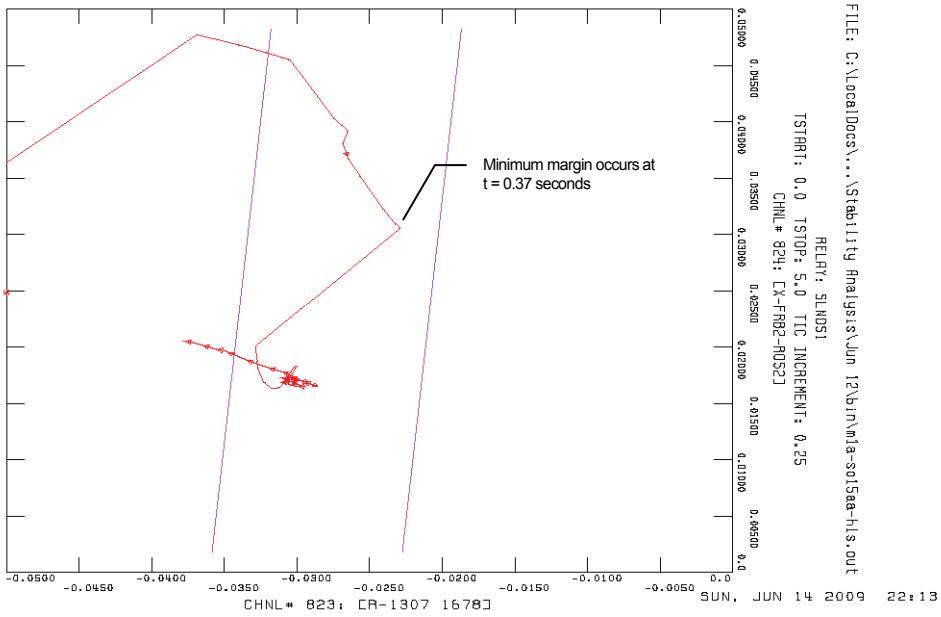

Figure 1-1: M602F Apparent Impedance at Forbes for SLG Fault at Dorsey with Delayed Clearing (*hls*)

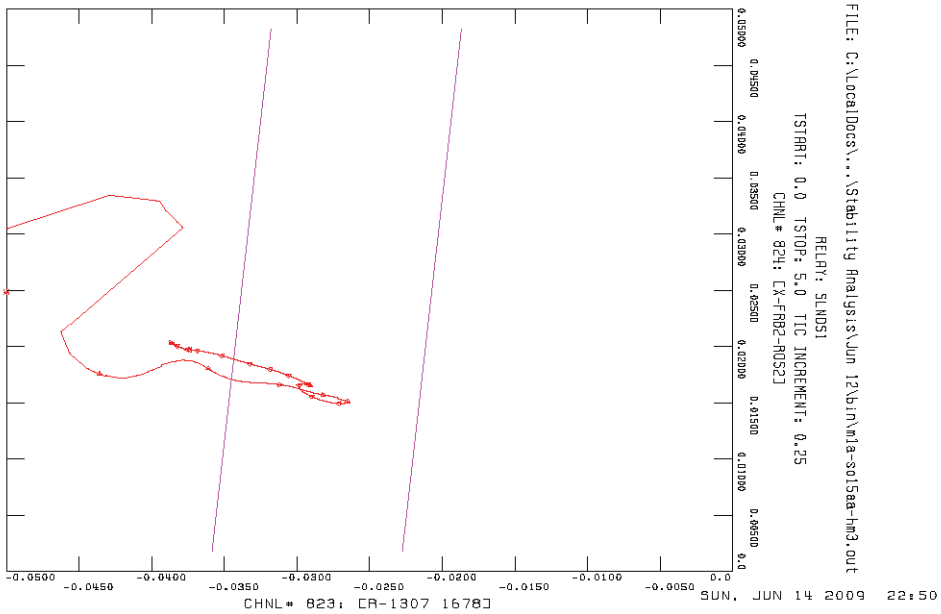

Figure 1-2: M602F Apparent Impedance at Forbes for 3PH fault at Maple River (*hm3*)

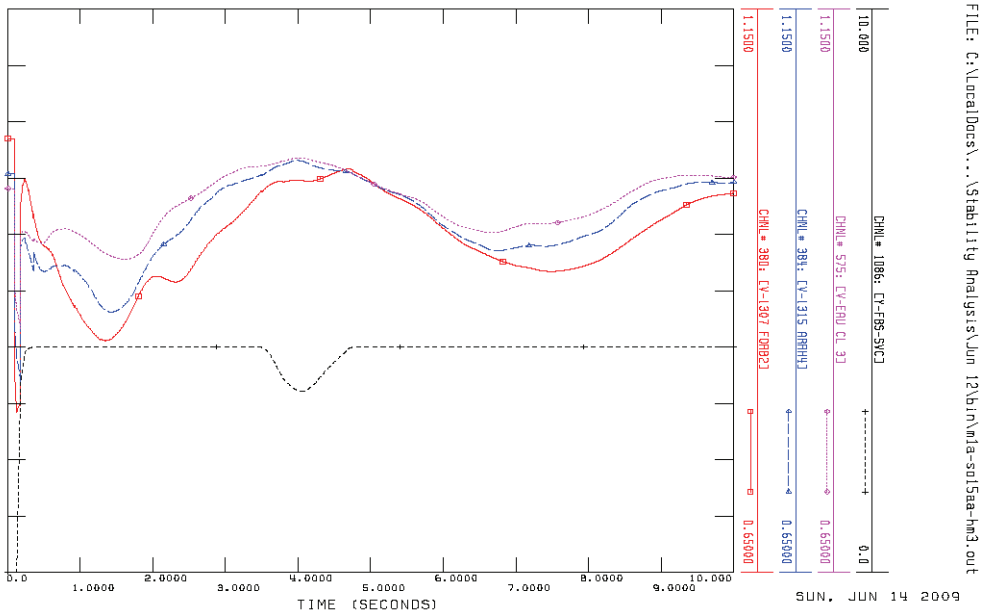

Figure 1-3: Bus Voltage and Forbes SVC Admittance for 3PH fault at Maple River (*hm3*)

1.6.3 Option 1 Results with Additional Reactive Support

Disturbances *h79*, *hm9*, *hlc* and *hoc* were repeated with additional reactive support added at the Forbes 500 kV bus. Results with an additional 400 MVAr of reactive support are summarized in Table 1-12. There are two 300 MVAr mechanically switched capacitors at Forbes; additional reactive support was simulated by switching a 400 MVAr capacitor 5 cycles after the fault is applied.

Table 1-12: Option 1 Results with Additional 400 MVAr Shunt at Forbes

ID	Description	MH-OH Blocked	DCAR Blocked	Transient Voltage Violations	M602F Relay Margin	Forbes SVC Reaches Dynamic Limit	Notes
h7z	3PH fault at Dorsey 500 on Maple River line	-	-	-	79%	X	
hmz	3PH fault at Maple River 500 on Dorsey line	X	-	-	58%	X	
hlz	SLG fault at Dorsey 500 on Maple River line, with breaker failure, trip Dorsey-Riel	X	-	-	15%	X	Minimum relay margin occurs during backup clearing.
hoz	SLG fault at Maple River 500 on 500-345 kV xfmr with breaker failure, trip Maple River-Dorsey	X	-	-	61%	X	

The Manitoba-Ontario relay does not operate in disturbance *h7z* (originally *h79*) but had to be blocked for the other disturbances. The M602F relay margin only violates criteria for *hlz* (originally *hlc*).

Figure 1-4 shows that additional reactive support reduces the magnitude of the voltage oscillations. However, in each simulation the Forbes SVC still hits the 400 MVAr dynamic limit for more than one second and exceeds the 110 MVAr steady-state limit at ten seconds.

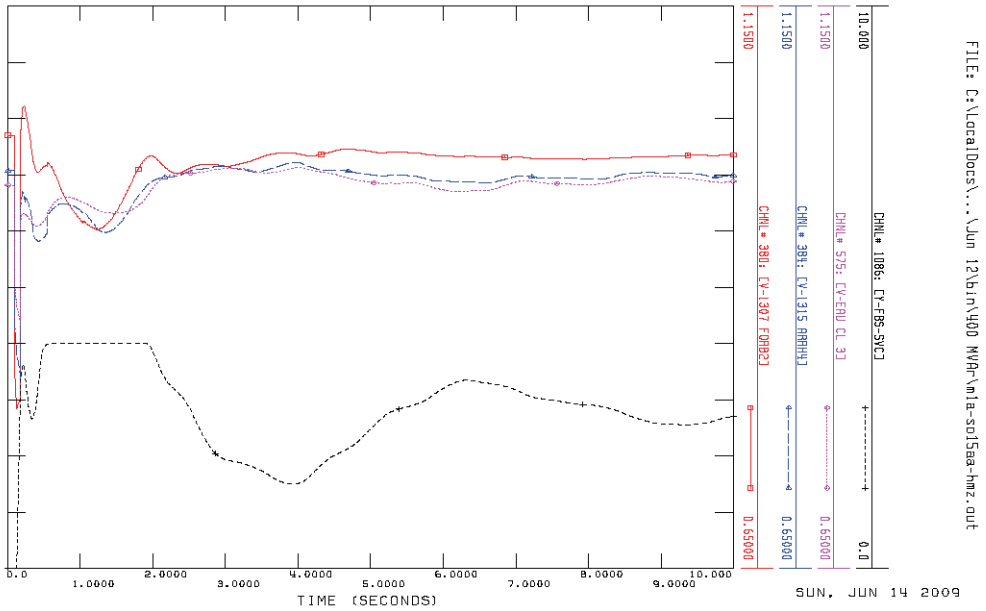

Figure 1-4: Bus Voltage and Forbes SVC Admittance with Additional Reactive Support for 3PH fault at Maple River (*hmz*)

Simulation results with an additional 600 MVAr of support at Forbes are similar to results for 400 MVAr except that the relay on the Manitoba-Ontario tie does not operate for any of the disturbances. SVC admittance and the 500 kV bus voltage at Forbes is shown in Figure 1-5 for the base Option 1 study case and the study case with additional 400 MVAr and 600 MVAr support. The SVC output should be less than or equal to the 110 MVAr continuous rating at the end of the simulation, which will require approximately 600 MVAr of support.

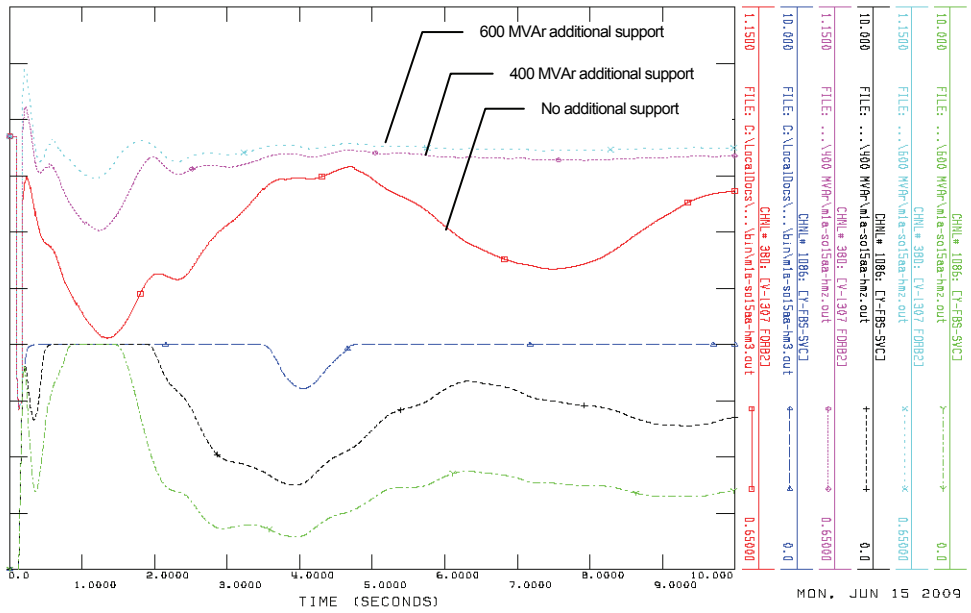

Figure 1-5: Forbes 500 kV Voltage and Forbes SVC Admittance for 3PH fault at Maple River (*hmz*)

Current through the Roseau series capacitors on M602F is shown in Figure 1-6 for the disturbances listed in Table 1-12. The series capacitors have inverse-time overcurrent relays that initiate a bypass of the series capacitors, which triggers the existing HVDC reduction scheme. The relay setting corresponds to operation in 1 second for a 3000 A current through the capacitors and operation in 5 seconds for a current of 2800 A. The current shown in Figure 1-6 should not trip the relays since the current does not exceed 2800 A for 5 seconds. Since much of the series capacitor's overload capability will have been used, it may be necessary to reduce the current to 2000 A in less than 30 minutes. Additional studies should be performed to confirm that the M602F series capacitors have adequate overload capability if outage of the new Dorsey-Maple River 500 kV line is not used to trigger HVDC reduction.

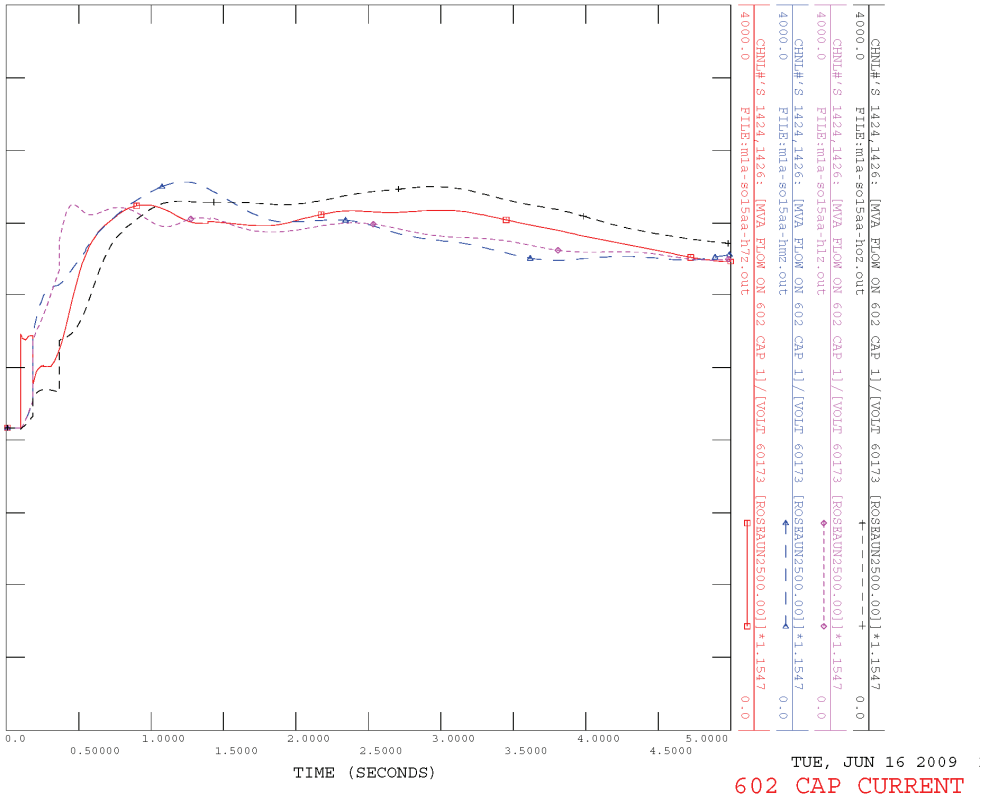

Figure 1-6: M602F Series Capacitor Current for Faults on Dorsey-Maple River 500 kV Line

The analysis summarized in this section indicates that tripping Dorsey-Maple River without a corresponding reduction to the HVDC power order requires the installation of more than 400 MVAr of additional dynamic (fast-switched capacitors) reactive support at Forbes and analysis of protection on the Monitoba-Ontario ties and M602F line to make sure the system is secure during the resulting power swing.

1.6.4 Option 1 Results with DC Reduction

Disturbances h79, hm9, hec, hlc and hoc were repeated with outage of the new Dorsey-Maple River 500 kV line used to trigger HVDC reduction. Reduction is assumed equal to 100% of the pre-disturbance flow on Dorsey-Maple River.

There are no criteria violations with a 100% reduction as shown in Table 1-13. The power order reduction increases the M602F relay margin for all disturbances, including the single-line-to-ground faults at Dorsey with delayed clearing, *he0* (originally *hec*) and *hl0* (originally *hlc*).

Table 1-13: Option 1 Results with DC Reduction

ID	Description	MH-OH Relay Trip*	DCAR Relay Trip*	Transient Voltage Violations	M602F Relay Margin	DCAR Relay Margin	Notes
h7d	3PH fault at Dorsey 500 on Maple River line	-	-	-	262%	507%	
hmd	3PH fault at Maple River 500 on Dorsey line	-	-	-	200%	507%	
he0	SLG fault at Dorsey 500 on Maple River line with breaker failure; trip 500-230 kV xfmr; xfmr outage triggers HVDC reduction	-	-	-	76%	445%	
hl0	SLG fault at Dorsey 500 on Maple River line, with breaker failure, trip Dorsey-Riel	-	-	-	76%	445%	
ho0	SLG fault at Maple River 500 on 500-345 kV xfmr with breaker failure, trip Maple River-Dorsey	-	-	-	220%	507%	

* MH-OH relay is DPDARE relay. DCAR is delta current admittance relay at Forbes.

The HVDC reduction resulting from the M602F or Dorsey-Maple River triggers in the study case are lower than the reduction that occurs for the M602F trigger in the benchmark case as shown in Table 1-14. Depending on the final design of the Option 1 transmission upgrade, the required amount of reduction may be less than 100%.

Table 1-14: DC Power Order Reduction

Trigger	Benchmark Case	Option 1 Study Case
M602F	100% = 1749 MW	100% = 1545 MW
Dorsey-Maple River		100% = 1460 MW

1.7 Results for Option 3 Study Case

Transient stability simulation results for the TSR study cases are summarized in Appendix C.

1.7.1 Option 3 Results

Significant results are summarized in Table 1-15. These disturbances involve outage of one of two facilities:

- the Dorsey-King 500 kV line without directly triggering HVDC reduction, or
- the King-Eau Claire 345 kV line.

Table 1-15: Option 3 Simulation Results

ID	Description	MH-OH Relay Trip*	DCAR Relay Trip*	Transient Voltage Violations	M602F Relay Margin	DCAR Relay Margin	Notes
pc0	SLG fault at King 345 on Eau Claire line with breaker failure; trip Chisago line			X			Minong voltage = 0.80
pcs	SLG fault at King 345 on Eau Claire line with breaker failure; trip Chisago line; cross trip Eau Claire-Arpin			X			Minong voltage = 0.80
hc9	3PH fault at Dorsey 500 on King line	X	X		45%	<0%	M602F margin violation
hfs	SLG fault at Dorsey 500 on King line with breaker failure; trip Dorsey 500-230 kV xfmr; xfmr outage triggers HVDC reduction				11%	143%	M602F margin violation - minimum margin occurs during backup clearing.
hna	SLG fault at Dorsey 500 on King line with breaker failure; trip Dorsey-Riel #2	X	X		11%	<0%	M602F margin violation - minimum margin occurs during backup clearing.
hd9	3PH fault at King 500 on Dorsey line	X	X	X	38%	<0%	M602F margin violation, MP voltage violations
his	SLG fault at King 345 on 500-345 kV xfmr with breaker failure; trip Eau Claire line			X			Minong voltage = 0.81

* MH-OH relay is DPDARE relay. DCAR is delta current admittance relay at Forbes.

Outage of King-Eau Claire in disturbances *his*, *pc0* and *pcs* cause a transient voltage violation at the Minong 161 kV bus. This constraint is analyzed in Section 1.7.2.

Disturbances *hc9*, *hna* and *hd9* cause the relay on the Manitoba-Ontario tie and the DCAR DC reduction relay at Forbes to operate. These relays are intended to operate for severe disturbances that could lead to voltage collapse and are not intended to operate for category B or category C disturbances. The analysis summarized in Section 1.7.3 was performed to determine what happens if the settings of the Manitoba-Ontario relay and DCAR relay could be changed so that neither relay operates for the Dorsey-King outage.

Neither the Manitoba-Ontario relay nor the DCAR relay operate in disturbance hfs but the out-of-step relay on M602F violates the 50% minimum relay margin criterion. This disturbance is a fault at Dorsey on the King line with delayed clearing. The margin violation occurs during the backup clearing time, which means that the violation is independent of the facility disconnected to clear the fault.

1.7.2 Minong Voltage Violation

As shown in Figure 1-7, disturbances *his*, *pc0* and *pcs* cause a transient voltage violation at the Minong 161 kV bus. A second 75 MVAR shunt capacitor at the Stone Lake 345 kV bus increases the minimum transient voltage to 0.82 per unit and eliminates the violation. In disturbances *pc0* and *pcs* the voltage violation occurs approximately 0.52 seconds after the fault is applied at King. The existing capacitor at the Stone Lake 345 kV bus is modeled with a 15-cycle insertion time; if the capacitors are switched sequentially, the insertion time for each capacitor needs to be less than 12 cycles so that both capacitors are on before the violation occurs. Table 1-16 shows a comparison of the minimum transient voltage at Arrowhead and Minong in the benchmark and study cases.

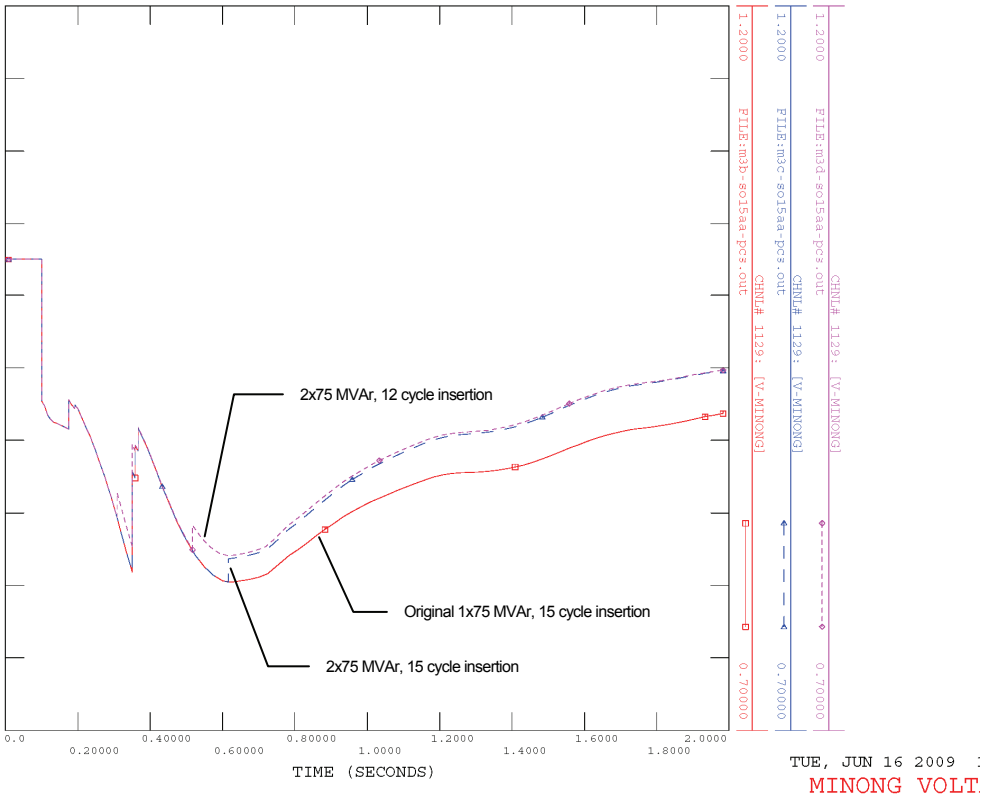

Figure 1-7: Minong Bus Voltage for SLG Fault at King with Delayed Clearing (pcs)

Table 1-16: Minimum Transient Voltage for Disturbance PCS

Case	MWEX/Rochester-LaCrosse	Minong 161 kV	Arrowhead 230 kV
Pre-Benchmark moa-so15aa	1519 MW/0 MW	0.86 per unit	0.88 per unit
Benchmark mba-so15aa	1497 MW/247 MW	0.88 per unit	0.90 per unit
Option 1 study case m1a-so15aa	1641 MW/309 MW	0.83 per unit	0.87 per unit
Option 3 study case - m3a-so15aa - with 2x75 MVAr cap at Stone Lake	1722 MW/292 MW	0.80 per unit 0.82 per unit	0.84 per unit 0.82 per unit

1.7.3 Option 3 Results with Relays Blocked

Disturbances *hc9*, *hna* and *hd9* were repeated with the Manitoba-Ontario, DCAR and M602F relays blocked as indicated in Table 1-17 to determine what happens if the settings of the relays could be changed so that the relays do not operate for the Dorsey-King outage.

Results are summarized in Table 1-17. Three-phase faults on the Dorsey-King 500 kV line cause stability problems as shown in Figure 1-8.

Table 1-17: Option 3 Results with Relays Blocked

ID	Description	MH-OH Blocked	DCAR Blocked	M602F OOS Blocked	Transient Voltage Violations	M602F Relay Margin	Forbes SVC Reaches Dynamic Limit	Notes
hc3	3PH fault at Dorsey 500 on King line	X	X	X	X	<0%	X	Loss of synchronism if relays are blocked
hns	SLG fault at Dorsey 500 on King line with breaker failure; trip Dorsey-Riel #2	X	X	X	X	<0%	X	M602F margin violation, MP voltage violations
hd3	3PH fault at King 500 on Dorsey line	X	X	X	X	<0%	X	Transient voltage instability if relays are blocked

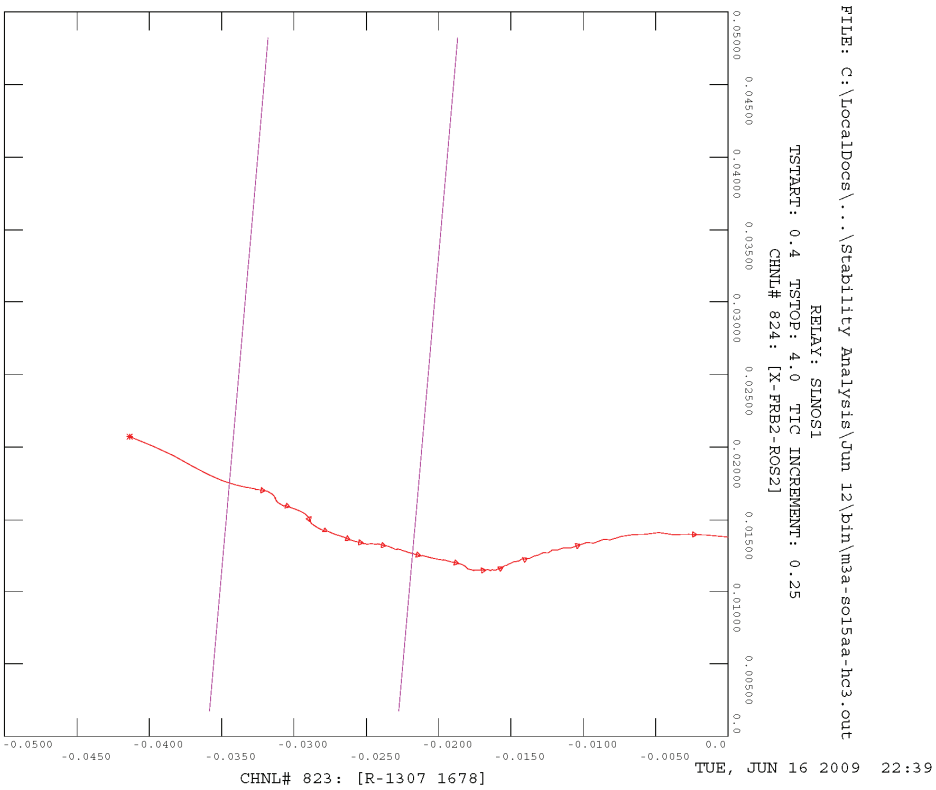

Figure 1-8: M602F Apparent Impedance at Forbes for 3PH Fault at Dorsey (*hc3*)

1.7.4 Option 3 Results with Additional Reactive Support

Disturbances *hc9*, *hna* and *hd9* were repeated with additional reactive support at the Forbes 500 kV bus. Results with an additional 400 MVAr of reactive support are summarized in Table 1-18. Additional reactive support was simulated by switching a 400 MVAr capacitor 5 cycles after the fault is applied, resulting in a total of 600+400=1000 MVAr of shunt capacitors in addition to the SVC.

Figure 1-9 shows that with an additional 400 MVAr of reactive support at Forbes, there are still severe voltage dips and the Forbes SVC remains at its 400 MVAr dynamic limit for most of the simulation. The magnitude of the voltage oscillation is significantly smaller with 600 MVAr of additional support as shown in Figure 1-10. The SVC output should be less than or equal to the 110 MVAr continuous rating at the end of the simulation, which will require approximately 900 MVAr of support.

Table 1-18: Option 3 Results with Additional 400 MVAr Shunt at Forbes

ID	Description	MH-OH Blocked	DCAR Blocked	M602F OOS Blocked	Transient Voltage Violations	M602F Relay Margin	Forbes SVC Reaches Dynamic Limit	Notes
hcz	3PH fault at Dorsey 500 on King line	X	-	-	-	31%	X	M602F margin violation
hnz	SLG fault at Dorsey 500 on King line with breaker failure; trip Dorsey-Riel #2	X	X	X	-	<0%	X	M602F blocked for simulation
hdz	3PH fault at King 500 on Dorsey line	X	-	X	-	<0%	X	M602F blocked for simulation

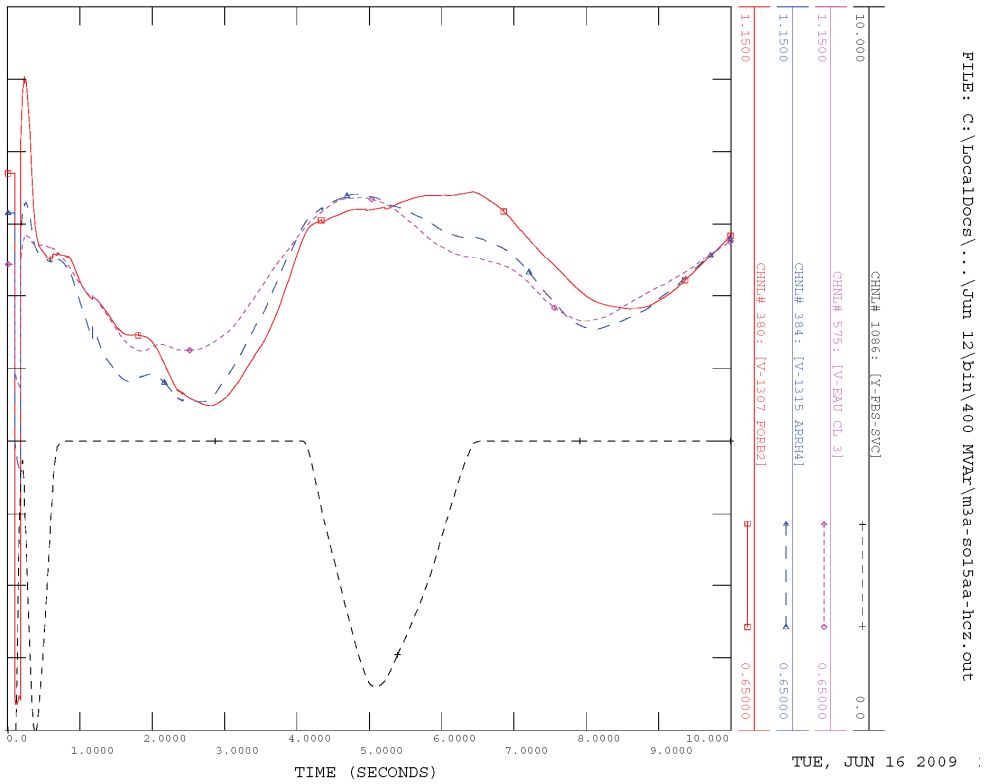

Figure 1-9: Bus Voltage and Forbes SVC Admittance with Additional Reactive Support for 3PH fault at Dorsey (*hcz*)

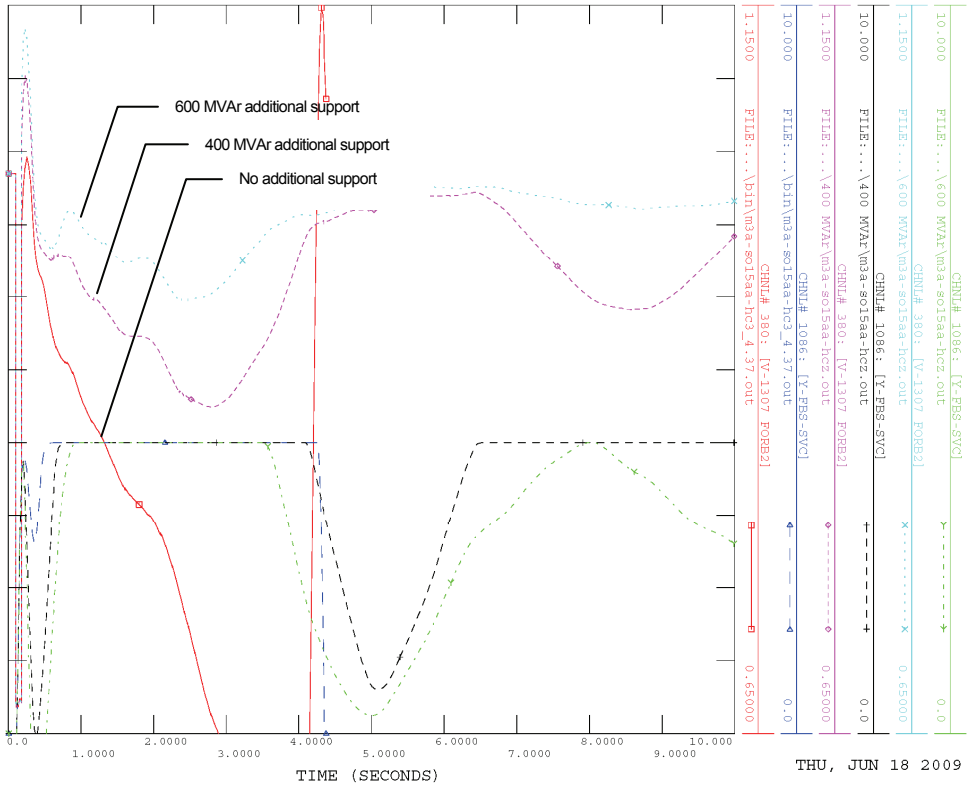

Figure 1-10: Forbes 500 kV Voltage and Forbes SVC Admittance for 3PH fault at Dorsey (*hcz*)

Current through the Roseau series capacitors on M602F is shown in Figure 1-11 for the disturbances listed in Table 1-17. The series capacitors have inverse-time overcurrent relays that initiate a bypass of the series capacitors, which triggers the existing HVDC reduction scheme. The relay setting corresponds to operation in 1 second for a 3000 A current through the capacitors and operation in 5 seconds for a current of 2800 A. The current shown in Figure 1-11 will trip the relays since the current exceeds 3000 A for more than 1 second. Additional mitigation will be required if the relay settings can not be adjusted and the new Dorsey-Maple River 500 kV line is not used to trigger HVDC reduction.

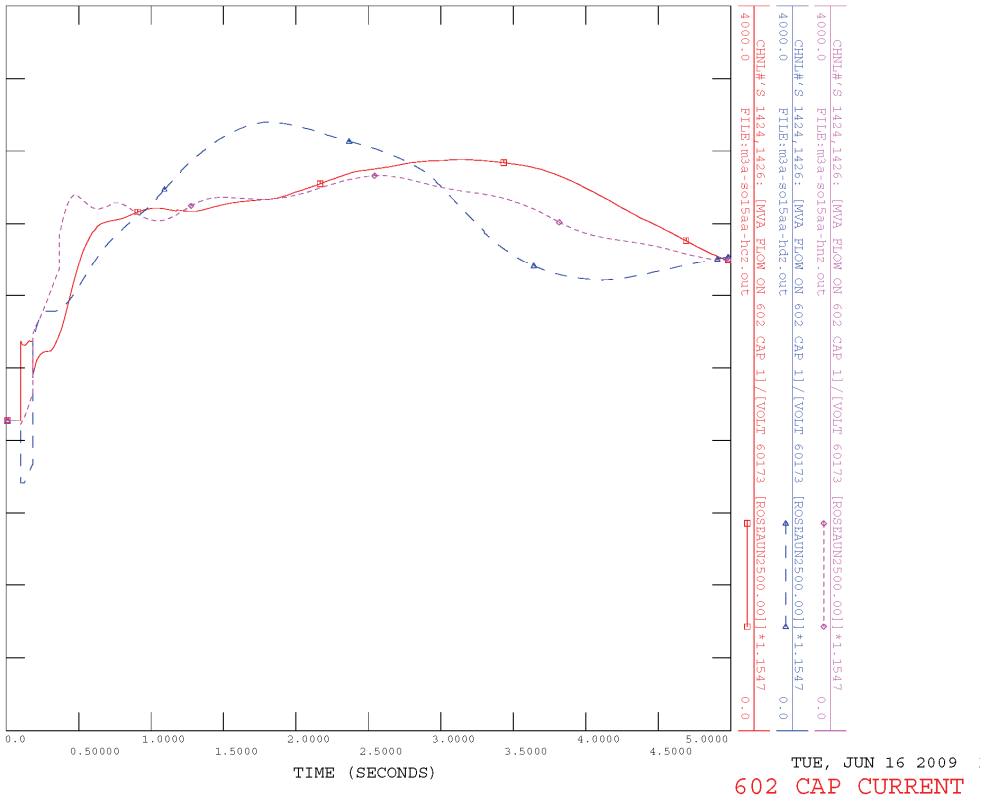

Figure 1-11: M602F Series Capacitor Current for Faults on Dorsey-King 500 kV Line

1.7.5 Option 3 Results with DC Reduction

Disturbances *hc9*, *hfs*, *hna* and *hd9* were repeated with outage of the new Dorsey-King 500 kV line used to trigger reduction of the power order on Manitoba Hydro's HVDC lines. Reduction is assumed equal to 100% of the pre-disturbance flow on Dorsey-King.

There are no criteria violations with a 100% reduction as shown in Table 1-19. The power order reduction increases the M602F relay margin for all disturbances, including the single-line-to-ground faults at Dorsey with delayed clearing, *hf0* (originally *hfs*) and *hn0* (originally *hna*).

Table 1-19: Option 3 Results with DC Reduction

ID	Description	MH-OH Relay Trip*	DCAR Relay Trip*	Transient Voltage Violations	M602F Relay Margin	DCAR Relay Margin	Notes
hcd	3PH fault at Dorsey 500 on King line	-	-	-	233%	507%	
hf0	SLG fault at Dorsey 500 on King line with breaker failure; trip Dorsey 500-230 kV xfmr; xfmr outage triggers HVDC reduction	-	-	-	60%	409%	
hn0	SLG fault at Dorsey 500 on King line with breaker failure; trip Dorsey-Riel #2	-	-	-	60%	409%	
hdd	3PH fault at King 500 on Dorsey line	-	-	-	185%	507%	

* MH-OH relay is DPDARE relay. DCAR is delta current admittance relay at Forbes

The power order reduction resulting from the M602F or Dorsey-Maple River triggers in the study case are lower than the reduction that occurs for the M602F trigger in the benchmark case as shown in Table 1-20. Depending on the final design of the Option 3 transmission upgrade, the required amount of reduction may be less than 100%.

Table 1-20: DC Power Order Reduction

Trigger	Benchmark Case	Option 3 Study Case
M602F	100% = 1749 MW	100% = 1583 MW
Dorsey-King		100% = 1362 MW

Appendix

A

Stability Power Flow Model Development

A.1 Pre-Benchmark Case

1.1 Apply Response file provided by ATC to update model

```
2015SUOP_ATC_20090304_v29.idv
```

1.2 Add Big Stone II (generator and 230 kV outlet)

```
i-addBGSGrntFlls230.idv (added here but removed by later response file)
i-addBGSMrrs230.idv
purge_Ortonville230.idv
BSPII_BSP_JHNSJCT_MORRIS_1272.idv
BSPII_BSP_CANBY_GFLS_1272BNDL.idv
i-addBGSII.idv
```

1.3 Add MTEP near-term projects

```
ALTW_1289_Marshalltown-Toledo_115V.idv
ALTW_1618_Heron Lake-Lakefield_161kV.idv
altw_1753_Winnebago Jct_161-69_kV_75_MVA_TRFs1&2.idv
altw_1761_Tripoli-Readlyn_69_kV_Rebuild.idv
ALTW_Arnold-Washburn_1739-161kV_Upgrade.idv
ITCM_Grand_Mound-1619_161kV-CONVERTED_v2.idv
altw_hiawatha-Lws_Flds-1342_161-115kV.idv
altw_salem-1287_345-161kV_448_MVA.idv
ATC_(339)_Jefferson-Stonybrook_138_kV_and_Uprates.idv
ATC_(1553)_Hiawatha_Cap_1x16_3.idv
GRE-PROJECT-TOWER(1021)(for mp).idv
xel-1368-1369-1370-NEWRICHMOND.idv
xel-1373-NEWULM-TS.idv
xel-1457-BRIGO_.idv
xel-1489-WOODBURY-TANNERSLAKE.idv
xel-1545-MANKATO_115KV_LOOP_v2.idv
xel-1548-LACROSSE.idv
xel-1548-mONROECO_CAPBANK.idv
xel-1549-EAUCLAIRE_v2.idv
XEL-1959-YANKEEDOODLE-PILOTKNOB_v2.idv
```

1.4 Add MTEP out-year projects excluding CapX

```
ALTW_1758_Beaver_Channel-2nd_AVE_69_kV_Rebuild-CONVERTED.idv
ALTW_Hazelton-1288_345-161kV_335_MVA-CONVERTED.idv
ALTW_Hills-Washington-1755_69kV_Rbld-CONVERTED.idv
ALTW_Leon-1645_69kV_7MVAR-CONVERTED.idv
ALTW_N_Cntrville_69kV-1772_7MVAR-CONVERTED.idv
ALTW_Quad-RkCrk-Salem-1345_Terminals-CONVERTED.idv
ALTW_Salem-Lore-Hazelton-1340_345kV-CONVERTED.idv
ALTW_Toledo-Belle-1289_Plaine_Stoney_Pt-CONVERTED.idv
GRE-1021-EMBARRASS-TOWER115-CONVERTED.idv
GRE-1022-BADOURA-LONGLAKE115-CONVERTED.idv
GRE-1361-BADOURA-BIRCHLAKE115_BL115_69-CONVERTED.idv
GRE-PROJECT-599-ENTPPK_CRKDLK(20152)-CONVERTED.idv
ITCM_1341_Hazleton_161-69_kV_75_MVA_bothTRFs-CONVERTED.idv
ITCM_1473_Mason_City_Emery-Armour_69kV-CONVERTED_v2.idv
ITCM_1522_6th-Beverly_161kV-CONVERTED.idv
ITCM_1618_Heron Lake-Lakefield_161kV-CONVERTED.idv
ITCM_1641_Ottumwa_161kV_50MVAR-CONVERTED.idv
ITCM_1739_Arnold-Washburn_161kV_Upgrade-CONVERTED.idv
ITCM_1753_Winnebago Jct_161-69_kV_75_MVA_TRF-CONVERTED.idv
ITCM_1756_Dyersville-Seippel_Rd_69kV2-CONVERTED.idv
MP-MISO-PROJECT-1482-Pepin-Lk-r2-CONVERTED.idv
OTP-1033-SLVRLK-CONVERTED.idv
OTP-971-WINGERXFMR-20080613 [08-09-16 09_34]-CONVERTED.idv
OTP-MTEPA-2091-CASSLKXFMR-CONVERTED.idv
OTP-MTEPA-2092-SOCASCADE-CONVERTED.idv
SMP-MISO-LAKECITY-1367-AREA [08-10-18 16_21]-CONVERTED.idv
xel-1371-BLACKDOG-WILSON2-UPGRADE_v30-CONVERTED.idv
xel-1455-MERP-RIVERSIDE_v30-CONVERTED.idv
XEL-1487-SOMMERSET-CONVERTED.idv
XEL-1953-SAUKRIVER-STCLOUD-CONVERTED.idv
XEL-1954-WSIOUXFALLS-PATHFINDER-CONVERTED.idv
XEL-1960-TRAVERSE-STPETER-CONVERTED.idv
XEL-1961_LAKEEMILY_CAP-CONVERTED.idv
XEL-552-IRONWOOD_2ND_TR-CONVERTED.idv
XEL-56-CHISAGO-STCROIXFLS [08-10-31 18_27]-CONVERTED_v2.idv
XEL-675-SCOTTCO-WESTGATE-CONVERTED.idv
XEL-PROJECT-1380-WWACONIA-SCOTTCO-115KV-CONVERTED.idv
XEL-PROJECT-1958-StoneLake-Couderay-CONVERTED.idv
```

1.5 Apply miscellaneous updates and corrections

```
GRE-MISO-PROJECT-KRMRLK(53801)-CONVERTED.idv
GRE-MISO-PROJECT-LWRNCTP(20138)-CONVERTED.idv
MP-MISO-Dunka-Load-CONVERTED.idv
MP-MISO-PROJECT-LL-BAD-PINE-PEQ-CONVERTED.idv
add-essar-mn-detail-r1.idv

The following facilities were placed in service:
      - CSLTNET-Buffalo 115 kV line
      - Running 230-69 kV xfmr
      - Moranville 230/115 kV xfmr

The following facilities were purged
      - Center-Harvey-Prairie 345 kV line
      - Center 345/230 kV xfmr #2
      - Harvey 345/230 kV xfmr
```

```
Activity GNET used to replace generators with negative MVA load at the
following buses:
      - Cloquet 115 kV (61668)
      - Chandler 69 kV (bus 62710)
```

1.6 Add NR generating facilities

```
G519 Mesaba.idv
G618_5d.idv
G904_5d.idv
G930_A422_A423_5d.idv
```

1.7 Reduce generation in North Dakota by 540 MW so that North Dakota load is approximately 80% of summer peak. Generating units in the Dakotas dispatched above Pmax (given in power flow case) were reduced to Pmax and wind generation in eastern ND was turned off at Ashtabula, Edgley and Langdon.

1.8 Turn on generation in the GRE and XEL control areas that will be used to sink A388 and A416; scale load in the TVA control area by corresponding amount.

1.9 Manitoba Hyro system updates including the addition of Bipole 3. HVDC loading adjusted to maintain export level and prepare to source TSRs at Dorsey in the study cases. Bipole 1 = 797 MW, Bipole 2 = 903 MW, Bipole 3 = 1540 MW.

```
1-add transcona stuff-2004series.idv
2-Riel 230-500 buses 2004-series.idv
3-riel-sum-08s-2004series.idv
4-BP3_and_Conawapa.idv
5-Gull.idv
Bipole 3 changes.idv
Dorsey--Riel-Ckt2-500kV.idv
```

1.10 Dispatch wind generation in southwest Minnesota at 1083 MW; sink using Xcel Energy generation in the Twin Cities.

```
SW-MN-WIND3.idv
```

1.11 Apply setexports.ipl to adjust NDEX, MHEX and MWEX to their simultaneous maximum capability. NDEX=2450 MW, MHEX = 2175 MW, MWEX - 1525 MW

1.12 Scale load in the TVA control area to make up for load and generation changes

A.2 Benchmark Case

2.1 Add CapX 2020 Group 1 Projects

```
i-1-SWMINN_TC_345additionB_dpk'.idv
i-2-MapleRiver-AlexSS-WaitePark-Monticello_add.idv
i-3-alex-cloud-V29.idv
i-4-Bos230Wil_GIMod.idv
i-5-almx-no-bvd.idv
```

2.2 Add Big Stone 345 kV outlet facilities

```
XEL-1457-HAZEL.idv
MODIFY BIGSTONII.idv
```

A.3 TSR Study Case

3.1 Increase loading on MH bipole 1 and 2 from 1700 MW to 2830 MW and make corresponding change to MH generation schedule at Conawapa and Keeyask

3.2 Adjust generation to sink study TSR

3.3 Add transmission upgrades

3.3.1 Option 1

```
MHEB_Case\upgrades\Dorsey--MapleRiver-midcomp-500kV.idv
MHEB_Case\upgrades\MapleRiver--Helena-midcomp-500kV.idv
```

3.3.2 Option 3

```
MHEB_Case\upgrades\ Dorsey--King-500kV.idv
```

A.4 Model Data for Network Upgrade Option 1 and 3

A.4.1 Option 1

```
DATA FOR BUS  63057 [MIDCOMP-    500.00] RESIDING IN AREA  600, ZONE  601, OWNER  600:

 CODE PLOAD   QLOAD     I - L O A D     Y - L O A D G-SHUNT B-SHUNT
  1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 X------- TO BUS --------X
   BUS# X-- NAME --X BASKV CKT   LINE R   LINE X CHARGING ST MET RATE-A RATE-B RATE-C
  63058 HELENA      500.00  1   0.00126  0.02100  1.87000  1  F  1732.0 1905.0 2361.0
  63059 MIDCOMP-    500.00  1   0.00000 -0.02099  0.00000  1  T  1732.0 1905.0 1732.0


 DATA FOR BUS  63058 [HELENA      500.00] RESIDING IN AREA  600, ZONE  601, OWNER  600:

 CODE PLOAD   QLOAD     I - L O A D     Y - L O A D G-SHUNT B-SHUNT
  1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 X------- TO BUS --------X
   BUS# X-- NAME --X BASKV CKT   LINE R   LINE X CHARGING ST MET RATE-A RATE-B RATE-C
  63057 MIDCOMP-    500.00  1   0.00126  0.02100  1.87000  1  T  1732.0 1905.0 2361.0

 X------- TO BUS --------X        XFRMER    S W M C C      SPECIFIED
   BUS# X-- NAME --X BASKV CKT X-- NAME --X T 1 T Z M   R 1-2    X 1-2  SBAS1-2
  60502 HELNASS3    345.00  1  HLENA500     1 F F 1 1  0.00006  0.00470  100.0
  60502 HELNASS3    345.00  2  HLENA500     1 F F 1 1  0.00006  0.00470  100.0

 X------- TO BUS --------X     C
   BUS# X-- NAME --X BASKV CKT W  WINDV1  NOMV1  WINDV2  NOMV2  RATEA  RATEB  RATEC
  60502 HELNASS3    345.00  1  1 1.00000 0.0000 1.00000 0.0000 1203.0 1203.0 1563.9
  60502 HELNASS3    345.00  2  1 1.00000 0.0000 1.00000 0.0000 1203.0 1203.0 1563.9

 X------- TO BUS --------X     W C
   BUS# X-- NAME --X BASKV CKT 1 W CN   RMAX    RMIN    VMAX    VMIN  NTPS
  60502 HELNASS3    345.00  1  F 1  0 1.10000 0.90000 1.10000 0.90000   33
  60502 HELNASS3    345.00  2  F 1  0 1.10000 0.90000 1.10000 0.90000   33


 DATA FOR BUS  63059 [MIDCOMP-    500.00] RESIDING IN AREA  600, ZONE  601, OWNER  600:

 CODE PLOAD   QLOAD     I - L O A D     Y - L O A D G-SHUNT B-SHUNT
  1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 X------- TO BUS --------X
   BUS# X-- NAME --X BASKV CKT   LINE R   LINE X CHARGING ST MET RATE-A RATE-B RATE-C
  63057 MIDCOMP-    500.00  1   0.00000 -0.02099  0.00000  1  F  1732.0 1905.0 1732.0
  63060 MAPLERIV    500.00  1   0.00126  0.02100  1.87000  1  T  1732.0 1905.0 2361.0


 DATA FOR BUS  63060 [MAPLERIV    500.00] RESIDING IN AREA  620, ZONE    1, OWNER  657:

 CODE PLOAD   QLOAD     I - L O A D     Y - L O A D G-SHUNT B-SHUNT
  1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 X------- TO BUS --------X
   BUS# X-- NAME --X BASKV CKT   LINE R   LINE X CHARGING ST MET RATE-A RATE-B RATE-C
  63059 MIDCOMP-    500.00  1   0.00126  0.02100  1.87000  1  F  1732.0 1905.0 2361.0
  63062 MIDCOMP-    500.00  1   0.00145  0.02415  2.15000  1  T  1732.0 1905.0 2361.0

 X------- TO BUS --------X        XFRMER    S W M C C      SPECIFIED
   BUS# X-- NAME --X BASKV CKT X-- NAME --X T 1 T Z M   R 1-2    X 1-2  SBAS1-2
  66792 MAPLE R3    345.00  1  MPLRV500     1 F F 1 1  0.00006  0.00470  100.0
```

```
X------- TO BUS --------X     C
  BUS# X-- NAME --X BASKV CKT W  WINDV1  NOMV1  WINDV2  NOMV2  RATEA  RATEB  RATEC
 66792 MAPLE R3    345.00  1  1 1.00000 0.0000 1.00000 0.0000 1203.0 1203.0 1563.9

X------- TO BUS --------X     W C
  BUS# X-- NAME --X BASKV CKT 1 W CN   RMAX    RMIN    VMAX    VMIN  NTPS
 66792 MAPLE R3    345.00  1  F 1  0 1.10000 0.90000 1.10000 0.90000   33


DATA FOR BUS  63061 [MIDCOMP-    500.00] RESIDING IN AREA  620, ZONE    1, OWNER  657:

CODE PLOAD   QLOAD     I - L O A D     Y - L O A D G-SHUNT B-SHUNT
 1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

X------- TO BUS --------X
  BUS# X-- NAME --X BASKV CKT   LINE R   LINE X CHARGING ST MET RATE-A RATE-B RATE-C
 63062 MIDCOMP-    500.00  1   0.00000 -0.02414  0.00000  1  F  1732.0 1905.0 1732.0
 67564 DORSEY 2    500.00  1   0.00145  0.02415  2.15000  1  T  1732.0 1905.0 2361.0


DATA FOR BUS  63062 [MIDCOMP-    500.00] RESIDING IN AREA  620, ZONE    1, OWNER  657:

CODE PLOAD   QLOAD     I - L O A D     Y - L O A D G-SHUNT B-SHUNT
 1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

X------- TO BUS --------X
  BUS# X-- NAME --X BASKV CKT   LINE R   LINE X CHARGING ST MET RATE-A RATE-B RATE-C
 63060 MAPLERIV    500.00  1   0.00145  0.02415  2.15000  1  F  1732.0 1905.0 2361.0
 63061 MIDCOMP-    500.00  1   0.00000 -0.02414  0.00000  1  T  1732.0 1905.0 1732.0
```

A.4.2 Option 3

```
DATA FOR BUS  63061 [MIDCOMP-    500.00] RESIDING IN AREA  600, ZONE  601, OWNER  600:

 CODE PLOAD   QLOAD     I - L O A D     Y - L O A D G-SHUNT B-SHUNT
  1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 X------- TO BUS --------X
   BUS# X-- NAME --X BASKV CKT   LINE R   LINE X CHARGING ST MET RATE-A RATE-B RATE-C
  63062 MIDCOMP-    500.00  1   0.00000 -0.05349  0.00000  1  F  1732.0 1905.0 1732.0
  67564 DORSEY 2    500.00  1   0.00300  0.05350  5.00000  1  T  1732.0 1905.0 2361.0


 DATA FOR BUS  63062 [MIDCOMP-    500.00] RESIDING IN AREA  600, ZONE  601, OWNER  600:

 CODE PLOAD   QLOAD     I - L O A D     Y - L O A D G-SHUNT B-SHUNT
  1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 X------- TO BUS --------X
   BUS# X-- NAME --X BASKV CKT   LINE R   LINE X CHARGING ST MET RATE-A RATE-B RATE-C
  63061 MIDCOMP-    500.00  1   0.00000 -0.05349  0.00000  1  T  1732.0 1905.0 1732.0
  63064 AS KING     500.00  1   0.00300  0.05350  5.00000  1  F  1732.0 1905.0 2361.0


 DATA FOR BUS  63064 [AS KING     500.00] RESIDING IN AREA  600, ZONE  601, OWNER  600:

 CODE PLOAD   QLOAD     I - L O A D     Y - L O A D G-SHUNT B-SHUNT
  1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0

 X------- TO BUS --------X
   BUS# X-- NAME --X BASKV CKT   LINE R   LINE X CHARGING ST MET RATE-A RATE-B RATE-C
  63062 MIDCOMP-    500.00  1   0.00300  0.05350  5.00000  1  T  1732.0 1905.0 2361.0

 X------- TO BUS --------X        XFRMER    S W M C C      SPECIFIED
   BUS# X-- NAME --X BASKV CKT X-- NAME --X T 1 T Z M   R 1-2    X 1-2  SBAS1-2
  60186 AS KING3    345.00  1  KING500/     1 T F 1 1  0.00006  0.00470  100.0
  60186 AS KING3    345.00  2  KING500/     1 F F 1 1  0.00006  0.00470  100.0

 X------- TO BUS --------X     C
   BUS# X-- NAME --X BASKV CKT W  WINDV1  NOMV1  WINDV2  NOMV2  RATEA  RATEB  RATEC
  60186 AS KING3    345.00  1  1 1.00000 0.0000 1.00000 0.0000 1203.0 1203.0 1563.9
  60186 AS KING3    345.00  2  1 1.00000 0.0000    0.0 1.00000 0.0000 1203.0 1203.0

 X------- TO BUS --------X     W C
   BUS# X-- NAME --X BASKV CKT 1 W CN   RMAX    RMIN    VMAX    VMIN  NTPS
  60186 AS KING3    345.00  1  T 1  0 1.10000 0.90000 1.10000 0.90000   33
  60186 AS KING3    345.00  2  F 1  0 1.10000 0.90000 1.10000 0.90000   33
```

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Appendix

B

Power Flow Summaries

B.1 Pre-Benchmark Case without CapX, MH TSRs or Transmission Upgrade Options

P O W E R F L O W S U M M A R Y

NDEX:	2451 MW	ECL-ARP:	626 MW
MHEX:	2174 MW	PRI-BYN:	702 MW
MWEX:	1519 MW	AHD-SLK:	638 MW
KING-ECL:	880 MW	SLK-GPK:	444 MW
COOPER S:	1116 MW	WNE-WKS:	545 MW
FTCAL S:	669 MW	GGS:	1623 MW
GRIS-LNC:	696 MW	QC WEST:	130 MW
MAP R-ALEX:	0 MW	WIL-BOWS:	0 MW
NROC-NLAX:	0 MW		

LOAD LEVELS AS PERCENT OF 2015 SUMMER PEAK:

NORTH DAKOTA	(ZONE 90,990)	2904.1 MW,	78.3% OF	3710.2 MW
NSP	(AREA 600)	8085.1 MW,	68.0% OF	11889.2 MW
MAN HYDRO	(AREA 667)	2348.2 MW,	76.3% OF	3076.0 MW

Load/Losses	MW / MW	Generation	MW	Export	MW
Manitoba	2348/ 242	MH total gross	4960	ATC West Import	1306
Ont. total	22150/ 478	Wpg River	568	ATC SW Import	642
NW	915/ 36	7 Sisters	170	ATC SE Import	-1577
Sask.	2150/ 82	OH total gross	21884	East Bias	286
MP	2341/ 174	northwest	717	SPC>WAPA (B10T)	167
NSP	8085/ 537	SPC total gross	2406	MH>SPC (3-230)	62
N. Dakota	2904/ 294	MP total gross	2859	MH>SPC (FALLS)	0
Manitoba	481 MVARS	ND Cfd AC gross	3149	OH>MH @Kenora	-197
Ont. total	13082 MVARS	net	2978	OH>MP @Ft Fran	149
NW	489 MVARS	NSP East gross	1942	OH E>W @Wawa	187
Sask.	502 MVARS	net	1810	OH>East USA	0
MP	669 MVARS	West gross	3057	F601C @Forbes	1678
NSP	1710 MVARS	net	2895	D602F @Riel	1855
N. Dakota	756 MVARS	Total net	6177	L20D @Letell	238
ATC	10812/ 306	WAPA SD Hydro	1497	R50M @Richer	142
ATC	3159 MVARS	Pleasant Valley	110	G82R @Glenboro	-62
		LGS/Trimont	109		
		SW MN Wind	1084		
		N DAK WIND	252		
		Swing Bus	869		

Tfmrs	MVA/ Load	Ph Shifters	Deg/ MW	DC Lines	MW
Wshell #1 7-7	105/ 73%	Stinson	30/ 31	CU (1,2)	1103
Wshell #2 7-7	105/ 73%	Boundary Dam	9/ 167	SQ BU (3,4)	455
Drayton#1 4-7	44/ 31%	Whiteshell	99/ 201	MH Bipole 1	797
Drayton#2 4-7	56/ 30%	Int Falls	120/ 149	MH Bipole 2	903
Dorsey #1 2-4	484/ 40%	St. Lawrence	16/ 0	MH (BP1+BP2)	1700
Dorsey #2 2-4	564/ 47%	Arrowhead	4/ 639	Miles City E>W	-150
Forbes 2-4	43/ 6%			RCDC (15)	0
Stone Lk 3-5	182/ 54%			Stegall (10)	0

Dorsey SC's	I/S	MVAR	Qmax/ Qmin
MIL 7-9G	17.0 2	-105	600/ -330
SCE 1-3G	18.2 3	-86	480/ -240
SCA 4-6G	18.2 3	-86	480/ -240
Total		-277	1560/ -810
Margin		1837	

SVC's	MVAR	Qmax/ Qmin
Forbes	500 40	400/ -450
Fargo	13.2 9	20/ -135
Watertown	20.0 -11	125/ -86

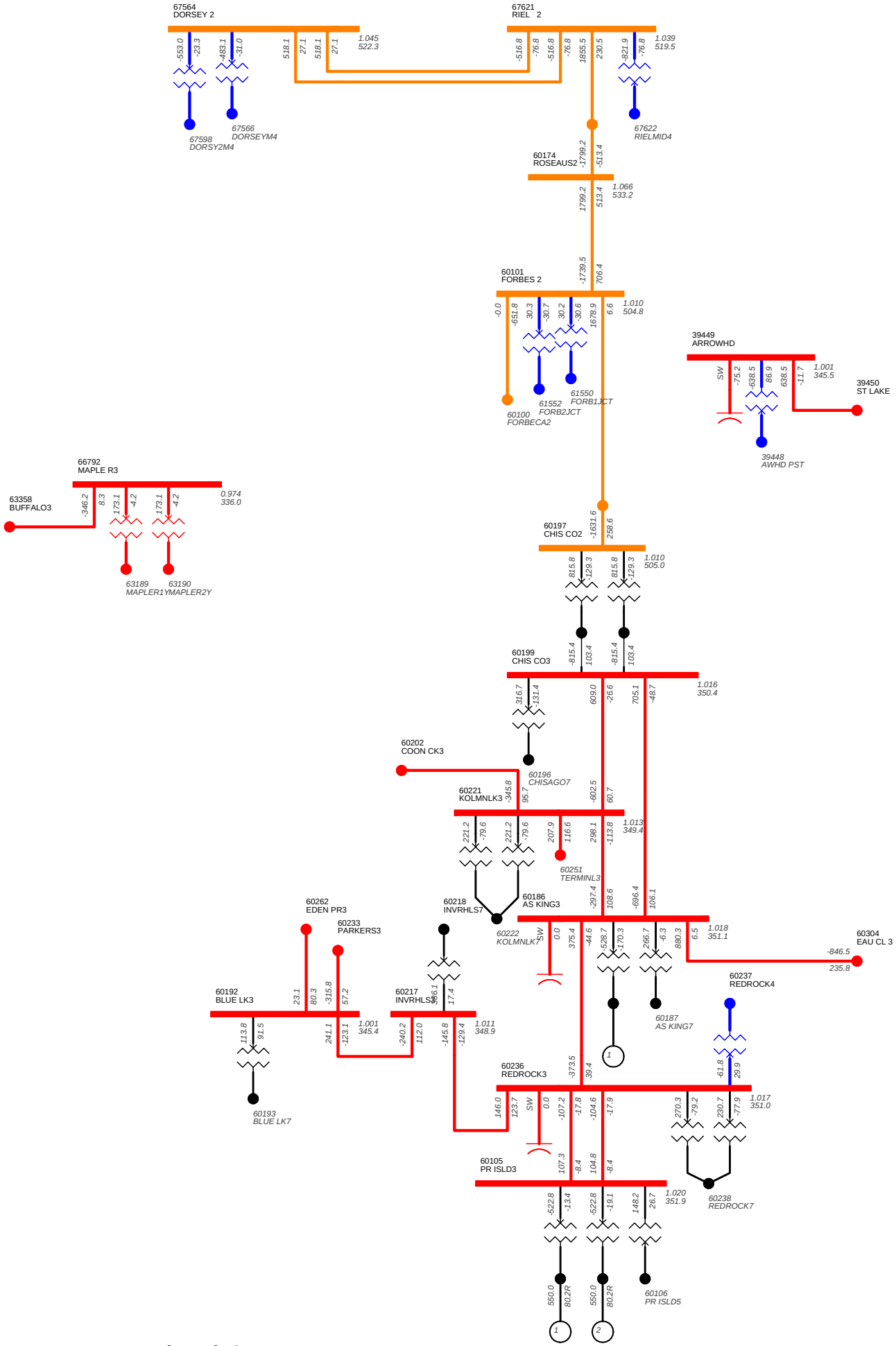
Series Caps	Num In Serv
Roseau	500 2 of 2
Chisago	500 1 of 1

Caps/Reactors	MVAR	Caps/Reactors	MVAR	Caps/Reactors	MVAR
Balta (FS) 230	0	Arrowhead 230	160	Chisago T 9 34.5	60
Drayton 115	20	Blackberry 230	47	Chisago T 10 34.5	60
Drayton 13.8	0	Minntac 115	45	Forbes 230	70
Eau Claire(FS) 161	356	Riverton 230	47	Forbes 500	600
Kohlman Lake 115	240	Roseau Co.(FS) 230	0		0
Parkers Lk(FS) 115	0	Running (FS) 230	30	Fargo 115	27
Prairie (FS) 115	40	Running react 230	0	Watertown 20	20
Ramsey (FS) 230	0	Shannon 230	72	Watertown 230	76
Red Rock 115	240		0		0
Rugby 13.8	-25	Glenboro 230	0	Arrowhead 345	75
Split Rock(FS) 115	80	Laverendrye 110	98	Stone Lake 345	0
Sheyenne (FS) 115	40	Richer react 230	0	Stone Lk Reac 345	0
Wilton/Bemidji 115	20	St Vital 110	98	Stone Lake 161	0
	0		0	Grdnr Pk Reac 345	0
	0		0	Grdnr Pk Caps 115	0
	0		0	Arpin Caps 138	52
	0		0	Council Creek 138	16

Bus Voltages	V,pu	Bus Voltages	V,pu	Bus Voltages	V,kV
Adams 345	1.009	Arrowhead 230	0.997	Whiteshell 110	118.9
Alexandria 115	1.017	Badoura 115	1.022	Kenora 220	246.6
Audubon 115	1.034	Blackberry 230	1.035	Dryden 220	250.8
Bemidji 115	1.010	Boise Cascade 13.8	1.051	Fort Frances 220	244.5
Byron 345	1.017	Boise Cascade 115	1.019	Mackenzie 220	253.7
Chisago Co. 345	1.016	ETCO 115	1.002	Lakehead 220	246.3
Chisago Co. 500	1.010	Forbes 230	1.015	Marathon 220	253.2
Drayton 230	1.031	Forbes 500	1.010	Wawa 220	254.9
Eau Claire 345	1.027	Hubbard 115	1.016	Mississagi 220	250.7
WEST FARIBAULT 115	1.016	Intl Falls 115	1.020	Fort Frances 118	118.8
LaPorte 115	1.008	Minntac 115	1.011	Lakehead 118	122.8
Maple River 230	1.027	Moranville 230	1.024	Birch 118	120.2
Marshall Tap 115	1.025	Riverton 230	1.014	Marathon 118	123.4
Owatonna 161	0.996	Running 230	1.025		0.000
Prairie 115	1.032	Shannon 230	1.026	Arrowhead 345	1.001
Prairie 230	1.026	Stinson MN 115	1.008	Stone Lake 345	1.003
Ramsey 230	1.003	Jamestown 345	0.979	Stone Lake 161	1.011
Roseau County 230	1.024	Groton 345	1.019	Gardner Park 345	1.035
Roseau County 500	1.066	Watertown 230	1.030	Weston 115	1.035
Sheyenne 230	1.028	Watertown 345	1.025	Arpin 345	1.023
Thief R Falls 115	1.027		0.000	Eau Claire 161	1.037
Tioga 230	1.033	Dorsey 230	1.045	Council Creek 161	0.972
Wahpeton 230	1.013	Dorsey 500	1.045	Hydro Lane 161	1.012
Winger 115	1.040		0.000	Wien 115	1.030
	0.000		0.000		0.000
	0.000		0.000		0.000
	0.000		0.000		0.000

Steady State Relay Margins (measured from inner blinder)

Relay Location	Manuf/Type	PSS Model	South	North	Em North
1) B10T-Tioga (South)	GE OST	SLLP	333%	N/A	N/A
2) -Tioga (North)	GE OST	SLLP	686%	N/A	N/A
3) -Tioga (Em North)	GE OST	SLLP		N/A	N/A
4) D602F-RIEL	ATP ???	SLINOS	375%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	222%	N/A	N/A
6) -Forbes (Em Nrth)	APT S-PRO	SLINOS		N/A	N/A
8) F3M-Intl Falls	APT S-PRO	SLINOS	323%	N/A	N/A
9) G82R-Rugby	APT	SLINOS	N/A	1221%	
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	880%	N/A	N/A
11) -Drayton (Em Nrth)	ASEA RXZF2	SLINOS		N/A	N/A
12) R50M-Moranville (Norm)	APT, West	SLINOS	939%	N/A	N/A
13) -Moranville (Em N)	ASEA RXZF2	SLINOS		N/A	N/A



Pre-Benchmark Case

Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR

KV: <=161.000<=230.000 <=345.000 >345.000

B.2 Benchmark Case without MH TSRs or Transmission Upgrade Options

```
                    P O W E R   F L O W   S U M M A R Y
--------------------------------------------------------------------------------
               NDEX:      2271 MW         ECL-ARP:  661 MW
               MHEX:      2176 MW         PRI-BYN:   74 MW
               MWEX:      1497 MW         AHD-SLK:  645 MW
               KING-ECL:   850 MW         SLK-GPK:  459 MW
               COOPER S:  1104 MW         WNE-WKS:  538 MW
               FTCAL S:    647 MW         GGS:     1611 MW
               GRIS-LNC:   663 MW         QC WEST:  148 MW
               MAP R-ALEX: 318 MW         WIL-BOWS:-102 MW
               NROC-NLAX:  247 MW

          LOAD LEVELS AS PERCENT OF 2015 SUMMER PEAK:
          NORTH DAKOTA (ZONE 90,990) 2904.1 MW,  78.3% OF  3710.2 MW
          NSP             (AREA 600) 8075.1 MW,  67.9% OF  11889.2 MW
          MAN HYDRO       (AREA 667) 2348.2 MW,  76.3% OF  3076.0 MW

Load/Losses   MW  / MW       Generation        MW       Export            MW
----------- ------ -----     --------------- ------     --------------- ------
Manitoba      2348/ 244      MH total gross    4960     ATC West Import   1399
Ont. total   22150/ 478         Wpg River       568     ATC SW Import      614
     NW        915/  36         7 Sisters       170     ATC SE Import    -1628
Sask.         2150/  82      OH total gross   21884     East Bias          149
MP            2341/ 145         northwest       717     SPC>WAPA (B10T)    164
NSP           8075/ 480      SPC total gross   2406     MH>SPC  (3-230)     60
N. Dakota     2904/ 282      MP total gross    2859     MH>SPC  (FALLS)      0
Manitoba       481 MVARS     ND Cfd AC gross   3149     OH>MH  @Kenora    -196
Ont. total   13082 MVARS              net       2978     OH>MP  @Ft Fran    151
     NW        489 MVARS     NSP East gross    1942     OH E>W @Wawa       190
Sask.          502 MVARS              net       1810     OH>East USA          0
MP             669 MVARS          West gross    3057     F601C  @Forbes    1521
NSP           1714 MVARS              net       2895     D602F  @Riel      1777
N. Dakota      756 MVARS          Total net     6167     L20D   @Letell     287
ATC           10812/ 317      WAPA SD Hydro     1497     R50M   @Richer     139
ATC            3159 MVARS     Pleasant Valley    110     G82R   @Glenboro   -28
                              LGS/Trimont        109
                              SW MN Wind        1084
                              N DAK WIND         252
                              Swing Bus          758


Tfmrs          MVA/ Load      Ph Shifters  Deg/  MW      DC Lines          MW
-------------- ---- -----     ------------ --- -----     --------------- ------
Wshell #1 7-7  105/  73%      Stinson       27/   30     CU (1,2)          1104
Wshell #2 7-7  105/  73%      Boundary Dam   3/  164     SQ BU (3,4)        455
Drayton#1 4-7   49/  35%      Whiteshell    98/  199     MH Bipole 1        797
Drayton#2 4-7   63/  33%      Int Falls    121/  150     MH Bipole 2        903
Dorsey #1 2-4  464/  38%      St. Lawrence  16/    0     MH (BP1+BP2)      1700
Dorsey #2 2-4  548/  45%      Arrowhead      1/  646     Miles City E>W    -150
Forbes    2-4   78/  11%                                 RCDC (15)            0
Stone Lk  3-5  174/  51%                                 Stegall (10)         0

Dorsey SC's       I/S  MVAR  Qmax/ Qmin    SVC's              MVAR  Qmax/ Qmin
----------------- --- -----  ---- -----    ----------------- -----  ---- -----
MIL 7-9G     17.0  2   -132   600/ -330    Forbes        500    17   400/ -450
SCE 1-3G     18.2  3   -108   480/ -240    Fargo        13.2   -23    20/ -135
SCA 4-6G     18.2  3   -108   480/ -240    Watertown    20.0    15   125/  -86
                        ----  ---- -----
       Total            -349  1560/ -810   Series Caps       Num In Serv
       Margin           1909               ----------------- -----------
                                           Roseau        500   2 of 2
                                           Chisago       500   1 of 1
```

Caps/Reactors		MVAR
Balta	(FS) 230	0
Drayton	115	20
Drayton	13.8	0
Eau Claire	(FS) 161	356
Kohlman Lake	115	240
Parkers Lk	(FS) 115	0
Prairie	(FS) 115	40
Ramsey	(FS) 230	0
Red Rock	115	240
Rugby	13.8	-25
Split Rock	(FS) 115	80
Sheyenne	(FS) 115	40
Wilton/Bemidji	115	20
		0
		0
		0
		0

Caps/Reactors		MVAR
Arrowhead	230	160
Blackberry	230	47
Minntac	115	45
Riverton	230	47
Roseau Co.	(FS) 230	0
Running	(FS) 230	30
Running react	230	0
Shannon	230	72
		0
Glenboro	230	0
Laverendrye	110	98
Richer react	230	0
St Vital	110	98
		0
		0
		0
		0

Caps/Reactors		MVAR
Chisago T 9	34.5	60
Chisago T 10	34.5	60
Forbes	230	70
Forbes	500	600
		0
Fargo	115	27
Watertown	20	20
Watertown	230	0
		0
Arrowhead	345	75
Stone Lake	345	0
Stone Lk Reac	345	0
Stone Lake	161	0
Grdnr Pk Reac	345	0
Grdnr Pk Caps	115	0
Arpin Caps	138	52
Council Creek	138	16

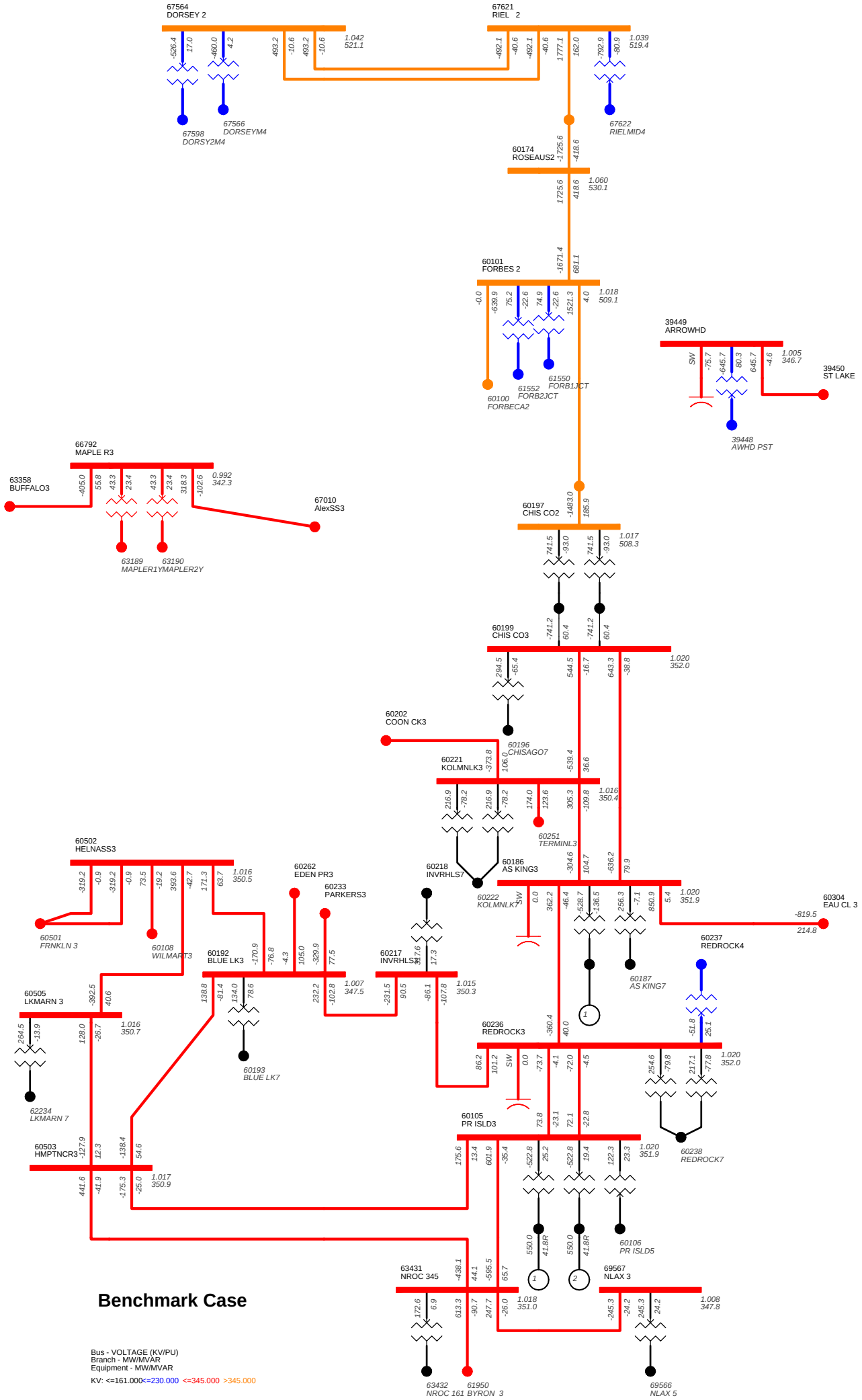
Bus Voltages		V,pu
Adams	345	1.009
Alexandria	115	1.028
Audubon	115	1.050
Bemidji	115	1.036
Byron	345	1.019
Chisago Co.	345	1.020
Chisago Co.	500	1.017
Drayton	230	1.028
Eau Claire	345	1.026
WEST FARIBAULT	115	1.030
LaPorte	115	1.030
Maple River	230	1.041
Marshall Tap	115	1.021
Owatonna	161	1.005
Prairie	115	1.037
Prairie	230	1.030
Ramsey	230	1.006
Roseau County	230	1.026
Roseau County	500	1.060
Sheyenne	230	1.039
Thief R Falls	115	1.035
Tioga	230	1.034
Wahpeton	230	1.027
Winger	115	1.055
		0.000
		0.000
		0.000

Bus Voltages		V,pu
Arrowhead	230	1.002
Badoura	115	1.039
Blackberry	230	1.035
Boise Cascade	13.8	1.051
Boise Cascade	115	1.020
ETCO	115	1.007
Forbes	230	1.022
Forbes	500	1.018
Hubbard	115	1.034
Intl Falls	115	1.020
Minntac	115	1.015
Moranville	230	1.026
Riverton	230	1.030
Running	230	1.027
Shannon	230	1.029
Stinson MN	115	1.013
Jamestown	345	0.982
Groton	345	1.021
Watertown	230	1.030
Watertown	345	1.028
		0.000
Dorsey	230	1.045
Dorsey	500	1.042
		0.000
		0.000
		0.000
		0.000

Bus Voltages		V,kV
Whiteshell	110	118.9
Kenora	220	246.6
Dryden	220	250.8
Fort Frances	220	244.5
Mackenzie	220	253.7
Lakehead	220	246.2
Marathon	220	253.0
Wawa	220	254.8
Mississagi	220	250.7
Fort Frances	118	118.8
Lakehead	118	122.8
Birch	118	120.2
Marathon	118	123.3
		0.000
Arrowhead	345	1.005
Stone Lake	345	1.004
Stone Lake	161	1.011
Gardner Park	345	1.035
Weston	115	1.035
Arpin	345	1.020
Eau Claire	161	1.034
Council Creek	161	0.972
Hydro Lane	161	1.009
Wien	115	1.027
		0.000
		0.000
		0.000

Steady State Relay Margins (measured from inner blinder)

Relay Location	Manuf/Type	PSS Model	South	North	Em North
1) B10T-Tioga (South)	GE OST	SLLP	343%	N/A	N/A
2) -Tioga (North)	GE OST	SLLP	704%	N/A	N/A
3) -Tioga (Em North)	GE OST	SLLP		N/A	N/A
4) D602F-RIEL	ATP ???	SLINOS	412%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	245%	N/A	N/A
6) -Forbes (Em Nrth)	APT S-PRO	SLINOS		N/A	N/A
8) F3M-Intl Falls	APT S-PRO	SLINOS	319%	N/A	N/A
9) G82R-Rugby	APT	SLINOS	100%	N/A	N/A
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	688%	N/A	N/A
11) -Drayton (Em Nrth)	ASEA RXZF2	SLINOS		N/A	N/A
12) R50M-Moranville (Norm)	APT, West	SLINOS	964%	N/A	N/A
13) -Moranville (Em N)	ASEA RXZF2	SLINOS		N/A	N/A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RIEL 2
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521.1
1.039
519.4
67598
DORSY2M4
67566
DORSEYM4
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RIELMID4
60174
ROSEAUS2
1.060
530.1
60101
FORBES 2
1.018
509.1
60100
FORBECA2
61552
FORB2JCT
61550
FORB1JCT
39449
ARROWHD
1.005
346.7
39450
ST LAKE
39448
AWHD PST
66792
MAPLE R3
0.992
342.3
63358
BUFFALO3
67010
AlexSS3
63189
MAPLER1Y
63190
MAPLER2Y
60197
CHIS CO2
1.017
508.3
60199
CHIS CO3
1.020
352.0
60202
COON CK3
60196
CHISAGO7
60221
KOLMNLK3
1.016
350.4
60251
TERMINL3
60218
INVRHLS7
60186
AS KING3
60222
KOLMNLK7
1.020
351.9
60304
EAU CL 3
60502
HELNASS3
1.016
350.5
60501
FRNKLN 3
60108
WILMART3
60262
EDEN PR3
60233
PARKERS3
60192
BLUE LK3
60217
INVRHLS3
1.007
347.5
1.015
350.3
60237
REDROCK4
60187
AS KING7
60505
LKMARN 3
1.016
350.7
62234
LKMARN 7
60193
BLUE LK7
60236
REDROCK3
1.020
352.0
60238
REDROCK7
60105
PR ISLD3
1.020
351.9
60503
HMPTNCR3
1.017
350.9
60106
PR ISLD5
63431
NROC 345
1.018
351.0
69567
NLAX 3
1.008
347.8
63432
NROC 161
61950
BYRON 3
69566
NLAX 5
Benchmark Case
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000<=230.000 <=345.000 >345.000

B.3 Study Case with MH TSRs and Transmission Upgrade Option 1

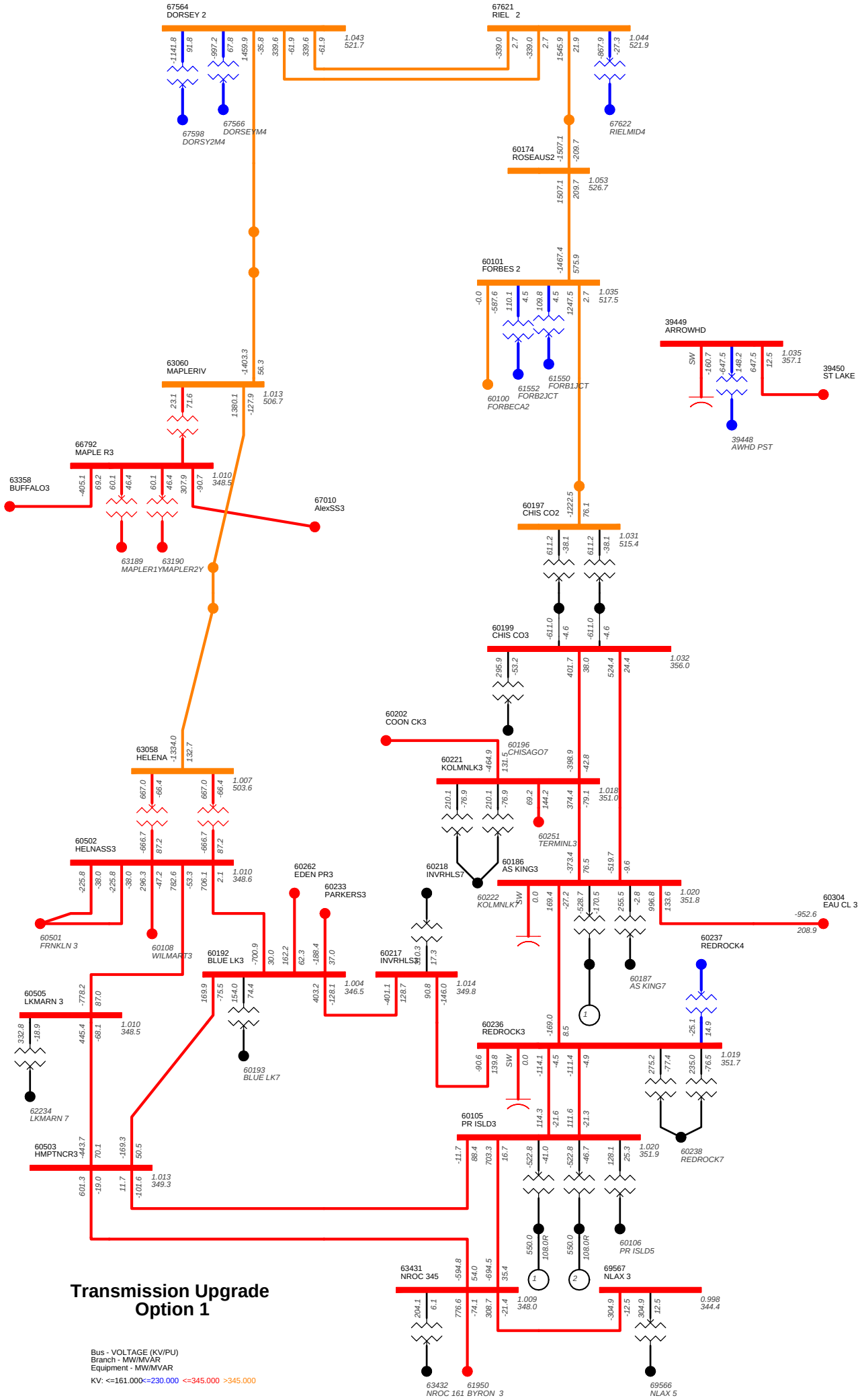
```
                    P O W E R   F L O W   S U M M A R Y
--------------------------------------------------------------------------------
               NDEX:      2287 MW         ECL-ARP:  810 MW
               MHEX:      1849 MW         PRI-BYN:   27 MW
               MWEX:      1645 MW         AHD-SLK:  647 MW
               KING-ECL:   996 MW         SLK-GPK:  506 MW
               COOPER S:  1144 MW         WNE-WKS:  546 MW
               FTCAL S:    698 MW         GGS:     1615 MW
               GRIS-LNC:   671 MW         QC WEST:   66 MW
               MAP R-ALEX: 307 MW         WIL-BOWS: -69 MW
               NROC-NLAX:  308 MW         DOR-MAPR:1459 MW
               MAPR-HELN: 1380 MW         New MHEX:3309 MW

          LOAD LEVELS AS PERCENT OF 2015 SUMMER PEAK:
          NORTH DAKOTA (ZONE 90,990) 2904.1 MW,  78.3% OF  3710.2 MW
          NSP             (AREA 600) 8075.1 MW,  67.9% OF  11889.2 MW
          MAN HYDRO       (AREA 667) 2348.2 MW,  76.3% OF  3076.0 MW

Load/Losses   MW  / MW       Generation        MW       Export            MW
----------- ------ -----     --------------- ------     --------------- ------
Manitoba      2348/ 330       MH total gross    6179     ATC West Import   1667
Ont. total   22150/ 478          Wpg River       568     ATC SW Import      711
     NW        915/  36          7 Sisters       170     ATC SE Import    -1394
Sask.         2150/  82       OH total gross   21884     East Bias          186
MP            2341/ 134          northwest       717     SPC>WAPA (B10T)    163
NSP           8075/ 524       SPC total gross   2406     MH>SPC  (3-230)     59
N. Dakota     2904/ 275       MP total gross    2609     MH>SPC  (FALLS)      0
Manitoba       481 MVARS      ND Cfd AC gross   3149     OH>MH  @Kenora    -195
Ont. total   13082 MVARS            net         2978     OH>MP  @Ft Fran    151
     NW        489 MVARS      NSP East gross    1942     OH E>W @Wawa       190
Sask.          502 MVARS            net         1810     OH>East USA          0
MP             669 MVARS          West gross      3027     F601C  @Forbes    1247
NSP           1714 MVARS            net         2865     D602F  @Riel      1545
N. Dakota      756 MVARS          Total net       6087     L20D   @Letell     236
ATC           10812/ 328       WAPA SD Hydro     1497     R50M   @Richer     128
ATC            3159 MVARS      Pleasant Valley      0     G82R   @Glenboro   -61
                               LGS/Trimont         19
                               SW MN Wind        1084
                               N DAK WIND         252
                               Swing Bus          931


Tfmrs           MVA/ Load     Ph Shifters  Deg/  MW      DC Lines          MW
------------- ---- -----     ------------ --- -----     --------------- ------
Wshell #1 7-7  105/  73%     Stinson       29/   26     CU (1,2)          1104
Wshell #2 7-7  105/  73%     Boundary Dam   9/  164     SQ BU (3,4)        455
Drayton#1 4-7   43/  31%     Whiteshell    95/  199     MH Bipole 1       1521
Drayton#2 4-7   55/  29%     Int Falls    119/  150     MH Bipole 2       1723
Dorsey #1 2-4  999/  83%     St. Lawrence  16/    0     MH (BP1+BP2)      3245
Dorsey #2 2-4 1150/  95%     Arrowhead      6/  648     Miles City E>W    -150
Forbes    2-4  109/  16%                               RCDC (15)            0
Stone Lk  3-5  132/  39%                               Stegall (10)         0

Dorsey SC's       I/S  MVAR  Qmax/ Qmin    SVC's              MVAR  Qmax/ Qmin
---------------- --- -----  ---- -----    ---------------- -----  ---- -----
MIL 7-9G     17.0  2    320   600/ -330    Forbes            500   -55   400/ -450
SCE 1-3G     18.2  3    261   480/ -240    Fargo            13.2   -28    20/ -135
SCA 4-6G     18.2  3    261   480/ -240    Watertown        20.0    28   125/  -86
                          -----  ---- -----
       Total              843  1560/ -810    Series Caps       Num In Serv
       Margin             717                ---------------- -----------
                                             Roseau            500   2 of 2
                                             Chisago           500   1 of 1
```

Caps/Reactors	MVAR	Caps/Reactors	MVAR	Caps/Reactors	MVAR
Balta (FS) 230	0	Arrowhead 230	160	Chisago T 9 34.5	60
Drayton 115	20	Blackberry 230	47	Chisago T 10 34.5	60
Drayton 13.8	0	Minntac 115	45	Forbes 230	70
Eau Claire(FS) 161	356	Riverton 230	47	Forbes 500	600
Kohlman Lake 115	240	Roseau Co.(FS) 230	0		0
Parkers Lk(FS) 115	0	Running (FS) 230	30	Fargo 115	0
Prairie (FS) 115	40	Running react 230	0	Watertown 20	20
Ramsey (FS) 230	0	Shannon 230	72	Watertown 230	0
Red Rock 115	240		0		0
Rugby 13.8	-25	Glenboro 230	0	Arrowhead 345	150
Split Rock(FS) 115	80	Laverendrye 110	98	Stone Lake 345	0
Sheyenne (FS) 115	40	Richer react 230	0	Stone Lk Reac 345	0
Wilton/Bemidji 115	20	St Vital 110	98	Stone Lake 161	40
	0		0	Grdnr Pk Reac 345	0
	0		0	Grdnr Pk Caps 115	0
	0		0	Arpin Caps 138	52
	0		0	Council Creek 138	16

Bus Voltages	V,pu	Bus Voltages	V,pu	Bus Voltages	V,kV
Adams 345	0.997	Arrowhead 230	1.011	Whiteshell 110	118.9
Alexandria 115	1.036	Badoura 115	1.046	Kenora 220	246.7
Audubon 115	1.059	Blackberry 230	1.035	Dryden 220	250.9
Bemidji 115	1.043	Boise Cascade 13.8	1.053	Fort Frances 220	244.8
Byron 345	1.009	Boise Cascade 115	1.022	Mackenzie 220	253.8
Chisago Co. 345	1.032	ETCO 115	1.015	Lakehead 220	246.3
Chisago Co. 500	1.031	Forbes 230	1.034	Marathon 220	253.1
Drayton 230	1.041	Forbes 500	1.035	Wawa 220	254.8
Eau Claire 345	0.991	Hubbard 115	1.041	Mississagi 220	250.7
WEST FARIBAULT 115	1.025	Intl Falls 115	1.022	Fort Frances 118	119.0
LaPorte 115	1.037	Minntac 115	1.023	Lakehead 118	122.8
Maple River 230	1.055	Moranville 230	1.034	Birch 118	120.2
Marshall Tap 115	1.023	Riverton 230	1.035	Marathon 118	123.3
Owatonna 161	1.000	Running 230	1.036		0.000
Prairie 115	1.047	Shannon 230	1.034	Arrowhead 345	1.035
Prairie 230	1.040	Stinson MN 115	1.020	Stone Lake 345	1.025
Ramsey 230	1.010	Jamestown 345	0.994	Stone Lake 161	1.035
Roseau County 230	1.034	Groton 345	1.024	Gardner Park 345	1.035
Roseau County 500	1.053	Watertown 230	1.030	Weston 115	1.035
Sheyenne 230	1.050	Watertown 345	1.029	Arpin 345	1.001
Thief R Falls 115	1.047		0.000	Eau Claire 161	1.032
Tioga 230	1.033	Dorsey 230	1.045	Council Creek 161	0.971
Wahpeton 230	1.034	Dorsey 500	1.043	Hydro Lane 161	1.005
Winger 115	1.065		0.000	Wien 115	1.034
	0.000		0.000		0.000
	0.000		0.000		0.000
	0.000		0.000		0.000

Steady State Relay Margins (measured from inner blinder)

Relay Location	Manuf/Type	PSS Model	South	North	Em North
1) B10T-Tioga (South)	GE OST	SLLP	345%	N/A	N/A
2) -Tioga (North)	GE OST	SLLP	708%	N/A	N/A
3) -Tioga (Em North)	GE OST	SLLP		N/A	N/A
4) D602F-RIEL	ATP ???	SLINOS	542%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	324%	N/A	N/A
6) -Forbes (Em Nrth)	APT S-PRO	SLINOS		N/A	N/A
8) F3M-Intl Falls	APT S-PRO	SLINOS	321%	N/A	N/A
9) G82R-Rugby	APT	SLINOS	N/A	1247%	
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	911%	N/A	N/A
11) -Drayton (Em Nrth)	ASEA RXZF2	SLINOS		N/A	N/A
12) R50M-Moranville (Norm)	APT, West	SLINOS	1093%	N/A	N/A
13) -Moranville (Em N)	ASEA RXZF2	SLINOS		N/A	N/A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RIEL 2
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FORB2JCT
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FORB1JCT
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AWHD PST
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BUFFALO3
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MAPLER1Y
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MAPLER2Y
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COON CK3
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CHISAGO7
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HELENA
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KOLMNLK3
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TERMINL3
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HELNASS3
1.010
348.6
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EDEN PR3
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PARKERS3
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INVRHLS7
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AS KING3
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EAU CL 3
60501
FRNKLN 3
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WILMART3
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BLUE LK3
1.004
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INVRHLS3
1.014
349.8
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REDROCK4
60187
AS KING7
60505
LKMARN 3
1.010
348.5
60193
BLUE LK7
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REDROCK3
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PR ISLD3
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1.013
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1.020
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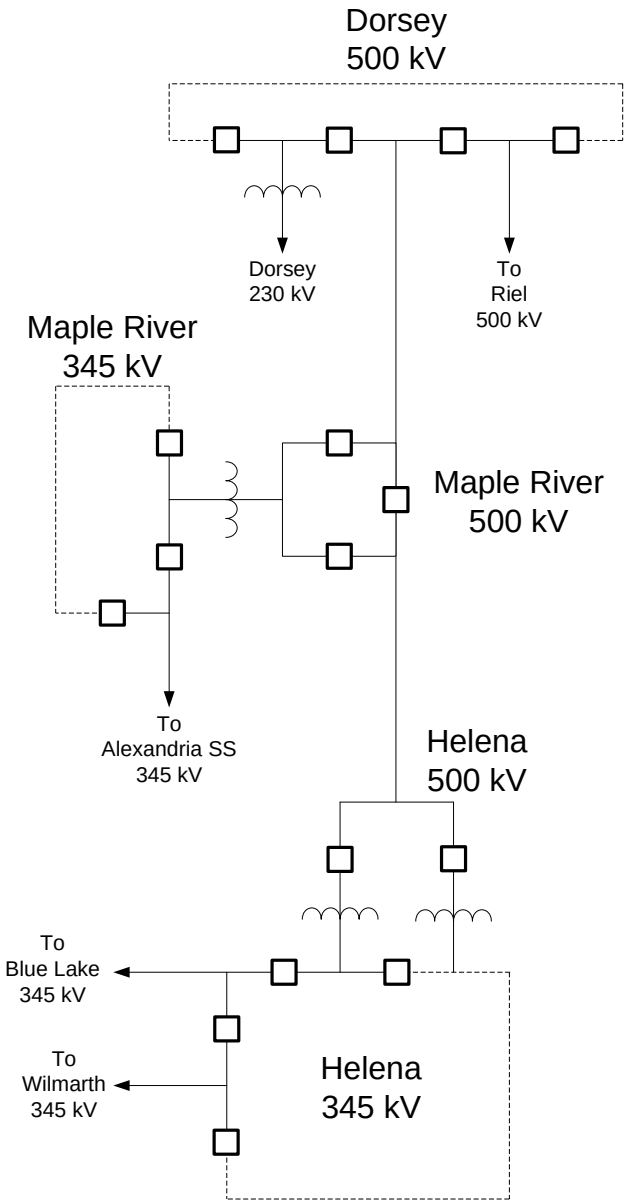
REDROCK7
60106
PR ISLD5
63431
NROC 345
1.009
348.0
69567
NLAX 3
0.998
344.4
63432
NROC 161
61950
BYRON 3
69566
NLAX 5
Transmission Upgrade
Option 1
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000

Option 1
System Topology Assumptions



Note: This diagram documents assumptions made when disturbances were defined and does not necessarily reflect actual or proposed substation layouts.

B.4 Study Case with MH TSRs and Transmission Upgrade Option 3

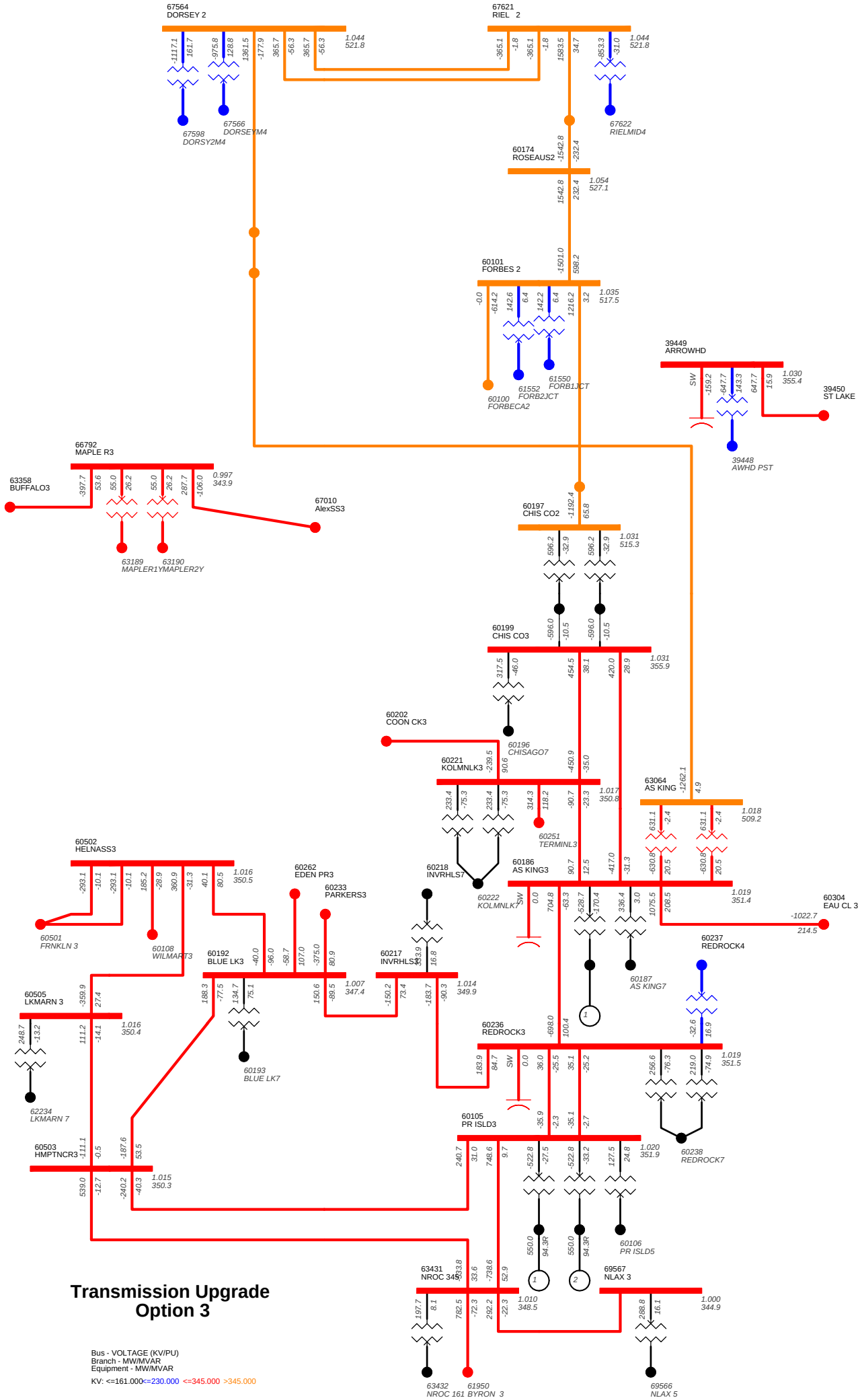
```
                    P O W E R   F L O W   S U M M A R Y
--------------------------------------------------------------------------------
               NDEX:      2300 MW         ECL-ARP:  839 MW
               MHEX:      1949 MW         PRI-BYN:   35 MW
               MWEX:      1724 MW         AHD-SLK:  647 MW
               KING-ECL:  1075 MW         SLK-GPK:  514 MW
               COOPER S:  1128 MW         WNE-WKS:  543 MW
               FTCAL S:    677 MW         GGS:     1615 MW
               GRIS-LNC:   673 MW         QC WEST:   79 MW
               MAP R-ALEX: 287 MW         WIL-BOWS: -87 MW
               NROC-NLAX:  292 MW         DOR-ASK: 1361 MW
               New MHEX:3311 MW

          LOAD LEVELS AS PERCENT OF 2015 SUMMER PEAK:
          NORTH DAKOTA (ZONE 90,990) 2904.1 MW,  78.3% OF  3710.2 MW
          NSP             (AREA 600) 8075.1 MW,  67.9% OF  11889.2 MW
          MAN HYDRO       (AREA 667) 2348.2 MW,  76.3% OF  3076.0 MW

Load/Losses   MW  / MW       Generation        MW       Export            MW
----------- ------ -----     --------------- ------     --------------- ------
Manitoba      2348/ 332       MH total gross    6179     ATC West Import   1702
Ont. total   22150/ 478          Wpg River       568     ATC SW Import      700
     NW        915/  36          7 Sisters       170     ATC SE Import    -1412
Sask.         2150/  82       OH total gross   21884     East Bias          156
MP            2341/ 136          northwest       717     SPC>WAPA (B10T)    161
NSP           8075/ 592       SPC total gross   2406     MH>SPC  (3-230)     57
N. Dakota     2904/ 277       MP total gross    2609     MH>SPC  (FALLS)      0
Manitoba       481 MVARS      ND Cfd AC gross   3149     OH>MH  @Kenora    -194
Ont. total   13082 MVARS            net         2978     OH>MP  @Ft Fran    149
     NW        489 MVARS      NSP East gross    1942     OH E>W @Wawa        190
Sask.          502 MVARS            net         1810     OH>East USA          0
MP             669 MVARS          West gross      3027     F601C  @Forbes    1216
NSP           1714 MVARS            net         2865     D602F  @Riel      1583
N. Dakota      756 MVARS          Total net       6087     L20D   @Letell     268
ATC           10812/ 332       WAPA SD Hydro     1497     R50M   @Richer     134
ATC            3159 MVARS      Pleasant Valley      0     G82R   @Glenboro   -36
                               LGS/Trimont         19
                               SW MN Wind        1084
                               N DAK WIND         252
                               Swing Bus          935


Tfmrs           MVA/ Load     Ph Shifters  Deg/  MW      DC Lines          MW
------------- ---- -----     ------------ --- -----     --------------- ------
Wshell #1 7-7  104/  72%     Stinson       30/   29     CU (1,2)          1103
Wshell #2 7-7  104/  72%     Boundary Dam   4/  162     SQ BU (3,4)        455
Drayton#1 4-7   47/  33%     Whiteshell   100/  198     MH Bipole 1       1522
Drayton#2 4-7   60/  32%     Int Falls    122/  149     MH Bipole 2       1723
Dorsey #1 2-4  982/  81%     St. Lawrence  16/    0     MH (BP1+BP2)      3245
Dorsey #2 2-4 1136/  94%     Arrowhead      7/  648     Miles City E>W    -150
Forbes    2-4  142/  21%                               RCDC (15)            0
Stone Lk  3-5  123/  36%                               Stegall (10)         0

Dorsey SC's       I/S  MVAR  Qmax/ Qmin    SVC's              MVAR  Qmax/ Qmin
---------------- --- -----  ---- -----    ---------------- -----  ---- -----
MIL 7-9G     17.0  2    269   600/ -330    Forbes            500   -28   400/ -450
SCE 1-3G     18.2  3    220   480/ -240    Fargo            13.2    -7    20/ -135
SCA 4-6G     18.2  3    220   480/ -240    Watertown        20.0     9   125/  -86
                          -----  ---- -----
       Total              710  1560/ -810    Series Caps       Num In Serv
       Margin             850                ---------------- -----------
                                             Roseau            500   2 of 2
                                             Chisago           500   1 of 1
```

Caps/Reactors	MVAR	Caps/Reactors	MVAR	Caps/Reactors	MVAR
Balta (FS) 230	0	Arrowhead 230	160	Chisago T 9 34.5	60
Drayton 115	20	Blackberry 230	47	Chisago T 10 34.5	60
Drayton 13.8	0	Minntac 115	45	Forbes 230	70
Eau Claire(FS) 161	356	Riverton 230	47	Forbes 500	600
Kohlman Lake 115	240	Roseau Co.(FS) 230	0		0
Parkers Lk(FS) 115	0	Running (FS) 230	30	Fargo 115	0
Prairie (FS) 115	40	Running react 230	0	Watertown 20	20
Ramsey (FS) 230	0	Shannon 230	72	Watertown 230	0
Red Rock 115	240		0		0
Rugby 13.8	-25	Glenboro 230	0	Arrowhead 345	150
Split Rock(FS) 115	80	Laverendrye 110	98	Stone Lake 345	0
Sheyenne (FS) 115	40	Richer react 230	0	Stone Lk Reac 345	0
Wilton/Bemidji 115	20	St Vital 110	98	Stone Lake 161	40
	0		0	Grdnr Pk Reac 345	0
	0		0	Grdnr Pk Caps 115	0
	0		0	Arpin Caps 138	52
	0		0	Council Creek 138	16

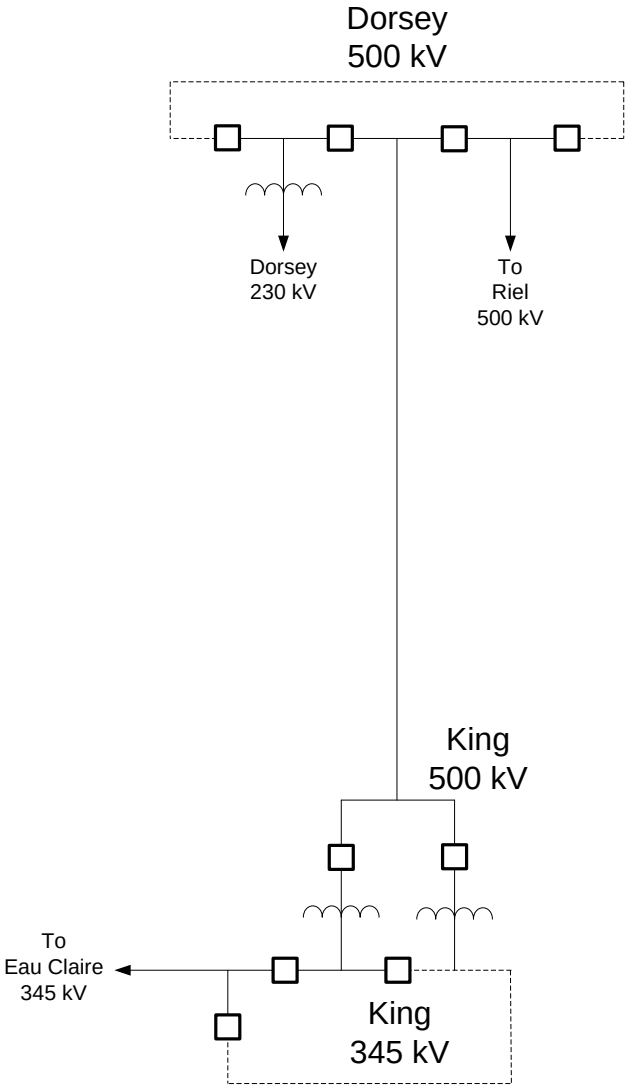
Bus Voltages	V,pu	Bus Voltages	V,pu	Bus Voltages	V,kV
Adams 345	0.998	Arrowhead 230	1.008	Whiteshell 110	118.9
Alexandria 115	1.033	Badoura 115	1.043	Kenora 220	246.7
Audubon 115	1.054	Blackberry 230	1.035	Dryden 220	250.9
Bemidji 115	1.039	Boise Cascade 13.8	1.052	Fort Frances 220	244.6
Byron 345	1.010	Boise Cascade 115	1.020	Mackenzie 220	253.8
Chisago Co. 345	1.031	ETCO 115	1.013	Lakehead 220	246.2
Chisago Co. 500	1.031	Forbes 230	1.034	Marathon 220	253.1
Drayton 230	1.034	Forbes 500	1.035	Wawa 220	254.8
Eau Claire 345	0.972	Hubbard 115	1.038	Mississagi 220	250.7
WEST FARIBAULT 115	1.028	Intl Falls 115	1.021	Fort Frances 118	118.9
LaPorte 115	1.034	Minntac 115	1.021	Lakehead 118	122.8
Maple River 230	1.045	Moranville 230	1.031	Birch 118	120.2
Marshall Tap 115	1.022	Riverton 230	1.033	Marathon 118	123.3
Owatonna 161	1.002	Running 230	1.034		0.000
Prairie 115	1.041	Shannon 230	1.033	Arrowhead 345	1.030
Prairie 230	1.035	Stinson MN 115	1.016	Stone Lake 345	1.019
Ramsey 230	1.008	Jamestown 345	0.986	Stone Lake 161	1.029
Roseau County 230	1.031	Groton 345	1.022	Gardner Park 345	1.031
Roseau County 500	1.054	Watertown 230	1.030	Weston 115	1.035
Sheyenne 230	1.042	Watertown 345	1.028	Arpin 345	0.988
Thief R Falls 115	1.040		0.000	Eau Claire 161	1.029
Tioga 230	1.034	Dorsey 230	1.045	Council Creek 161	0.968
Wahpeton 230	1.030	Dorsey 500	1.044	Hydro Lane 161	1.001
Winger 115	1.059		0.000	Wien 115	1.033
	0.000		0.000		0.000
	0.000		0.000		0.000
	0.000		0.000		0.000

Steady State Relay Margins (measured from inner blinder)

Relay Location	Manuf/Type	PSS Model	South	North	Em North
1) B10T-Tioga (South)	GE OST	SLLP	352%	N/A	N/A
2) -Tioga (North)	GE OST	SLLP	721%	N/A	N/A
3) -Tioga (Em North)	GE OST	SLLP		N/A	N/A
4) D602F-RIEL	ATP ???	SLINOS	520%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	311%	N/A	N/A
6) -Forbes (Em Nrth)	APT S-PRO	SLINOS		N/A	N/A
8) F3M-Intl Falls	APT S-PRO	SLINOS	323%	N/A	N/A
9) G82R-Rugby	APT	SLINOS	N/A	878%	
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	763%	N/A	N/A
11) -Drayton (Em Nrth)	ASEA RXZF2	SLINOS		N/A	N/A
12) R50M-Moranville (Norm)	APT, West	SLINOS	1028%	N/A	N/A
13) -Moranville (Em N)	ASEA RXZF2	SLINOS		N/A	N/A


67564
DORSEY 2
67621
RIEL 2
1.044
521.8
1.044
521.8
67598
DORSY2M4
67566
DORSEYM4
67622
RIELMID4
60174
ROSEAUS2
1.054
527.1
60101
FORBES 2
1.035
517.5
60100
FORBECA2
61552
FORB2JCT
61550
FORB1JCT
39449
ARROWHD
1.030
355.4
39450
ST LAKE
39448
AWHD PST
66792
MAPLE R3
0.997
343.9
63358
BUFFALO3
67010
AlexSS3
63189
MAPLER1Y
63190
MAPLER2Y
60197
CHIS CO2
1.031
515.3
60199
CHIS CO3
1.031
355.9
60202
COON CK3
60196
CHISAGO7
60221
KOLMNLK3
1.017
350.8
63064
AS KING
1.018
509.2
60251
TERMINL3
60218
INVRHLS7
60222
KOLMNLK7
60186
AS KING3
1.019
351.4
60304
EAU CL 3
60502
HELNASS3
1.016
350.5
60501
FRNKLN 3
60108
WILMART3
60262
EDEN PR3
60233
PARKERS3
60192
BLUE LK3
1.007
347.4
60217
INVRHLS3
1.014
349.9
60237
REDROCK4
60187
AS KING7
60505
LKMARN 3
1.016
350.4
62234
LKMARN 7
60193
BLUE LK7
60236
REDROCK3
1.019
351.5
60238
REDROCK7
60105
PR ISLD3
1.020
351.9
60503
HMPTNCR3
1.015
350.3
60106
PR ISLD5
63431
NROC 345
1.010
348.5
69567
NLAX 3
1.000
344.9
63432
NROC 161
61950
BYRON 3
69566
NLAX 5
Transmission Upgrade
Option 3
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000

Option 3
System Topology Assumptions



Note: This diagram documents assumptions made when disturbances were defined and does not necessarily reflect actual or proposed substation layouts.

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Appendix

C

Transient Stability Summary Tables

Table C-1: Pre-Benchmark Case

1	**Case No.**	1	2	3	4	5
2	**Case Name**	M0a-so15aa-ag1	M0a-so15aa-ag3	M0a-so15aa-ei2	M0a-so15aa-eq1	M0a-so15aa-fds
3	**Disturbance**	ag1	ag3	ei2	eq1	fds
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 20 2009 16:37	MAY 20 2009 16:40	MAY 20 2009 16:43	MAY 20 2009 16:46	MAY 20 2009 16:49
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2451 / 286	2451 / 286	2451 / 286	2451 / 286	2451 / 286
10	MHEX / L20D	2174 / 238	2174 / 238	2174 / 238	2174 / 238	2174 / 238
11	ECL-ARP / PRI-BYN	626 / 702	626 / 702	626 / 702	626 / 702	626 / 702
12	MWEX / AHD-SLK	1519 / 638	1519 / 638	1519 / 638	1519 / 638	1519 / 638
13	D602F / F601C	1855 / 1678	1855 / 1678	1855 / 1678	1855 / 1678	1855 / 1678
14	B10T / MH>SPC	167 / 62	167 / 62	167 / 62	167 / 62	167 / 62
15	OH E-W / OH>MH	187 / -197	187 / -197	187 / -197	187 / -197	187 / -197
16	R50M / OH>MP	142 / 149	142 / 149	142 / 149	142 / 149	142 / 149
17	G82R	-62	-62	-62	-62	-62
18	Dorsey bipole / CU bipole	1700 / 1103	1700 / 1103	1700 / 1103	1700 / 1103	1700 / 1103
19	Dorsey Reserve / Wtrtn SVC	1837 / -11	1837 / -11	1837 / -11	1837 / -11	1837 / -11
20	Forbes SVC / MSC	40 / 600	40 / 600	40 / 600	40 / 600	40 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.045 / 1.045	1.045 / 1.045	1.045 / 1.045	1.045 / 1.045	1.045 / 1.045
24	Roseau 500/Forbes 500	1.028 / 1.010	1.028 / 1.010	1.028 / 1.010	1.028 / 1.010	1.028 / 1.010
25	Chisago 500/EauClaire 345	1.010 / 1.027	1.010 / 1.027	1.010 / 1.027	1.010 / 1.027	1.010 / 1.027
26	Int Falls 115/Badoura 115	1.020 / 1.022	1.020 / 1.022	1.020 / 1.022	1.020 / 1.022	1.020 / 1.022
27	Drayton 230/Groton 345	1.031 / 1.019	1.031 / 1.019	1.031 / 1.019	1.031 / 1.019	1.031 / 1.019
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	223% / 375%	223% / 375%	223% / 375%	223% / 375%	223% / 375%
30	G82R at Rugby/L20D at Drayton	999% / 881%	999% / 881%	999% / 881%	999% / 881%	999% / 881%
31	R50M/F3M	939% / 324%	939% / 324%	939% / 324%	939% / 324%	939% / 324%
32	B10T	335%	335%	335%	335%	335%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.97 | 1.00	0.97 | 1.02	0.95 | 1.04	0.97 | 1.02	0.96 | 1.01
35	Boise 115	1.00 | 1.03	1.00 | 1.03	0.99 | 1.01	1.00 | 1.02	1.01 | 1.03
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05
37	Forbes 230	1.01 | 1.02	1.01 | 1.02	0.97 | 1.03	0.99 | 1.02	1.00 | 1.02
38	Riverton 230	0.99 | 1.03	0.98 | 1.03	0.93 | 1.03	0.97 | 1.04	0.97 | 1.04
39	Coal Creek 230	0.97 | 1.11	0.97 | 1.11	1.01 | 1.10	1.00 | 1.16	0.96 | 1.13
40	Jamestown 345	0.91 | 1.03	0.89 | 1.03	0.85 | 1.03	0.87 | 1.04	0.81 | 1.06
41	Drayton 230	1.01 | 1.06	1.00 | 1.07	0.98 | 1.07	1.02 | 1.08	1.00 | 1.08
42	Groton 345	0.91 | 1.04	0.91 | 1.04	0.91 | 1.07	0.94 | 1.06	0.95 | 1.06
43	Minong 161	0.98 | 1.02	0.98 | 1.03	0.99 | 1.06	1.00 | 1.04	0.98 | 1.02
44	Wahpeton 115	0.98 | 1.06	0.97 | 1.06	0.92 | 1.07	0.96 | 1.07	0.95 | 1.08
45	Watertown 345	0.98 | 1.03	0.98 | 1.04	0.95 | 1.06	0.98 | 1.05	0.98 | 1.05
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 79.41%	KING 3 / 75.81%	SHERC3 / 23.73%	KING 3 / 22.95%	MNTCE3 / 63.22%
55	Dorsey SUVP / UdHold					
56	Forbes DC Red (DCAR)	470%	452%	507%	507%	451%
57	K22W (max +dP @ t, d-ang)	10.5@(2.40832,2.3)	16.1@(2.37499,0.2)	66.6@(2.41666,-31.7)	45.9@(2.34166,-19.2)	13.8@(2.46666,-1.0)
58	K22W (max -dP @ t, d-ang)	19.1@(1.80833,0.1)	20.1@(0.72500,5.3)	3.1@(0.45000,0.2)	2.6@(0.30833,0.1)	13.6@(0.74166,2.3)
59	K22W (max d-ang @ t, dP)	7.1@(1.05000,-6.5)	7.8@(0.99166,-8.1)	-51.8@(10.00821,39.0)	-29.2@(10.00821,22.2)	4.8@(1.05000,-3.8)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	183% / 308%	178% / 299%	142% / 239%	171% / 288%	191% / 322%
63	G82R at Rugby/L20D at Drayton	999% / 725%	999% / 706%	999% / 616%	65% / 636%	999% / 700%
64	R50M / F3M	806% / 281%	789% / 274%	747% / 219%	810% / 253%	816% / 287%
65	B10T	198%	183%	105%	129%	172%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 2 | 1) / (0 | 1 | 1)	(1 | 3 | 1) / (0 | 2 | 2)	(1 | 3 | 1) / (0 | 1 | 1)	(1 | 4 | 1) / (0 | 1 | 1)	(1 | 2 | 1) / (0 | 2 | 2)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 3 | 2) / (1 | 1 | 1)	(1 | 3 | 2) / (1 | 2 | 2)	(1 | 4 | 2) / (1 | 2 | 2)	(1 | 4 | 2) / (1 | 1 | 1)	(1 | 5 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	M0a-so15aa-ag1	M0a-so15aa-ag3	M0a-so15aa-ei2	M0a-so15aa-eq1	M0a-so15aa-fds
Disturbance	ag1	ag3	ei2	eq1	fds
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					

Table C-1: Pre-Benchmark Case

	Case No.	6	7	8	9	10
2	**Case Name**	M0a-so15aa-nad	M0a-so15aa-nmz	M0a-so15aa-pas	M0a-so15aa-pcs	M0a-so15aa-pct
3	**Disturbance**	nad	nmz	pas	pcs	pct
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 20 2009 16:52	MAY 20 2009 16:56	MAY 20 2009 16:59	MAY 20 2009 16:33	MAY 20 2009 17:02
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2451 / 286	2451 / 286	2451 / 286	2451 / 286	2451 / 286
10	MHEX / L20D	2174 / 238	2174 / 238	2174 / 238	2174 / 238	2174 / 238
11	ECL-ARP / PRI-BYN	626 / 702	626 / 702	626 / 702	626 / 702	626 / 702
12	MWEX / AHD-SLK	1519 / 638	1519 / 638	1519 / 638	1519 / 638	1519 / 638
13	D602F / F601C	1855 / 1678	1855 / 1678	1855 / 1678	1855 / 1678	1855 / 1678
14	B10T / MH>SPC	167 / 62	167 / 62	167 / 62	167 / 62	167 / 62
15	OH E-W / OH>MH	187 / -197	187 / -197	187 / -197	187 / -197	187 / -197
16	R50M / OH>MP	142 / 149	142 / 149	142 / 149	142 / 149	142 / 149
17	G82R	-62	-62	-62	-62	-62
18	Dorsey bipole / CU bipole	1700 / 1103	1700 / 1103	1700 / 1103	1700 / 1103	1700 / 1103
19	Dorsey Reserve / Wtrtn SVC	1837 / -11	1837 / -11	1837 / -11	1837 / -11	1837 / -11
20	Forbes SVC / MSC	40 / 600	40 / 600	40 / 600	40 / 600	40 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.045 / 1.045	1.045 / 1.045	1.045 / 1.045	1.045 / 1.045	1.045 / 1.045
24	Roseau 500/Forbes 500	1.028 / 1.010	1.028 / 1.010	1.028 / 1.010	1.028 / 1.010	1.028 / 1.010
25	Chisago 500/EauClaire 345	1.010 / 1.027	1.010 / 1.027	1.010 / 1.027	1.010 / 1.027	1.010 / 1.027
26	Int Falls 115/Badoura 115	1.020 / 1.022	1.020 / 1.022	1.020 / 1.022	1.020 / 1.022	1.020 / 1.022
27	Drayton 230/Groton 345	1.031 / 1.019	1.031 / 1.019	1.031 / 1.019	1.031 / 1.019	1.031 / 1.019
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	223% / 375%	223% / 375%	223% / 375%	223% / 375%	223% / 375%
30	G82R at Rugby/L20D at Drayton	999% / 881%	999% / 881%	999% / 881%	999% / 881%	999% / 881%
31	R50M/F3M	939% / 324%	939% / 324%	939% / 324%	939% / 324%	939% / 324%
32	B10T	335%	335%	335%	335%	335%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.05	0.89 | 1.08	1.00 | 1.06	0.88 | 0.98	0.94 | 0.98
35	Boise 115	0.89 | 1.03	0.94 | 1.04	0.96 | 1.03	1.01 | 1.04	1.02 | 1.03
36	Dorsey 230	1.05 | 1.08	1.06 | 1.09	1.06 | 1.09	1.04 | 1.07	1.04 | 1.05
37	Forbes 230	1.00 | 1.03	0.99 | 1.03	0.99 | 1.05	1.00 | 1.04	1.01 | 1.02
38	Riverton 230	0.96 | 1.03	0.89 | 1.03	0.95 | 1.02	0.99 | 1.03	1.01 | 1.02
39	Coal Creek 230	0.99 | 1.08	0.94 | 1.08	0.99 | 1.09	0.97 | 1.08	1.02 | 1.04
40	Jamestown 345	0.91 | 1.01	0.85 | 1.01	0.91 | 0.99	0.93 | 1.00	0.98 | 0.99
41	Drayton 230	0.98 | 1.07	0.98 | 1.09	0.99 | 1.07	1.02 | 1.04	1.03 | 1.04
42	Groton 345	0.97 | 1.04	0.91 | 1.06	0.97 | 1.03	0.98 | 1.03	1.01 | 1.03
43	Minong 161	1.02 | 1.07	0.94 | 1.11	1.03 | 1.08	0.86 | 0.99	0.94 | 0.99
44	Wahpeton 115	0.95 | 1.05	0.91 | 1.06	0.95 | 1.04	1.01 | 1.04	1.03 | 1.04
45	Watertown 345	0.99 | 1.04	0.94 | 1.05	0.99 | 1.03	1.00 | 1.03	1.02 | 1.03
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 35.26%	KING 3 / 28.68%	KING 3 / 41.73%	SHERC3 / 73.95%	SHERC3 / 59.37%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.150		
56	Forbes DC Red (DCAR)	507%	507%	507%	165%	299%
57	K22W (max +dP @ t, d-ang)	92.6@(2.06666,-46.5)	127.7@(2.17499,-55.9)	80.3@(2.08333,-40.9)	4.6@(3.45831,4.1)	0.0@(0.10000,0.0)
58	K22W (max -dP @ t, d-ang)	94.8@(0.27500,10.6)	69.7@(0.24167,6.6)	66.0@(0.27500,5.9)	54.0@(1.65000,17.9)	29.4@(2.14999,12.4)
59	K22W (max d-ang @ t, dP)	-80.6@(10.00821,41.1)	-87.0@(10.00821,68.5)	-76.3@(10.00821,45.1)	25.7@(1.06666,-40.1)	12.5@(2.00833,-29.2)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.16667 sec / 0.16667 sec	0.18333 sec / 0.18333 sec	0.38333 sec / 0.18333 sec	189% / 317%	223% / 375%
63	G82R at Rugby/L20D at Drayton	999% / 427%	999% / 555%	999% / 516%	999% / 667%	999% / 805%
64	R50M / F3M	274% / 96%	433% / 149%	413% / 171%	698% / 324%	864% / 324%
65	B10T	121%	94%	141%	160%	283%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 1 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 3 | 2) / (0 | 1 | 1)	(1 | 2 | 1) / (0 | 1 | 1)	(1 | 8 | 2) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 2 | 1) / (1 | 5 | 3)	(0 | 1 | 0) / (1 | 3 | 2)	(0 | 0 | 0) / (1 | 3 | 2)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 5 | 4) / (1 | 1 | 1)	(1 | 5 | 4) / (1 | 2 | 2)	(1 | 4 | 4) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	M0a-so15aa-nad	M0a-so15aa-nmz	M0a-so15aa-pas	M0a-so15aa-pcs	M0a-so15aa-pct
Disturbance	nad	nmz	pas	pcs	pct
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(5T)(6T)	(5T)(6T)	(5T)(6T)		

Table C-1: Pre-Benchmark Case

1	**Case No.**	11	12
2	**Case Name**	M0a-so15aa-pys	M0a-so15aa-pyt
3	**Disturbance**	pys	pyt
4	**Prior Outage**	None	None
5	**Date/Time**	MAY 20 2009 17:05	MAY 20 2009 17:08
6	**Comments**		
7			
8	**Steady State Flows**		
9	NDEX / EAST BIAS	2451 / 286	2451 / 286
10	MHEX / L20D	2174 / 238	2174 / 238
11	ECL-ARP / PRI-BYN	626 / 702	626 / 702
12	MWEX / AHD-SLK	1519 / 638	1519 / 638
13	D602F / F601C	1855 / 1678	1855 / 1678
14	B10T / MH>SPC	167 / 62	167 / 62
15	OH E-W / OH>MH	187 / -197	187 / -197
16	R50M / OH>MP	142 / 149	142 / 149
17	G82R	-62	-62
18	Dorsey bipole / CU bipole	1700 / 1103	1700 / 1103
19	Dorsey Reserve / Wtrtn SVC	1837 / -11	1837 / -11
20	Forbes SVC / MSC	40 / 600	40 / 600
21	RCDC	0	0
22	**Steady State Vltgs**		
23	Dorsey 500/Dorsey 230	1.045 / 1.045	1.045 / 1.045
24	Roseau 500/Forbes 500	1.028 / 1.010	1.028 / 1.010
25	Chisago 500/EauClaire 345	1.010 / 1.027	1.010 / 1.027
26	Int Falls 115/Badoura 115	1.020 / 1.022	1.020 / 1.022
27	Drayton 230/Groton 345	1.031 / 1.019	1.031 / 1.019
28	**SS OS Relay Margins**		
29	D602F at Forbes/Dorsey	223% / 375%	223% / 375%
30	G82R at Rugby/L20D at Drayton	999% / 881%	999% / 881%
31	R50M/F3M	939% / 324%	939% / 324%
32	B10T	335%	335%
33	**Min/MaxTransientVltg**		
34	Arrowhd 230	0.98 | 1.02	0.97 | 1.00
35	Boise 115	1.01 | 1.04	1.02 | 1.03
36	Dorsey 230	1.04 | 1.06	1.04 | 1.05
37	Forbes 230	1.00 | 1.05	1.01 | 1.02
38	Riverton 230	1.00 | 1.03	1.01 | 1.03
39	Coal Creek 230	0.98 | 1.08	1.02 | 1.04
40	Jamestown 345	0.94 | 1.00	0.98 | 0.99
41	Drayton 230	1.02 | 1.05	1.03 | 1.04
42	Groton 345	0.99 | 1.03	1.01 | 1.02
43	Minong 161	0.97 | 1.04	0.98 | 1.01
44	Wahpeton 115	1.01 | 1.04	1.03 | 1.04
45	Watertown 345	1.00 | 1.03	1.02 | 1.02
46	**Dynamic Voltage Warnings**		
47		none	none
48			
49			
50			
51			
52			
53			
54	Worst Case Angle Damping	SHERC3 / 77.66%	SHERC3 / 59.13%
55	Dorsey SUVP / UdHold		
56	Forbes DC Red (DCAR)	219%	361%
57	K22W (max +dP @ t, d-ang)	10.1@(3.44997,0.6)	0.0@(0.10000,0.0)
58	K22W (max -dP @ t, d-ang)	35.6@(1.62500,9.0)	19.9@(1.69166,7.7)
59	K22W (max d-ang @ t, dP)	18.9@(1.02500,-23.3)	8.1@(2.17499,-18.0)
60	**OS Rel Trip / Marg**		
61	MH - OH		
62	D602F at Forbes/Dorsey	185% / 309%	223% / 375%
63	G82R at Rugby/L20D at Drayton	999% / 708%	999% / 815%
64	R50M / F3M	741% / 309%	911% / 324%
65	B10T	171%	283%
66	**FSCAPS (SS/Unav/Final)**		
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 3 | 3)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A

Case	M0a-so15aa-pys	M0a-so15aa-pyt
Disturbance	pys	pyt
System Response	OK	OK
70% or 120% Violations		
ORWG Criteria Violations		
Line Tripping		

Table C-2: Benchmark Case

1	**Case No.**	1	2	3	4	5
2	**Case Name**	Mba-so15aa-ag1	Mba-so15aa-ag3	Mba-so15aa-ei2	Mba-so15aa-eq1	Mba-so15aa-fds
3	**Disturbance**	ag1	ag3	ei2	eq1	fds
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 26 2009 16:52	MAY 26 2009 16:54	MAY 26 2009 16:57	MAY 26 2009 17:00	MAY 26 2009 17:03
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2271 / 149	2271 / 149	2271 / 149	2271 / 149	2271 / 149
10	MHEX / L20D	2176 / 287	2176 / 287	2176 / 287	2176 / 287	2176 / 287
11	ECL-ARP / PRI-BYN	661 / 74	661 / 74	661 / 74	661 / 74	661 / 74
12	MWEX / AHD-SLK	1497 / 645	1497 / 645	1497 / 645	1497 / 645	1497 / 645
13	D602F / F601C	1777 / 1521	1777 / 1521	1777 / 1521	1777 / 1521	1777 / 1521
14	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60	164 / 60
15	OH E-W / OH>MH	190 / -196	190 / -196	190 / -196	190 / -196	190 / -196
16	R50M / OH>MP	139 / 151	139 / 151	139 / 151	139 / 151	139 / 151
17	G82R	-28	-28	-28	-28	-28
18	Dorsey bipole / CU bipole	1700 / 1104	1700 / 1104	1700 / 1104	1700 / 1104	1700 / 1104
19	Dorsey Reserve / Wtrtn SVC	1909 / 15	1909 / 15	1909 / 15	1909 / 15	1909 / 15
20	Forbes SVC / MSC	17 / 600	17 / 600	17 / 600	17 / 600	17 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.042 / 1.045	1.042 / 1.045	1.042 / 1.045	1.042 / 1.045	1.042 / 1.045
24	Roseau 500/Forbes 500	1.039 / 1.018	1.039 / 1.018	1.039 / 1.018	1.039 / 1.018	1.039 / 1.018
25	Chisago 500/EauClaire 345	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026
26	Int Falls 115/Badoura 115	1.020 / 1.039	1.020 / 1.039	1.020 / 1.039	1.020 / 1.039	1.020 / 1.039
27	Drayton 230/Groton 345	1.028 / 1.021	1.028 / 1.021	1.028 / 1.021	1.028 / 1.021	1.028 / 1.021
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	246% / 413%	246% / 413%	246% / 413%	246% / 413%	246% / 413%
30	G82R at Rugby/L20D at Drayton	999% / 689%	999% / 689%	999% / 689%	999% / 689%	999% / 689%
31	R50M/F3M	965% / 319%	965% / 319%	965% / 319%	965% / 319%	965% / 319%
32	B10T	345%	345%	345%	345%	345%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.98 | 1.01	0.98 | 1.02	0.97 | 1.04	0.98 | 1.03	0.96 | 1.02
35	Boise 115	1.00 | 1.03	1.00 | 1.03	0.99 | 1.01	1.00 | 1.02	1.01 | 1.03
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05
37	Forbes 230	1.01 | 1.03	1.01 | 1.03	0.99 | 1.03	1.01 | 1.03	1.01 | 1.03
38	Riverton 230	1.01 | 1.04	1.00 | 1.04	0.97 | 1.05	1.00 | 1.05	0.99 | 1.05
39	Coal Creek 230	0.97 | 1.11	0.97 | 1.11	1.02 | 1.11	0.99 | 1.16	0.97 | 1.12
40	Jamestown 345	0.91 | 1.02	0.90 | 1.02	0.84 | 1.04	0.86 | 1.05	0.81 | 1.05
41	Drayton 230	1.01 | 1.05	1.00 | 1.04	0.98 | 1.06	1.02 | 1.07	1.00 | 1.06
42	Groton 345	0.92 | 1.04	0.92 | 1.04	0.93 | 1.06	0.95 | 1.06	0.95 | 1.06
43	Minong 161	0.98 | 1.02	0.98 | 1.04	1.00 | 1.05	1.00 | 1.04	0.98 | 1.02
44	Wahpeton 115	1.00 | 1.07	0.99 | 1.06	0.95 | 1.08	0.98 | 1.08	0.97 | 1.08
45	Watertown 345	0.98 | 1.04	0.99 | 1.04	0.97 | 1.05	0.99 | 1.05	0.99 | 1.05
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 77.44%	KING 3 / 74.30%	SHERC3 / 28.74%	KING 3 / 27.99%	MNTCE3 / 75.67%
55	Dorsey SUVP / UdHold					
56	Forbes DC Red (DCAR)	460%	452%	507%	507%	457%
57	K22W (max +dP @ t, d-ang)	10.5@(2.39166,2.0)	14.9@(2.35832,0.2)	65.5@(2.39999,-29.2)	45.4@(2.30833,-18.2)	12.5@(2.41666,-1.2)
58	K22W (max -dP @ t, d-ang)	18.2@(1.80000,0.3)	19.3@(0.74166,5.4)	1.6@(0.38333,0.1)	2.4@(0.29167,0.1)	12.8@(0.75833,2.6)
59	K22W (max d-ang @ t, dP)	6.8@(1.05000,-6.3)	7.7@(0.99166,-8.6)	-49.3@(10.00821,37.2)	-28.4@(10.00821,21.2)	4.6@(1.02500,-4.2)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	204% / 343%	199% / 334%	177% / 299%	202% / 340%	216% / 363%
63	G82R at Rugby/L20D at Drayton	999% / 590%	999% / 580%	999% / 511%	47% / 537%	999% / 588%
64	R50M / F3M	839% / 279%	820% / 274%	815% / 220%	868% / 248%	855% / 282%
65	B10T	211%	204%	111%	130%	190%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 2 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 3 | 1) / (0 | 1 | 1)	(1 | 3 | 1) / (0 | 1 | 1)	(1 | 3 | 1) / (0 | 2 | 2)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 4 | 1) / (1 | 1 | 1)	(1 | 3 | 1) / (1 | 1 | 1)	(1 | 3 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	Mba-so15aa-ag1	Mba-so15aa-ag3	Mba-so15aa-ei2	Mba-so15aa-eq1	Mba-so15aa-fds
Disturbance	ag1	ag3	ei2	eq1	fds
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					

Table C-2: Benchmark Case

	Case No.	6	7	8	9	10
2	**Case Name**	Mba-so15aa-nad	Mba-so15aa-nmz	Mba-so15aa-pas	Mba-so15aa-pcs	Mba-so15aa-pct
3	**Disturbance**	nad	nmz	pas	pcs	pct
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 26 2009 17:06	MAY 26 2009 17:10	MAY 26 2009 17:13	MAY 26 2009 17:16	MAY 26 2009 17:19
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2271 / 149	2271 / 149	2271 / 149	2271 / 149	2271 / 149
10	MHEX / L20D	2176 / 287	2176 / 287	2176 / 287	2176 / 287	2176 / 287
11	ECL-ARP / PRI-BYN	661 / 74	661 / 74	661 / 74	661 / 74	661 / 74
12	MWEX / AHD-SLK	1497 / 645	1497 / 645	1497 / 645	1497 / 645	1497 / 645
13	D602F / F601C	1777 / 1521	1777 / 1521	1777 / 1521	1777 / 1521	1777 / 1521
14	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60	164 / 60
15	OH E-W / OH>MH	190 / -196	190 / -196	190 / -196	190 / -196	190 / -196
16	R50M / OH>MP	139 / 151	139 / 151	139 / 151	139 / 151	139 / 151
17	G82R	-28	-28	-28	-28	-28
18	Dorsey bipole / CU bipole	1700 / 1104	1700 / 1104	1700 / 1104	1700 / 1104	1700 / 1104
19	Dorsey Reserve / Wtrtn SVC	1909 / 15	1909 / 15	1909 / 15	1909 / 15	1909 / 15
20	Forbes SVC / MSC	17 / 600	17 / 600	17 / 600	17 / 600	17 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.042 / 1.045	1.042 / 1.045	1.042 / 1.045	1.042 / 1.045	1.042 / 1.045
24	Roseau 500/Forbes 500	1.039 / 1.018	1.039 / 1.018	1.039 / 1.018	1.039 / 1.018	1.039 / 1.018
25	Chisago 500/EauClaire 345	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026
26	Int Falls 115/Badoura 115	1.020 / 1.039	1.020 / 1.039	1.020 / 1.039	1.020 / 1.039	1.020 / 1.039
27	Drayton 230/Groton 345	1.028 / 1.021	1.028 / 1.021	1.028 / 1.021	1.028 / 1.021	1.028 / 1.021
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	246% / 413%	246% / 413%	246% / 413%	246% / 413%	246% / 413%
30	G82R at Rugby/L20D at Drayton	999% / 689%	999% / 689%	999% / 689%	999% / 689%	999% / 689%
31	R50M/F3M	965% / 319%	965% / 319%	965% / 319%	965% / 319%	965% / 319%
32	B10T	345%	345%	345%	345%	345%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.00 | 1.06	0.93 | 1.07	1.00 | 1.07	0.90 | 0.99	0.95 | 0.98
35	Boise 115	0.91 | 1.03	0.96 | 1.03	0.97 | 1.02	1.01 | 1.04	1.02 | 1.03
36	Dorsey 230	1.05 | 1.08	1.06 | 1.09	1.05 | 1.09	1.04 | 1.07	1.04 | 1.05
37	Forbes 230	1.01 | 1.03	1.00 | 1.04	1.00 | 1.05	1.01 | 1.05	1.02 | 1.02
38	Riverton 230	1.00 | 1.05	0.94 | 1.06	1.00 | 1.05	1.01 | 1.04	1.03 | 1.03
39	Coal Creek 230	0.99 | 1.07	0.95 | 1.07	0.99 | 1.07	0.97 | 1.08	1.02 | 1.04
40	Jamestown 345	0.91 | 0.99	0.83 | 1.01	0.91 | 0.99	0.94 | 1.01	0.98 | 1.00
41	Drayton 230	0.96 | 1.07	0.97 | 1.09	0.98 | 1.07	1.01 | 1.04	1.02 | 1.04
42	Groton 345	0.97 | 1.04	0.92 | 1.06	0.97 | 1.03	0.99 | 1.04	1.01 | 1.03
43	Minong 161	1.02 | 1.07	0.96 | 1.09	1.03 | 1.08	0.88 | 1.00	0.94 | 0.99
44	Wahpeton 115	0.99 | 1.06	0.94 | 1.07	0.99 | 1.06	1.03 | 1.06	1.04 | 1.05
45	Watertown 345	1.00 | 1.04	0.96 | 1.05	1.00 | 1.04	1.01 | 1.04	1.02 | 1.03
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 34.85%	KING 3 / 30.66%	KING 3 / 39.55%	SHERC3 / 73.39%	SHERC3 / 61.92%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.150		
56	Forbes DC Red (DCAR)	507%	507%	507%	215%	330%
57	K22W (max +dP @ t, d-ang)	103.9@(2.04166,-45.6)	126.9@(2.12499,-54.8)	89.4@(2.08333,-42.6)	4.8@(3.36664,2.7)	0.0@(0.10000,0.0)
58	K22W (max -dP @ t, d-ang)	90.8@(0.27500,10.2)	65.7@(0.24167,6.2)	61.9@(0.27500,5.6)	45.1@(1.60000,14.9)	28.1@(2.05000,11.5)
59	K22W (max d-ang @ t, dP)	-76.5@(10.00821,41.9)	-83.3@(10.00821,67.0)	-72.6@(10.00821,44.7)	23.3@(1.02500,-34.4)	11.5@(1.91666,-27.9)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.16667 sec / 0.16667 sec	0.18333 sec / 0.18333 sec	0.38333 sec / 0.18333 sec	205% / 344%	245% / 410%
63	G82R at Rugby/L20D at Drayton	999% / 338%	999% / 440%	999% / 410%	999% / 527%	999% / 650%
64	R50M / F3M	366% / 119%	532% / 166%	448% / 175%	726% / 319%	884% / 319%
65	B10T	108%	86%	128%	157%	295%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 1 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 4 | 1) / (0 | 1 | 1)	(1 | 3 | 1) / (0 | 1 | 1)	(1 | 2 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 2 | 0) / (1 | 5 | 3)	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 3 | 2)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 4 | 2) / (1 | 2 | 2)	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	Mba-so15aa-nad	Mba-so15aa-nmz	Mba-so15aa-pas	Mba-so15aa-pcs	Mba-so15aa-pct
Disturbance	nad	nmz	pas	pcs	pct
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(5T)(6T)	(5T)(6T)	(5T)(6T)		

Table C-2: Benchmark Case

1	**Case No.**	11	12
2	**Case Name**	Mba-so15aa-pzs	Mba-so15aa-pzt
3	**Disturbance**	pzs	pzt
4	**Prior Outage**	None	None
5	**Date/Time**	MAY 26 2009 17:22	MAY 26 2009 17:25
6	**Comments**		
7			
8	**Steady State Flows**		
9	NDEX / EAST BIAS	2271 / 149	2271 / 149
10	MHEX / L20D	2176 / 287	2176 / 287
11	ECL-ARP / PRI-BYN	661 / 74	661 / 74
12	MWEX / AHD-SLK	1497 / 645	1497 / 645
13	D602F / F601C	1777 / 1521	1777 / 1521
14	B10T / MH>SPC	164 / 60	164 / 60
15	OH E-W / OH>MH	190 / -196	190 / -196
16	R50M / OH>MP	139 / 151	139 / 151
17	G82R	-28	-28
18	Dorsey bipole / CU bipole	1700 / 1104	1700 / 1104
19	Dorsey Reserve / Wtrtn SVC	1909 / 15	1909 / 15
20	Forbes SVC / MSC	17 / 600	17 / 600
21	RCDC	0	0
22	**Steady State Vltgs**		
23	Dorsey 500/Dorsey 230	1.042 / 1.045	1.042 / 1.045
24	Roseau 500/Forbes 500	1.039 / 1.018	1.039 / 1.018
25	Chisago 500/EauClaire 345	1.017 / 1.026	1.017 / 1.026
26	Int Falls 115/Badoura 115	1.020 / 1.039	1.020 / 1.039
27	Drayton 230/Groton 345	1.028 / 1.021	1.028 / 1.021
28	**SS OS Relay Margins**		
29	D602F at Forbes/Dorsey	246% / 413%	246% / 413%
30	G82R at Rugby/L20D at Drayton	999% / 689%	999% / 689%
31	R50M/F3M	965% / 319%	965% / 319%
32	B10T	345%	345%
33	**Min/MaxTransientVltg**		
34	Arrowhd 230	0.99 | 1.04	1.00 | 1.00
35	Boise 115	1.00 | 1.04	1.02 | 1.02
36	Dorsey 230	1.04 | 1.06	1.04 | 1.05
37	Forbes 230	1.02 | 1.05	1.02 | 1.02
38	Riverton 230	1.02 | 1.05	1.03 | 1.03
39	Coal Creek 230	0.98 | 1.08	1.03 | 1.04
40	Jamestown 345	0.94 | 1.01	0.98 | 0.99
41	Drayton 230	1.02 | 1.04	1.03 | 1.03
42	Groton 345	0.99 | 1.04	1.02 | 1.02
43	Minong 161	1.00 | 1.05	1.00 | 1.01
44	Wahpeton 115	1.02 | 1.06	1.04 | 1.04
45	Watertown 345	1.01 | 1.04	1.03 | 1.03
46	**Dynamic Voltage Warnings**		
47		none	none
48			
49			
50			
51			
52			
53			
54	Worst Case Angle Damping	KING 3 / 75.27%	SHERC3 / 48.44%
55	Dorsey SUVP / UdHold		
56	Forbes DC Red (DCAR)	317%	473%
57	K22W (max +dP @ t, d-ang)	25.3@(2.41666,-5.3)	0.0@(0.10000,0.0)
58	K22W (max -dP @ t, d-ang)	25.9@(0.61666,9.1)	5.6@(1.61666,2.3)
59	K22W (max d-ang @ t, dP)	13.3@(0.92500,-15.2)	2.4@(2.09999,-5.4)
60	**OS Rel Trip / Marg**		
61	MH - OH		
62	D602F at Forbes/Dorsey	196% / 327%	246% / 413%
63	G82R at Rugby/L20D at Drayton	999% / 572%	999% / 680%
64	R50M / F3M	772% / 282%	953% / 319%
65	B10T	165%	332%
66	**FSCAPS (SS/Unav/Final)**		
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 3 | 3)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A

Case	Mba-so15aa-pzs	Mba-so15aa-pzt
Disturbance	pzs	pzt
System Response	OK	OK
70% or 120% Violations		
ORWG Criteria Violations		
Line Tripping		

Table C-3: TSR Study Case with Upgrade Option 1

	Case No.	1	2	3	4	5
	Case Name	m1a-so15aa-ag1	m1a-so15aa-ag3	m1a-so15aa-cts	m1a-so15aa-ei2	m1a-so15aa-em3
	Disturbance	ag1	ag3	cts	ei2	em3
	Prior Outage	None	None	None	None	None
	Date/Time	MAY 28 2009 11:35	MAY 28 2009 11:38	JUN 03 2009 17:43	MAY 28 2009 11:45	MAY 28 2009 11:48
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
	MWEX / AHD-SLK	1641 / 642	1641 / 642	1641 / 642	1641 / 642	1641 / 642
	D602F / F601C	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249
	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
	G82R	-61	-61	-61	-61	-61
	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
	Dorsey Reserve / Wtrtn SVC	717 / 29	717 / 29	717 / 29	717 / 29	717 / 29
	Forbes SVC / MSC	-45 / 600	-45 / 600	-45 / 600	-45 / 600	-45 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
	Int Falls 115/Badoura 115	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045
	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
	R50M/F3M	999% / 322%	999% / 322%	999% / 322%	999% / 322%	999% / 322%
	B10T	347%	347%	347%	347%	347%
	Min/MaxTransientVltg					
	Arrowhd 230	0.98 | 1.01	0.98 | 1.01	0.92 | 1.07	0.98 | 1.04	1.00 | 1.01
	Boise 115	1.01 | 1.03	1.01 | 1.03	0.98 | 1.02	1.00 | 1.02	1.02 | 1.02
	Dorsey 230	1.03 | 1.05	1.03 | 1.05	1.04 | 1.12	1.04 | 1.05	1.03 | 1.05
	Forbes 230	1.02 | 1.04	1.02 | 1.04	0.96 | 1.05	1.01 | 1.04	1.03 | 1.04
	Riverton 230	1.01 | 1.04	1.01 | 1.04	0.94 | 1.07	0.99 | 1.05	1.04 | 1.04
	Coal Creek 230	0.97 | 1.10	0.97 | 1.10	0.89 | 1.07	1.02 | 1.10	1.03 | 1.05
	Jamestown 345	0.93 | 1.02	0.93 | 1.02	0.79 | 1.04	0.87 | 1.02	0.99 | 1.00
	Drayton 230	1.02 | 1.05	1.01 | 1.05	0.97 | 1.08	1.00 | 1.06	1.04 | 1.04
	Groton 345	0.93 | 1.05	0.93 | 1.04	0.87 | 1.06	0.94 | 1.06	1.02 | 1.03
	Minong 161	1.00 | 1.03	1.00 | 1.03	0.98 | 1.10	1.02 | 1.07	1.03 | 1.04
	Wahpeton 115	1.01 | 1.06	1.01 | 1.06	0.92 | 1.08	0.98 | 1.07	1.05 | 1.05
	Watertown 345	0.99 | 1.04	0.99 | 1.04	0.92 | 1.05	0.98 | 1.05	1.03 | 1.03
	Dynamic Voltage Warnings					
		none	none		none	none
	Worst Case Angle Damping	KING 3 / 74.83%	KING 3 / 75.32%	KING 3 / 39.02%	SHERC3 / 31.81%	KING 3 / 36.68%
	Dorsey SUVP / UdHold					/ 0.133
	Forbes DC Red (DCAR)	475%	473%	507%	505%	494%
	K22W (max +dP @ t, d-ang)	10.7@(2.31666,2.2)	13.0@(2.28333,1.3)	103.9@(2.39166,-43.6)	70.4@(2.35832,-30.2)	31.4@(0.13333,-0.3)
	K22W (max -dP @ t, d-ang)	20.0@(1.74166,0.6)	18.9@(0.69166,4.8)	46.5@(0.42500,7.0)	0.0@(0.03333,0.0)	20.4@(0.26667,1.8)
	K22W (max d-ang @ t, dP)	6.5@(1.00000,-5.8)	7.0@(0.95000,-6.7)	-63.5@(10.00821,45.6)	-49.9@(10.00821,38.5)	-11.8@(10.00821,10.6)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	285% / 477%	283% / 473%	0.36667 sec / 0.36667 sec	242% / 405%	296% / 496%
	G82R at Rugby/L20D at Drayton	999% / 820%	999% / 814%	999% / 683%	999% / 757%	999% / 0.18333 sec
	R50M / F3M	971% / 285%	965% / 282%	678% / 195%	928% / 226%	978% / 293%
	B10T	218%	215%	80%	139%	282%
	FSCAPS (SS/Unav/Final)					
	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 2 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 5 | 1) / (0 | 2 | 2)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 5 | 0) / (1 | 2 | 2)	(1 | 2 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-ag1	m1a-so15aa-ag3	m1a-so15aa-cts	m1a-so15aa-ei2	m1a-so15aa-em3
Disturbance	ag1	ag3	cts	ei2	em3
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping			(5T)(6T)		(3T)

Table C-3: TSR Study Case with Upgrade Option 1

	Case No.	6	7	8	9	10
2	**Case Name**	m1a-so15aa-eq1	m1a-so15aa-fds	m1a-so15aa-mc3	m1a-so15aa-md3	m1a-so15aa-mis
3	**Disturbance**	eq1	fds	mc3	md3	mis
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 28 2009 11:51	MAY 28 2009 11:54	MAY 28 2009 11:57	MAY 28 2009 12:00	MAY 28 2009 12:03
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
12	MWEX / AHD-SLK	1641 / 642	1641 / 642	1641 / 642	1641 / 642	1641 / 642
13	D602F / F601C	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249
14	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
17	G82R	-61	-61	-61	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 29	717 / 29	717 / 29	717 / 29	717 / 29
20	Forbes SVC / MSC	-45 / 600	-45 / 600	-45 / 600	-45 / 600	-45 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
31	R50M/F3M	999% / 322%	999% / 322%	999% / 322%	999% / 322%	999% / 322%
32	B10T	347%	347%	347%	347%	347%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.98 | 1.03	0.96 | 1.02	1.01 | 1.01	1.00 | 1.00	1.00 | 1.01
35	Boise 115	1.00 | 1.02	1.01 | 1.03	1.01 | 1.02	1.02 | 1.02	1.04 | 1.06
36	Dorsey 230	1.04 | 1.05	1.04 | 1.06	1.03 | 1.05	1.03 | 1.05	1.04 | 1.05
37	Forbes 230	1.02 | 1.04	1.02 | 1.04	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04
38	Riverton 230	1.01 | 1.05	1.00 | 1.04	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04
39	Coal Creek 230	0.99 | 1.16	0.98 | 1.12	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04
40	Jamestown 345	0.88 | 1.04	0.85 | 1.04	0.99 | 1.00	0.99 | 0.99	0.99 | 1.00
41	Drayton 230	1.02 | 1.07	1.01 | 1.06	1.03 | 1.04	1.03 | 1.04	1.04 | 1.04
42	Groton 345	0.96 | 1.06	0.96 | 1.05	1.02 | 1.03	1.02 | 1.02	1.02 | 1.03
43	Minong 161	1.02 | 1.06	0.99 | 1.04	1.03 | 1.03	1.02 | 1.03	1.02 | 1.03
44	Wahpeton 115	1.00 | 1.07	0.99 | 1.07	1.05 | 1.05	1.05 | 1.05	1.05 | 1.05
45	Watertown 345	0.99 | 1.05	0.99 | 1.04	1.03 | 1.03	1.03 | 1.03	1.03 | 1.03
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 31.98%	STANT4 / 77.36%	KING 3 / 34.25%	ANTEL3 / 77.90%	SHERC3 / 20.13%
55	Dorsey SUVP / UdHold		/ 0.166	/ 0.133	/ 0.133	
56	Forbes DC Red (DCAR)	487%	446%	491%	498%	485%
57	K22W (max +dP @ t, d-ang)	48.0@(2.27499,-18.2)	12.3@(2.34999,-1.0)	28.2@(0.12500,0.4)	20.6@(0.12500,-0.4)	196.0@(0.35000,-11.9)
58	K22W (max -dP @ t, d-ang)	1.7@(0.30000,-0.1)	16.1@(0.58333,1.9)	22.0@(0.95833,-4.0)	10.2@(0.24167,0.5)	0.0@(0.35000,0.0)
59	K22W (max d-ang @ t, dP)	-27.8@(10.00821,20.7)	4.8@(0.96666,-3.2)	-8.2@(10.00821,-12.6)	-0.7@(3.44997,2.2)	-43.2@(0.96666,196.0)
60	**OS Rel Trip / Marg**					
61	MH - OH					0.35000 sec
62	D602F at Forbes/Dorsey	270% / 451%	274% / 459%	305% / 512%	325% / 542%	313% / 523%
63	G82R at Rugby/L20D at Drayton	66% / 743%	999% / 825%	999% / 859%	999% / 912%	999% / 874%
64	R50M / F3M	978% / 253%	934% / 289%	999% / 214%	999% / 318%	674% / 322%
65	B10T	149%	209%	102%	338%	318%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 1 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 2 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 0) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-eq1	m1a-so15aa-fds	m1a-so15aa-mc3	m1a-so15aa-md3	m1a-so15aa-mis
Disturbance	eq1	fds	mc3	md3	mis
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					(1T)

Table C-3: TSR Study Case with Upgrade Option 1

	Case No.	11	12	13	14	15
2	**Case Name**	m1a-so15aa-mjs	m1a-so15aa-mkd	m1a-so15aa-mks	m1a-so15aa-nad	m1a-so15aa-nmz
3	**Disturbance**	mjs	mkd	mks	nad	nmz
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 28 2009 12:06	MAY 28 2009 12:09	MAY 28 2009 12:12	MAY 28 2009 12:15	JUN 03 2009 17:47
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
12	MWEX / AHD-SLK	1641 / 642	1641 / 642	1641 / 642	1641 / 642	1641 / 642
13	D602F / F601C	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249
14	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
17	G82R	-61	-61	-61	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 29	717 / 29	717 / 29	717 / 29	717 / 29
20	Forbes SVC / MSC	-45 / 600	-45 / 600	-45 / 600	-45 / 600	-45 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
31	R50M/F3M	999% / 322%	999% / 322%	999% / 322%	999% / 322%	999% / 322%
32	B10T	347%	347%	347%	347%	347%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.98 | 1.00	0.93 | 1.01	0.98 | 1.02	0.99 | 1.05	0.95 | 1.05
35	Boise 115	1.02 | 1.03	1.02 | 1.03	1.02 | 1.03	0.97 | 1.01	0.98 | 1.02
36	Dorsey 230	1.04 | 1.06	1.04 | 1.05	1.04 | 1.07	1.04 | 1.07	1.04 | 1.07
37	Forbes 230	1.03 | 1.05	1.03 | 1.04	1.03 | 1.05	1.02 | 1.04	1.01 | 1.04
38	Riverton 230	1.02 | 1.04	0.99 | 1.03	1.01 | 1.04	1.00 | 1.05	0.97 | 1.06
39	Coal Creek 230	0.98 | 1.07	0.98 | 1.07	0.97 | 1.08	1.00 | 1.06	0.96 | 1.06
40	Jamestown 345	0.93 | 1.00	0.93 | 1.00	0.92 | 1.01	0.95 | 1.01	0.89 | 1.02
41	Drayton 230	1.02 | 1.05	1.01 | 1.04	1.02 | 1.05	1.01 | 1.06	1.00 | 1.07
42	Groton 345	0.99 | 1.03	0.98 | 1.03	0.98 | 1.03	1.00 | 1.04	0.95 | 1.05
43	Minong 161	1.00 | 1.02	0.95 | 1.04	0.99 | 1.04	1.02 | 1.08	0.99 | 1.08
44	Wahpeton 115	1.02 | 1.05	1.01 | 1.05	1.02 | 1.06	1.01 | 1.06	0.98 | 1.07
45	Watertown 345	1.01 | 1.03	1.00 | 1.03	1.00 | 1.03	1.01 | 1.04	0.98 | 1.05
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	SHERC3 / 75.93%	KING 3 / 79.65%	KING 3 / 81.07%	KING 3 / 38.58%	KING 3 / 34.64%
55	Dorsey SUVP / UdHold		/ 0.133		/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	454%	317%	391%	507%	507%
57	K22W (max +dP @ t, d-ang)	3.3@(0.11667,0.3)	11.8@(0.10833,1.4)	8.7@(3.27498,0.0)	83.6@(2.04166,-39.3)	89.9@(2.19166,-39.9)
58	K22W (max -dP @ t, d-ang)	17.6@(0.35833,2.8)	27.3@(0.22500,3.5)	29.6@(0.37500,5.4)	58.2@(0.25000,6.6)	45.3@(0.22500,4.4)
59	K22W (max d-ang @ t, dP)	5.7@(0.96666,-11.5)	13.3@(0.85000,-14.8)	9.9@(0.81666,-10.6)	-67.7@(10.00821,43.8)	-63.9@(10.00821,47.2)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	310% / 529%	325% / 543%	293% / 515%	0.16667 sec / 0.16667 sec	0.18333 sec / 0.18333 sec
63	G82R at Rugby/L20D at Drayton	999% / 836%	999% / 771%	999% / 805%	999% / 653%	999% / 757%
64	R50M / F3M	999% / 322%	970% / 322%	965% / 314%	593% / 167%	722% / 202%
65	B10T	251%	205%	215%	193%	146%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 1)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 2 | 1) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 2 | 0) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-mjs	m1a-so15aa-mkd	m1a-so15aa-mks	m1a-so15aa-nad	m1a-so15aa-nmz
Disturbance	mjs	mkd	mks	nad	nmz
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping				(5T)(6T)	(5T)(6T)

Table C-3: TSR Study Case with Upgrade Option 1

	Case No.	16	17	18	19	20
2	**Case Name**	m1a-so15aa-pas	m1a-so15aa-pc0	m1a-so15aa-pcs	m1a-so15aa-pct	m1a-so15aa-pzs
3	**Disturbance**	pas	pc0	pcs	pct	pzs
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 28 2009 12:22	MAY 28 2009 12:25	MAY 28 2009 12:28	MAY 28 2009 12:31	MAY 28 2009 12:34
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
12	MWEX / AHD-SLK	1641 / 642	1641 / 642	1641 / 642	1641 / 642	1641 / 642
13	D602F / F601C	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249
14	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
17	G82R	-61	-61	-61	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 29	717 / 29	717 / 29	717 / 29	717 / 29
20	Forbes SVC / MSC	-45 / 600	-45 / 600	-45 / 600	-45 / 600	-45 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
31	R50M/F3M	999% / 322%	999% / 322%	999% / 322%	999% / 322%	999% / 322%
32	B10T	347%	347%	347%	347%	347%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.05	0.87 | 0.99	0.87 | 0.97	0.92 | 0.96	0.98 | 1.03
35	Boise 115	0.99 | 1.02	1.01 | 1.04	1.02 | 1.05	1.02 | 1.03	1.01 | 1.04
36	Dorsey 230	1.05 | 1.07	1.03 | 1.08	1.03 | 1.09	1.04 | 1.05	1.03 | 1.08
37	Forbes 230	0.99 | 1.04	1.02 | 1.05	1.01 | 1.06	1.02 | 1.03	1.03 | 1.07
38	Riverton 230	1.00 | 1.05	1.01 | 1.04	1.02 | 1.04	1.02 | 1.04	1.03 | 1.05
39	Coal Creek 230	0.99 | 1.06	0.97 | 1.07	0.98 | 1.08	1.02 | 1.05	0.98 | 1.08
40	Jamestown 345	0.95 | 1.00	0.95 | 1.01	0.96 | 1.01	0.99 | 1.01	0.96 | 1.02
41	Drayton 230	1.02 | 1.06	1.03 | 1.05	1.03 | 1.06	1.04 | 1.05	1.03 | 1.06
42	Groton 345	1.00 | 1.04	0.99 | 1.03	1.00 | 1.03	1.01 | 1.03	1.00 | 1.04
43	Minong 161	1.03 | 1.09	0.83 | 1.00	0.83 | 0.98	0.90 | 0.96	0.98 | 1.05
44	Wahpeton 115	1.02 | 1.06	1.03 | 1.06	1.04 | 1.06	1.04 | 1.06	1.04 | 1.07
45	Watertown 345	1.01 | 1.04	1.01 | 1.04	1.01 | 1.04	1.02 | 1.03	1.01 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 40.05%	SHERC3 / 69.93%	KING 3 / 57.49%	SHERC3 / 49.49%	SHERC3 / 77.75%
55	Dorsey SUVP / UdHold	/ 0.150				
56	Forbes DC Red (DCAR)	439%	222%	200%	299%	330%
57	K22W (max +dP @ t, d-ang)	80.6@(2.04166,-38.0)	15.7@(3.36664,0.8)	6.4@(3.38331,4.6)	0.0@(0.10000,0.0)	21.7@(2.38332,-3.2)
58	K22W (max -dP @ t, d-ang)	39.8@(0.25833,3.6)	51.5@(1.56666,18.5)	56.1@(1.58333,21.0)	43.0@(2.19999,18.4)	33.4@(0.39166,5.4)
59	K22W (max d-ang @ t, dP)	-64.9@(10.00821,46.4)	25.1@(1.02500,-34.1)	25.5@(1.05833,-36.9)	18.5@(2.34166,-42.5)	14.8@(0.88333,-14.1)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.38333 sec / 0.18333 sec	296% / 492%	309% / 514%	325% / 543%	275% / 458%
63	G82R at Rugby/L20D at Drayton	999% / 712%	999% / 758%	999% / 774%	999% / 860%	999% / 790%
64	R50M / F3M	654% / 197%	858% / 309%	878% / 322%	982% / 322%	893% / 290%
65	B10T	216%	178%	194%	76%	180%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 3 | 3)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 2 | 2)	(1 | 2 | 2) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 1) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-pas	m1a-so15aa-pc0	m1a-so15aa-pcs	m1a-so15aa-pct	m1a-so15aa-pzs
Disturbance	pas	pc0	pcs	pct	pzs
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(5T)(6T)				

Table C-3: TSR Study Case with Upgrade Option 1

	Case No.	21	22	23	24	25
2	**Case Name**	m1a-so15aa-pzt	m1a-so15aa-ya3	m1a-so15aa-yas	m1a-so15aa-yb3	m1a-so15aa-h13
3	**Disturbance**	pzt	ya3	yas	yb3	h13
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 28 2009 12:37	MAY 28 2009 12:40	MAY 28 2009 12:43	MAY 28 2009 12:45	MAY 28 2009 13:35
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
12	MWEX / AHD-SLK	1641 / 642	1641 / 642	1641 / 642	1641 / 642	1641 / 642
13	D602F / F601C	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249
14	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
17	G82R	-61	-61	-61	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 29	717 / 29	717 / 29	717 / 29	717 / 29
20	Forbes SVC / MSC	-45 / 600	-45 / 600	-45 / 600	-45 / 600	-45 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
31	R50M/F3M	999% / 322%	999% / 322%	999% / 322%	999% / 322%	999% / 322%
32	B10T	347%	347%	347%	347%	347%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.00 | 1.00	1.02 | 1.02	0.96 | 0.99	1.03 | 1.04	0.99 | 1.02
35	Boise 115	1.02 | 1.02	1.03 | 1.04	1.02 | 1.04	1.03 | 1.04	1.01 | 1.02
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.07	1.04 | 1.05	1.01 | 1.05
37	Forbes 230	1.03 | 1.03	1.03 | 1.04	1.02 | 1.05	1.03 | 1.04	1.03 | 1.04
38	Riverton 230	1.03 | 1.04	1.02 | 1.03	1.02 | 1.03	1.03 | 1.03	1.03 | 1.04
39	Coal Creek 230	1.03 | 1.04	1.02 | 1.04	1.00 | 1.05	1.02 | 1.04	1.02 | 1.07
40	Jamestown 345	0.99 | 1.00	0.98 | 1.00	0.98 | 1.01	0.99 | 1.00	0.97 | 1.01
41	Drayton 230	1.04 | 1.04	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.02 | 1.05
42	Groton 345	1.02 | 1.02	1.01 | 1.02	1.01 | 1.02	1.02 | 1.02	1.01 | 1.04
43	Minong 161	1.02 | 1.02	0.98 | 1.00	0.97 | 1.02	0.99 | 1.02	1.01 | 1.05
44	Wahpeton 115	1.05 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.06
45	Watertown 345	1.03 | 1.03	1.02 | 1.03	1.02 | 1.03	1.02 | 1.03	1.03 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	SHERC3 / 41.73%	SHERC3 / 31.58%	SHERC3 / 32.36%	KING 3 / 42.52%	MNTCE3 / 60.62%
55	Dorsey SUVP / UdHold					/ 0.133
56	Forbes DC Red (DCAR)	470%	343%	406%	393%	468%
57	K22W (max +dP @ t, d-ang)	0.0@(0.10000,0.0)	5.0@(0.11667,0.7)	3.1@(0.11667,0.3)	3.3@(0.11667,0.5)	102.8@(0.15000,-2.0)
58	K22W (max -dP @ t, d-ang)	7.6@(2.05833,3.3)	31.6@(1.66666,15.1)	25.4@(1.60833,11.1)	21.3@(1.59166,9.8)	18.5@(2.93332,4.1)
59	K22W (max d-ang @ t, dP)	3.3@(2.22499,-7.3)	15.8@(1.98333,-28.7)	11.7@(1.94166,-20.5)	10.1@(1.88333,-18.9)	-7.1@(0.65833,-0.1)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	310% / 518%
63	G82R at Rugby/L20D at Drayton	999% / 899%	999% / 852%	999% / 863%	999% / 869%	999% / 839%
64	R50M / F3M	999% / 322%	999% / 322%	999% / 322%	999% / 322%	987% / 265%
65	B10T	333%	284%	291%	299%	279%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-pzt	m1a-so15aa-ya3	m1a-so15aa-yas	m1a-so15aa-yb3	m1a-so15aa-h13
Disturbance	pzt	ya3	yas	yb3	h13
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					

Table C-3: TSR Study Case with Upgrade Option 1

1	**Case No.**	26	27	28	29	30
2	**Case Name**	m1a-so15aa-h23	m1a-so15aa-h33	m1a-so15aa-h43	m1a-so15aa-h53	m1a-so15aa-h63
3	**Disturbance**	h23	h33	h43	h53	h63
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 28 2009 13:38	MAY 28 2009 13:41	MAY 28 2009 13:44	MAY 28 2009 13:47	MAY 28 2009 13:50
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
12	MWEX / AHD-SLK	1641 / 642	1641 / 642	1641 / 642	1641 / 642	1641 / 642
13	D602F / F601C	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249
14	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
17	G82R	-61	-61	-61	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 29	717 / 29	717 / 29	717 / 29	717 / 29
20	Forbes SVC / MSC	-45 / 600	-45 / 600	-45 / 600	-45 / 600	-45 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
31	R50M/F3M	999% / 322%	999% / 322%	999% / 322%	999% / 322%	999% / 322%
32	B10T	347%	347%	347%	347%	347%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.01 | 1.05	1.03 | 1.07	0.99 | 1.02	0.91 | 1.01	0.95 | 1.03
35	Boise 115	1.01 | 1.03	0.96 | 1.01	1.00 | 1.02	0.99 | 1.01	1.01 | 1.03
36	Dorsey 230	1.02 | 1.06	1.04 | 1.07	1.00 | 1.04	1.03 | 1.05	1.03 | 1.05
37	Forbes 230	1.03 | 1.05	1.05 | 1.07	1.02 | 1.04	0.98 | 1.02	1.02 | 1.04
38	Riverton 230	1.04 | 1.05	1.03 | 1.06	1.03 | 1.04	0.98 | 1.02	1.01 | 1.04
39	Coal Creek 230	1.03 | 1.06	1.01 | 1.07	1.02 | 1.06	1.00 | 1.06	1.00 | 1.06
40	Jamestown 345	0.98 | 1.02	0.96 | 1.01	0.97 | 1.00	0.98 | 1.01	0.97 | 1.01
41	Drayton 230	1.04 | 1.06	1.02 | 1.06	1.02 | 1.04	1.02 | 1.04	1.03 | 1.05
42	Groton 345	1.01 | 1.05	1.00 | 1.04	1.01 | 1.04	0.95 | 1.00	1.00 | 1.04
43	Minong 161	1.03 | 1.08	1.04 | 1.10	1.01 | 1.05	0.93 | 1.04	0.95 | 1.06
44	Wahpeton 115	1.05 | 1.07	1.03 | 1.06	1.04 | 1.06	1.01 | 1.04	1.03 | 1.06
45	Watertown 345	1.03 | 1.05	1.02 | 1.04	1.02 | 1.04	0.98 | 1.02	1.01 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 22.27%	KING 3 / 32.55%	MNTCE3 / 62.97%	KING 3 / 69.91%	SHERC3 / 77.85%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	459%	507%	478%	347%	364%
57	K22W (max +dP @ t, d-ang)	102.8@(0.15000,-2.0)	96.4@(0.15000,-1.7)	96.4@(0.15000,-1.7)	10.2@(0.11667,1.2)	24.8@(3.23331,-5.3)
58	K22W (max -dP @ t, d-ang)	0.0@(0.03333,0.0)	17.0@(0.25000,0.7)	31.3@(2.92498,7.3)	75.7@(1.33333,28.8)	42.9@(0.28333,6.4)
59	K22W (max d-ang @ t, dP)	-41.2@(10.00821,45.7)	-71.0@(10.00821,44.2)	7.5@(2.74998,-27.1)	29.9@(1.06666,-63.6)	18.2@(0.85000,-22.1)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	325% / 543%	0.18333 sec / 0.18333 sec	318% / 528%	154% / 257%	243% / 405%
63	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 793%	999% / 710%	999% / 692%	999% / 789%
64	R50M / F3M	999% / 247%	605% / 165%	804% / 263%	616% / 278%	821% / 279%
65	B10T	276%	223%	263%	148%	190%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 0) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-h23	m1a-so15aa-h33	m1a-so15aa-h43	m1a-so15aa-h53	m1a-so15aa-h63
Disturbance	h23	h33	h43	h53	h63
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping		(5T)(6T)			

Table C-3: TSR Study Case with Upgrade Option 1

	Case No.	31	32	33	34	35
2	**Case Name**	m1a-so15aa-h79	m1a-so15aa-h83	m1a-so15aa-h93	m1a-so15aa-he3	m1a-so15aa-hec
3	**Disturbance**	h79	h83	h93	he3	hec
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	JUN 12 2009 14:53	MAY 28 2009 13:57	MAY 28 2009 14:00	MAY 28 2009 13:32	JUN 11 2009 11:07
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
12	MWEX / AHD-SLK	1645 / 647	1641 / 642	1641 / 642	1641 / 642	1641 / 642
13	D602F / F601C	1545 / 1247	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249
14	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
17	G82R	-61	-61	-61	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 28	717 / 29	717 / 29	717 / 29	717 / 29
20	Forbes SVC / MSC	-55 / 600	-45 / 600	-45 / 600	-45 / 600	-45 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.046	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
31	R50M/F3M	999% / 321%	999% / 322%	999% / 322%	999% / 322%	999% / 322%
32	B10T	347%	347%	347%	347%	347%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.91 | 1.01	0.99 | 1.02	0.98 | 1.02	0.95 | 1.03	0.97 | 1.04
35	Boise 115	0.96 | 1.07	1.01 | 1.03	1.01 | 1.03	1.01 | 1.03	0.97 | 1.03
36	Dorsey 230	1.00 | 1.04	1.03 | 1.05	1.03 | 1.05	1.03 | 1.05	1.02 | 1.10
37	Forbes 230	0.93 | 1.01	1.03 | 1.05	1.03 | 1.04	1.02 | 1.04	0.97 | 1.03
38	Riverton 230	0.99 | 1.03	1.02 | 1.04	1.01 | 1.04	1.01 | 1.04	1.00 | 1.04
39	Coal Creek 230	1.00 | 1.05	1.00 | 1.08	1.00 | 1.07	1.00 | 1.06	1.00 | 1.07
40	Jamestown 345	0.92 | 0.97	0.96 | 1.01	0.96 | 1.01	0.97 | 1.01	0.92 | 0.99
41	Drayton 230	0.93 | 1.00	1.03 | 1.05	1.03 | 1.05	1.03 | 1.05	1.00 | 1.05
42	Groton 345	0.99 | 1.03	1.00 | 1.03	1.00 | 1.03	1.00 | 1.04	1.00 | 1.04
43	Minong 161	0.95 | 1.05	1.00 | 1.05	1.00 | 1.05	0.95 | 1.06	1.01 | 1.07
44	Wahpeton 115	1.01 | 1.04	1.03 | 1.06	1.03 | 1.05	1.03 | 1.06	1.02 | 1.06
45	Watertown 345	1.01 | 1.04	1.02 | 1.04	1.02 | 1.03	1.01 | 1.04	1.02 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	MNTCE3 / 59.36%	KING 3 / 76.62%	KING 3 / 78.49%	SHERC3 / 77.79%	KING 3 / 11.51%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	39%	417%	439%	360%	170%
57	K22W (max +dP @ t, d-ang)	196.0@(1.63333,6.4)	29.5@(0.11667,0.7)	24.5@(0.11667,0.7)	23.2@(3.23331,-4.5)	47.2@(0.13333,-0.6)
58	K22W (max -dP @ t, d-ang)	102.7@(1.63333,25.7)	38.6@(0.28333,5.6)	36.9@(0.28333,5.2)	43.3@(0.28333,6.5)	105.4@(0.44166,15.1)
59	K22W (max d-ang @ t, dP)	-35.6@(2.24166,196.0)	8.4@(0.60000,-1.5)	9.0@(0.65833,-5.2)	18.8@(0.85833,-23.2)	-28.7@(10.00821,-1.0)
60	**OS Rel Trip / Marg**					
61	MH - OH	1.63333 sec				
62	D602F at Forbes/Dorsey	52% / 85%	270% / 452%	265% / 442%	246% / 410%	21% / 22%
63	G82R at Rugby/L20D at Drayton	999% / 194%	999% / 786%	999% / 827%	999% / 789%	999% / 219%
64	R50M / F3M	201% / 213%	889% / 299%	899% / 297%	825% / 284%	333% / 197%
65	B10T	66%	241%	238%	189%	75%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 1)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 4 | 4) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 5 | 3) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 2 | 2) / (1 | 3 | 2)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 1 | 1) / (1 | 2 | 2)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-h79	m1a-so15aa-h83	m1a-so15aa-h93	m1a-so15aa-he3	m1a-so15aa-hec
Disturbance	h79	h83	h93	he3	hec
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(1T)				56

Table C-3: TSR Study Case with Upgrade Option 1

	Case No.	36	37	38	39	40
2	**Case Name**	m1a-so15aa-hhs	m1a-so15aa-hgs	m1a-so15aa-hjs	m1a-so15aa-hks	m1a-so15aa-hlc
3	**Disturbance**	hhs	hgs	hjs	hks	hlc
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 28 2009 13:23	MAY 28 2009 14:06	MAY 28 2009 13:26	MAY 28 2009 13:29	JUN 12 2009 16:13
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
12	MWEX / AHD-SLK	1641 / 642	1641 / 642	1641 / 642	1641 / 642	1645 / 647
13	D602F / F601C	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1247
14	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
17	G82R	-61	-61	-61	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 29	717 / 29	717 / 29	717 / 29	717 / 28
20	Forbes SVC / MSC	-45 / 600	-45 / 600	-45 / 600	-45 / 600	-55 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.046
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
31	R50M/F3M	999% / 322%	999% / 322%	999% / 322%	999% / 322%	999% / 321%
32	B10T	347%	347%	347%	347%	347%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.01	0.97 | 1.03	0.96 | 1.03	0.99 | 1.01	0.90 | 1.00
35	Boise 115	1.01 | 1.03	1.01 | 1.04	1.01 | 1.04	1.01 | 1.04	0.95 | 1.08
36	Dorsey 230	1.04 | 1.06	1.03 | 1.09	1.03 | 1.10	1.02 | 1.11	0.98 | 1.06
37	Forbes 230	1.03 | 1.05	1.02 | 1.06	1.02 | 1.06	1.03 | 1.06	0.91 | 1.00
38	Riverton 230	1.03 | 1.05	1.02 | 1.04	1.02 | 1.04	1.03 | 1.05	0.99 | 1.03
39	Coal Creek 230	1.00 | 1.07	1.01 | 1.07	1.01 | 1.07	1.00 | 1.07	1.00 | 1.05
40	Jamestown 345	0.98 | 1.03	0.98 | 1.01	0.98 | 1.02	0.98 | 1.02	0.92 | 0.97
41	Drayton 230	1.04 | 1.11	1.04 | 1.09	1.03 | 1.09	1.03 | 1.12	0.93 | 1.00
42	Groton 345	1.01 | 1.03	1.01 | 1.04	1.00 | 1.04	1.01 | 1.03	0.99 | 1.02
43	Minong 161	1.01 | 1.03	0.97 | 1.06	0.96 | 1.06	1.01 | 1.03	0.95 | 1.04
44	Wahpeton 115	1.03 | 1.07	1.05 | 1.06	1.04 | 1.06	1.03 | 1.07	1.01 | 1.04
45	Watertown 345	1.02 | 1.03	1.02 | 1.04	1.01 | 1.04	1.02 | 1.03	1.01 | 1.03
46	**Dynamic Voltage Warnings**					
47			none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 78.09%	SHERC3 / 79.83%	SHERC3 / 77.10%	SHERC3 / 81.95%	SHERC3 / 60.24%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.150	/ 0.141	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	461%	365%	357%	456%	55%
57	K22W (max +dP @ t, d-ang)	8.0@(0.11667,0.2)	20.4@(3.26664,-4.7)	17.9@(3.30831,-3.5)	8.0@(0.11667,0.2)	196.0@(1.21666,3.8)
58	K22W (max -dP @ t, d-ang)	13.3@(0.23333,1.3)	42.6@(0.39166,6.8)	49.1@(0.39166,7.7)	32.5@(0.38333,4.1)	116.5@(1.21666,23.9)
59	K22W (max d-ang @ t, dP)	4.1@(0.84166,-6.4)	15.4@(0.85000,-15.0)	17.6@(0.90000,-20.6)	5.0@(0.65833,-2.6)	-38.7@(1.79166,196.0)
60	**OS Rel Trip / Marg**					
61	MH - OH					1.21666 sec
62	D602F at Forbes/Dorsey	291% / 487%	246% / 410%	240% / 401%	257% / 428%	21% / 23%
63	G82R at Rugby/L20D at Drayton	999% / 632%	999% / 808%	999% / 785%	999% / 740%	999% / 175%
64	R50M / F3M	999% / 302%	836% / 278%	821% / 281%	911% / 306%	180% / 204%
65	B10T	265%	193%	180%	244%	47%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 1)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 5 | 1) / (0 | 1 | 1)	(1 | 2 | 1) / (0 | 1 | 1)	(1 | 2 | 1) / (0 | 1 | 1)	(1 | 4 | 1) / (0 | 1 | 1)	(1 |11 | 5) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 2 | 2) / (1 | 4 | 2)
71	Shey 115 / Split Rock 115	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 2) / (1 | 2 | 2)	(1 | 3 | 2) / (1 | 2 | 2)	(1 | 3 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-hhs	m1a-so15aa-hgs	m1a-so15aa-hjs	m1a-so15aa-hks	m1a-so15aa-hlc
Disturbance	hhs	hgs	hjs	hks	hlc
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					(1T)56

Table C-3: TSR Study Case with Upgrade Option 1

1	**Case No.**	41	42
2	**Case Name**	m1a-so15aa-hm9	m1a-so15aa-hoc
3	**Disturbance**	hm9	hoc
4	**Prior Outage**	None	None
5	**Date/Time**	JUN 12 2009 14:56	JUN 12 2009 15:02
6	**Comments**		
7			
8	**Steady State Flows**		
9	NDEX / EAST BIAS	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27
12	MWEX / AHD-SLK	1645 / 647	1645 / 647
13	D602F / F601C	1545 / 1247	1545 / 1247
14	B10T / MH>SPC	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151
17	G82R	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 28	717 / 28
20	Forbes SVC / MSC	-55 / 600	-55 / 600
21	RCDC	0	0
22	**Steady State Vltgs**		
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.046	1.022 / 1.046
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**		
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%
31	R50M/F3M	999% / 321%	999% / 321%
32	B10T	347%	347%
33	**Min/MaxTransientVltg**		
34	Arrowhd 230	0.91 | 1.05	0.86 | 1.03
35	Boise 115	0.96 | 1.09	0.96 | 1.08
36	Dorsey 230	1.01 | 1.06	1.01 | 1.14
37	Forbes 230	0.90 | 1.03	0.89 | 1.04
38	Riverton 230	0.98 | 1.05	0.97 | 1.04
39	Coal Creek 230	0.98 | 1.07	0.99 | 1.06
40	Jamestown 345	0.89 | 0.99	0.94 | 0.98
41	Drayton 230	0.91 | 1.04	0.94 | 1.08
42	Groton 345	0.98 | 1.04	0.96 | 1.02
43	Minong 161	0.94 | 1.09	0.92 | 1.08
44	Wahpeton 115	1.00 | 1.06	1.00 | 1.05
45	Watertown 345	1.01 | 1.04	0.99 | 1.03
46	**Dynamic Voltage Warnings**		
47		none	none
48			
49			
50			
51			
52			
53			
54	Worst Case Angle Damping	KING 3 / 38.95%	KING 3 / 53.41%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	-37%	-33%
57	K22W (max +dP @ t, d-ang)	196.0@(1.20000,12.9)	196.0@(1.46666,14.9)
58	K22W (max -dP @ t, d-ang)	113.8@(1.16666,33.4)	115.3@(1.46666,35.0)
59	K22W (max d-ang @ t, dP)	-59.3@(10.00821,196.0)	-53.9@(9.24989,196.0)
60	**OS Rel Trip / Marg**		
61	MH - OH	1.20000 sec	1.46666 sec
62	D602F at Forbes/Dorsey	44% / 72%	52% / 87%
63	G82R at Rugby/L20D at Drayton	999% / 170%	999% / 242%
64	R50M / F3M	331% / 238%	313% / 237%
65	B10T	35%	78%
66	**FSCAPS (SS/Unav/Final)**		
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 5 | 3) / (0 | 2 | 2)	(1 | 4 | 3) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 1 | 1) / (1 | 4 | 1)	(0 | 2 | 1) / (1 | 3 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A

Case	m1a-so15aa-hm9	m1a-so15aa-hoc
Disturbance	hm9	hoc
System Response	OK	OK
70% or 120% Violations		
ORWG Criteria Violations		
Line Tripping	2(1T)5	2(1T)

Table C-4: TSR Study Case with Upgrade Option 3

	Case No.	1	2	3	4	5
	Case Name	m3a-so15aa-ag1	m3a-so15aa-ag3	m3a-so15aa-cts	m3a-so15aa-ei2	m3a-so15aa-em3
	Disturbance	ag1	ag3	cts	ei2	em3
	Prior Outage	None	None	None	None	None
	Date/Time	MAY 28 2009 16:12	MAY 28 2009 16:15	JUN 03 2009 17:52	MAY 28 2009 16:22	MAY 28 2009 16:25
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2300 / 156	2300 / 156	2300 / 156	2300 / 156	2300 / 156
	MHEX / L20D	1949 / 268	1949 / 268	1949 / 268	1949 / 268	1949 / 268
	ECL-ARP / PRI-BYN	842 / 35	842 / 35	842 / 35	842 / 35	842 / 35
	MWEX / AHD-SLK	1722 / 643	1722 / 643	1722 / 643	1722 / 643	1722 / 643
	D602F / F601C	1582 / 1218	1582 / 1218	1582 / 1218	1582 / 1218	1582 / 1218
	B10T / MH>SPC	161 / 57	161 / 57	161 / 57	161 / 57	161 / 57
	OH E-W / OH>MH	190 / -194	190 / -194	190 / -194	190 / -194	190 / -194
	R50M / OH>MP	134 / 149	134 / 149	134 / 149	134 / 149	134 / 149
	G82R	-36	-36	-36	-36	-36
	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
	Dorsey Reserve / Wtrtn SVC	850 / 9	850 / 9	850 / 9	850 / 9	850 / 9
	Forbes SVC / MSC	-21 / 600	-21 / 600	-21 / 600	-21 / 600	-21 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045
	Roseau 500/Forbes 500	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035
	Chisago 500/EauClaire 345	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974
	Int Falls 115/Badoura 115	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044
	Drayton 230/Groton 345	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	312% / 521%	312% / 521%	312% / 521%	312% / 521%	312% / 521%
	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 764%	999% / 764%	999% / 764%	999% / 764%
	R50M/F3M	999% / 324%	999% / 324%	999% / 324%	999% / 324%	999% / 324%
	B10T	354%	354%	354%	354%	354%
	Min/MaxTransientVltg					
	Arrowhd 230	0.98 | 1.01	0.97 | 1.01	0.92 | 1.08	0.98 | 1.04	1.00 | 1.01
	Boise 115	1.01 | 1.03	1.01 | 1.03	0.98 | 1.02	0.99 | 1.02	1.01 | 1.02
	Dorsey 230	1.03 | 1.05	1.03 | 1.05	1.04 | 1.12	1.03 | 1.05	1.03 | 1.05
	Forbes 230	1.02 | 1.04	1.02 | 1.04	0.95 | 1.05	1.01 | 1.04	1.03 | 1.04
	Riverton 230	1.01 | 1.04	1.01 | 1.04	0.93 | 1.07	0.98 | 1.05	1.04 | 1.04
	Coal Creek 230	0.97 | 1.11	0.97 | 1.11	0.89 | 1.08	1.02 | 1.10	1.03 | 1.05
	Jamestown 345	0.91 | 1.02	0.91 | 1.02	0.75 | 1.04	0.84 | 1.03	0.98 | 0.99
	Drayton 230	1.01 | 1.05	1.01 | 1.05	0.97 | 1.09	0.99 | 1.07	1.03 | 1.04
	Groton 345	0.92 | 1.04	0.92 | 1.04	0.85 | 1.07	0.93 | 1.06	1.02 | 1.03
	Minong 161	0.99 | 1.03	0.99 | 1.03	0.97 | 1.11	1.02 | 1.07	1.02 | 1.04
	Wahpeton 115	1.00 | 1.07	1.00 | 1.06	0.90 | 1.08	0.96 | 1.08	1.05 | 1.05
	Watertown 345	0.98 | 1.04	0.99 | 1.04	0.91 | 1.06	0.98 | 1.05	1.03 | 1.03
	Dynamic Voltage Warnings					
		none	none	63061 [MIDCOMP] 1.25	63061 [MIDCOMP] 1.21	none
	Worst Case Angle Damping	KING 3 / 76.34%	KING 3 / 77.38%	KING 3 / 38.08%	SHERC3 / 32.02%	KING 3 / 31.51%
	Dorsey SUVP / UdHold			/ 0.141		/ 0.133
	Forbes DC Red (DCAR)	463%	461%	507%	507%	497%
	K22W (max +dP @ t, d-ang)	10.6@(2.37499,2.3)	13.3@(2.34166,1.3)	106.7@(2.41666,-48.5)	71.0@(2.43332,-31.0)	32.0@(0.13333,-0.3)
	K22W (max -dP @ t, d-ang)	20.7@(1.78333,0.9)	19.6@(0.74166,5.7)	49.8@(0.41666,7.5)	0.0@(0.02500,0.0)	24.0@(0.26667,2.1)
	K22W (max d-ang @ t, dP)	7.3@(1.05000,-6.6)	8.0@(0.99166,-8.2)	-66.8@(10.00821,52.2)	-50.5@(10.00821,39.8)	-13.3@(10.00821,11.5)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	265% / 443%	262% / 438%	0.36667 sec / 0.36667 sec	246% / 412%	275% / 462%
	G82R at Rugby/L20D at Drayton	999% / 663%	999% / 654%	999% / 497%	999% / 590%	999% / 0.18333 sec
	R50M / F3M	902% / 284%	892% / 281%	616% / 179%	915% / 220%	891% / 288%
	B10T	217%	214%	66%	126%	265%
	FSCAPS (SS/Unav/Final)					
	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 2 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 6 | 1) / (0 | 2 | 2)	(1 | 3 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 5 | 0) / (1 | 2 | 2)	(1 | 3 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	m3a-so15aa-ag1	m3a-so15aa-ag3	m3a-so15aa-cts	m3a-so15aa-ei2	m3a-so15aa-em3
Disturbance	ag1	ag3	cts	ei2	em3
System Response	OK	OK	OK	OK	OK
70% or 120% Violations			M	M	
ORWG Criteria Violations					
Line Tripping			(5T)(6T)		(3T)

Table C-4: TSR Study Case with Upgrade Option 3

1	**Case No.**	6	7	8	9	10
2	**Case Name**	m3a-so15aa-eq1	m3a-so15aa-fds	m3a-so15aa-mc3	m3a-so15aa-md3	m3a-so15aa-mis
3	**Disturbance**	eq1	fds	mc3	md3	mis
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 28 2009 16:28	MAY 28 2009 16:31	MAY 28 2009 16:34	MAY 28 2009 16:37	MAY 28 2009 16:40
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2300 / 156	2300 / 156	2300 / 156	2300 / 156	2300 / 156
10	MHEX / L20D	1949 / 268	1949 / 268	1949 / 268	1949 / 268	1949 / 268
11	ECL-ARP / PRI-BYN	842 / 35	842 / 35	842 / 35	842 / 35	842 / 35
12	MWEX / AHD-SLK	1722 / 643	1722 / 643	1722 / 643	1722 / 643	1722 / 643
13	D602F / F601C	1582 / 1218	1582 / 1218	1582 / 1218	1582 / 1218	1582 / 1218
14	B10T / MH>SPC	161 / 57	161 / 57	161 / 57	161 / 57	161 / 57
15	OH E-W / OH>MH	190 / -194	190 / -194	190 / -194	190 / -194	190 / -194
16	R50M / OH>MP	134 / 149	134 / 149	134 / 149	134 / 149	134 / 149
17	G82R	-36	-36	-36	-36	-36
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	850 / 9	850 / 9	850 / 9	850 / 9	850 / 9
20	Forbes SVC / MSC	-21 / 600	-21 / 600	-21 / 600	-21 / 600	-21 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045
24	Roseau 500/Forbes 500	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974
26	Int Falls 115/Badoura 115	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044
27	Drayton 230/Groton 345	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	312% / 521%	312% / 521%	312% / 521%	312% / 521%	312% / 521%
30	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 764%	999% / 764%	999% / 764%	999% / 764%
31	R50M/F3M	999% / 324%	999% / 324%	999% / 324%	999% / 324%	999% / 324%
32	B10T	354%	354%	354%	354%	354%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.98 | 1.03	0.96 | 1.01	1.00 | 1.01	1.00 | 1.00	1.00 | 1.01
35	Boise 115	1.00 | 1.02	1.01 | 1.03	1.00 | 1.02	1.02 | 1.02	1.04 | 1.06
36	Dorsey 230	1.04 | 1.05	1.03 | 1.06	1.03 | 1.05	1.03 | 1.05	1.04 | 1.05
37	Forbes 230	1.02 | 1.04	1.02 | 1.04	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04
38	Riverton 230	1.00 | 1.06	1.00 | 1.05	1.03 | 1.04	1.03 | 1.03	1.03 | 1.04
39	Coal Creek 230	0.99 | 1.16	0.97 | 1.12	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04
40	Jamestown 345	0.86 | 1.05	0.82 | 1.05	0.98 | 0.99	0.98 | 0.99	0.98 | 0.99
41	Drayton 230	1.02 | 1.08	1.01 | 1.05	1.02 | 1.04	1.03 | 1.04	1.03 | 1.04
42	Groton 345	0.95 | 1.06	0.96 | 1.06	1.02 | 1.02	1.02 | 1.02	1.02 | 1.02
43	Minong 161	1.02 | 1.06	0.99 | 1.03	1.02 | 1.03	1.02 | 1.02	1.02 | 1.03
44	Wahpeton 115	0.99 | 1.08	0.98 | 1.08	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05
45	Watertown 345	0.99 | 1.05	0.99 | 1.05	1.03 | 1.03	1.03 | 1.03	1.03 | 1.03
46	**Dynamic Voltage Warnings**					
47		63061 [MIDCOMP] 1.21	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 31.04%	MNTCE3 / 77.69%	KING 3 / 27.80%	ANTEL3 / 80.81%	KING 3 / 18.28%
55	Dorsey SUVP / UdHold			/ 0.133	/ 0.133	
56	Forbes DC Red (DCAR)	484%	450%	491%	497%	483%
57	K22W (max +dP @ t, d-ang)	50.5@(2.31666,-20.0)	10.7@(2.39999,-0.5)	28.9@(0.12500,0.4)	21.3@(0.12500,-0.4)	194.9@(0.35000,-11.8)
58	K22W (max -dP @ t, d-ang)	0.8@(0.29167,-0.1)	13.4@(0.77500,3.1)	22.3@(0.98333,-4.4)	11.7@(0.24167,0.7)	0.0@(0.35000,0.0)
59	K22W (max d-ang @ t, dP)	-29.9@(10.00821,22.8)	5.0@(1.02500,-4.2)	-8.8@(10.00821,-12.5)	-0.7@(3.49164,2.1)	-43.2@(0.96666,194.9)
60	**OS Rel Trip / Marg**					
61	MH - OH					0.35000 sec
62	D602F at Forbes/Dorsey	269% / 450%	276% / 462%	291% / 488%	309% / 514%	300% / 501%
63	G82R at Rugby/L20D at Drayton	54% / 607%	999% / 659%	999% / 707%	999% / 764%	999% / 729%
64	R50M / F3M	956% / 249%	913% / 289%	999% / 211%	999% / 319%	644% / 324%
65	B10T	140%	106%	336%	337%	347%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 1 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 3 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 3 | 1) / (1 | 1 | 1)	(1 | 2 | 0) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m3a-so15aa-eq1	m3a-so15aa-fds	m3a-so15aa-mc3	m3a-so15aa-md3	m3a-so15aa-mis
Disturbance	eq1	fds	mc3	md3	mis
System Response	OK	OK	OK	OK	OK
70% or 120% Violations	M				
ORWG Criteria Violations					
Line Tripping					(1T)

Table C-4: TSR Study Case with Upgrade Option 3

	Case No.	11	12	13	14	15
2	**Case Name**	m3a-so15aa-mjs	m3a-so15aa-mkd	m3a-so15aa-mks	m3a-so15aa-nad	m3a-so15aa-nmz
3	**Disturbance**	mjs	mkd	mks	nad	nmz
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 28 2009 16:43	MAY 28 2009 16:45	MAY 28 2009 16:48	MAY 28 2009 16:51	JUN 03 2009 17:55
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2300 / 156	2300 / 156	2300 / 156	2300 / 156	2300 / 156
10	MHEX / L20D	1949 / 268	1949 / 268	1949 / 268	1949 / 268	1949 / 268
11	ECL-ARP / PRI-BYN	842 / 35	842 / 35	842 / 35	842 / 35	842 / 35
12	MWEX / AHD-SLK	1722 / 643	1722 / 643	1722 / 643	1722 / 643	1722 / 643
13	D602F / F601C	1582 / 1218	1582 / 1218	1582 / 1218	1582 / 1218	1582 / 1218
14	B10T / MH>SPC	161 / 57	161 / 57	161 / 57	161 / 57	161 / 57
15	OH E-W / OH>MH	190 / -194	190 / -194	190 / -194	190 / -194	190 / -194
16	R50M / OH>MP	134 / 149	134 / 149	134 / 149	134 / 149	134 / 149
17	G82R	-36	-36	-36	-36	-36
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	850 / 9	850 / 9	850 / 9	850 / 9	850 / 9
20	Forbes SVC / MSC	-21 / 600	-21 / 600	-21 / 600	-21 / 600	-21 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045
24	Roseau 500/Forbes 500	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974
26	Int Falls 115/Badoura 115	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044
27	Drayton 230/Groton 345	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	312% / 521%	312% / 521%	312% / 521%	312% / 521%	312% / 521%
30	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 764%	999% / 764%	999% / 764%	999% / 764%
31	R50M/F3M	999% / 324%	999% / 324%	999% / 324%	999% / 324%	999% / 324%
32	B10T	354%	354%	354%	354%	354%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.97 | 1.00	0.92 | 1.01	0.96 | 1.02	0.99 | 1.06	0.95 | 1.06
35	Boise 115	1.02 | 1.03	1.02 | 1.03	1.01 | 1.03	0.97 | 1.01	0.97 | 1.02
36	Dorsey 230	1.03 | 1.06	1.03 | 1.05	1.03 | 1.07	1.04 | 1.07	1.04 | 1.08
37	Forbes 230	1.03 | 1.05	1.03 | 1.04	1.03 | 1.05	1.02 | 1.04	1.01 | 1.04
38	Riverton 230	1.01 | 1.04	0.99 | 1.04	1.00 | 1.04	1.00 | 1.05	0.97 | 1.06
39	Coal Creek 230	0.98 | 1.07	0.97 | 1.07	0.97 | 1.08	1.00 | 1.06	0.97 | 1.07
40	Jamestown 345	0.92 | 1.00	0.91 | 1.00	0.91 | 1.01	0.94 | 0.99	0.87 | 1.01
41	Drayton 230	1.01 | 1.04	1.01 | 1.04	1.02 | 1.05	1.00 | 1.05	0.99 | 1.07
42	Groton 345	0.98 | 1.03	0.98 | 1.03	0.97 | 1.03	1.00 | 1.04	0.95 | 1.05
43	Minong 161	0.99 | 1.02	0.94 | 1.04	0.98 | 1.04	1.02 | 1.08	0.99 | 1.10
44	Wahpeton 115	1.01 | 1.05	1.00 | 1.05	1.00 | 1.06	1.01 | 1.05	0.97 | 1.07
45	Watertown 345	1.01 | 1.03	1.00 | 1.03	1.00 | 1.03	1.01 | 1.04	0.98 | 1.05
46	**Dynamic Voltage Warnings**					
47		none	none	none	63061 [MIDCOMP] 1.22	63061 [MIDCOMP] 1.23
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	SHERC3 / 75.25%	KING 3 / 79.27%	KING 3 / 77.71%	KING 3 / 40.44%	KING 3 / 37.49%
55	Dorsey SUVP / UdHold		/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	447%	320%	396%	507%	507%
57	K22W (max +dP @ t, d-ang)	4.1@(0.11667,0.3)	13.2@(0.10833,1.6)	10.1@(3.34164,-0.9)	94.3@(2.01666,-41.9)	98.5@(2.12499,-44.3)
58	K22W (max -dP @ t, d-ang)	21.7@(0.35000,3.3)	32.3@(0.24167,4.7)	32.0@(0.36667,5.7)	66.3@(0.25833,7.6)	51.8@(0.23333,5.3)
59	K22W (max d-ang @ t, dP)	6.6@(1.06666,-17.6)	13.4@(0.89166,-21.6)	9.7@(0.81666,-9.9)	-69.7@(10.00821,49.2)	-68.7@(10.00821,54.4)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	291% / 504%	311% / 517%	268% / 478%	0.16667 sec / 0.16667 sec	0.18333 sec / 0.18333 sec
63	G82R at Rugby/L20D at Drayton	999% / 673%	999% / 623%	999% / 660%	999% / 481%	999% / 599%
64	R50M / F3M	924% / 324%	889% / 324%	893% / 311%	517% / 167%	659% / 193%
65	B10T	247%	201%	214%	192%	137%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 1)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 3 | 1) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 3 | 1) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m3a-so15aa-mjs	m3a-so15aa-mkd	m3a-so15aa-mks	m3a-so15aa-nad	m3a-so15aa-nmz
Disturbance	mjs	mkd	mks	nad	nmz
System Response	OK	OK	OK	OK	OK
70% or 120% Violations				M	M
ORWG Criteria Violations					
Line Tripping				(5T)(6T)	(5T)(6T)

Table C-4: TSR Study Case with Upgrade Option 3

1	**Case No.**	16	17	18	19	20
2	**Case Name**	m3a-so15aa-pas	m3a-so15aa-pc0	m3a-so15aa-pcs	m3a-so15aa-pct	m3a-so15aa-pzs
3	**Disturbance**	pas	pc0	pcs	pct	pzs
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 28 2009 16:58	MAY 28 2009 17:01	MAY 28 2009 17:04	MAY 28 2009 17:08	MAY 28 2009 14:09
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2300 / 156	2300 / 156	2300 / 156	2300 / 156	2300 / 156
10	MHEX / L20D	1949 / 268	1949 / 268	1949 / 268	1949 / 268	1949 / 268
11	ECL-ARP / PRI-BYN	842 / 35	842 / 35	842 / 35	842 / 35	842 / 35
12	MWEX / AHD-SLK	1722 / 643	1722 / 643	1722 / 643	1722 / 643	1722 / 643
13	D602F / F601C	1582 / 1218	1582 / 1218	1582 / 1218	1582 / 1218	1582 / 1218
14	B10T / MH>SPC	161 / 57	161 / 57	161 / 57	161 / 57	161 / 57
15	OH E-W / OH>MH	190 / -194	190 / -194	190 / -194	190 / -194	190 / -194
16	R50M / OH>MP	134 / 149	134 / 149	134 / 149	134 / 149	134 / 149
17	G82R	-36	-36	-36	-36	-36
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	850 / 9	850 / 9	850 / 9	850 / 9	850 / 9
20	Forbes SVC / MSC	-21 / 600	-21 / 600	-21 / 600	-21 / 600	-21 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045
24	Roseau 500/Forbes 500	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974
26	Int Falls 115/Badoura 115	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044
27	Drayton 230/Groton 345	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	312% / 521%	312% / 521%	312% / 521%	312% / 521%	312% / 521%
30	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 764%	999% / 764%	999% / 764%	999% / 764%
31	R50M/F3M	999% / 324%	999% / 324%	999% / 324%	999% / 324%	999% / 324%
32	B10T	354%	354%	354%	354%	354%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.06	0.84 | 0.99	0.84 | 0.97	0.89 | 0.95	0.97 | 1.02
35	Boise 115	0.99 | 1.02	1.01 | 1.04	1.01 | 1.04	1.02 | 1.03	1.01 | 1.04
36	Dorsey 230	1.04 | 1.07	1.03 | 1.09	1.04 | 1.10	1.04 | 1.05	1.03 | 1.08
37	Forbes 230	0.99 | 1.05	1.01 | 1.03	1.01 | 1.04	1.01 | 1.03	1.03 | 1.07
38	Riverton 230	1.01 | 1.05	1.00 | 1.05	1.01 | 1.04	1.02 | 1.04	1.02 | 1.05
39	Coal Creek 230	0.99 | 1.06	0.96 | 1.07	0.97 | 1.08	1.02 | 1.04	0.98 | 1.07
40	Jamestown 345	0.94 | 0.99	0.93 | 1.01	0.93 | 1.01	0.98 | 1.00	0.94 | 1.01
41	Drayton 230	1.00 | 1.05	1.03 | 1.07	1.02 | 1.07	1.03 | 1.04	1.02 | 1.05
42	Groton 345	1.00 | 1.04	0.98 | 1.03	0.99 | 1.03	1.01 | 1.03	0.99 | 1.04
43	Minong 161	1.03 | 1.10	(0.62)0.80 | 1.00	(0.62)0.80 | 0.98	0.87 | 0.95	0.97 | 1.05
44	Wahpeton 115	1.01 | 1.05	1.02 | 1.06	1.02 | 1.06	1.04 | 1.05	1.03 | 1.06
45	Watertown 345	1.01 | 1.04	1.00 | 1.04	1.01 | 1.04	1.02 | 1.03	1.01 | 1.04
46	**Dynamic Voltage Warnings**					
47		63061 [MIDCOMP] 1.22	61631 [MINONG 5] 0.80	61631 [MINONG 5] 0.80	none	none
48			63061 [MIDCOMP] 1.21	63061 [MIDCOMP] 1.23		
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 40.22%	SHERC3 / 64.73%	KING 3 / 52.48%	SHERC3 / 39.91%	SHERC3 / 75.47%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133		
56	Forbes DC Red (DCAR)	464%	226%	204%	275%	337%
57	K22W (max +dP @ t, d-ang)	94.8@(2.02500,-42.7)	17.0@(3.43331,-0.5)	5.0@(3.47497,4.3)	0.0@(0.10000,0.0)	21.0@(3.30831,-4.5)
58	K22W (max -dP @ t, d-ang)	45.7@(0.25833,4.1)	58.7@(0.38333,9.6)	64.0@(1.70000,24.7)	52.9@(2.24999,22.8)	33.2@(0.38333,5.2)
59	K22W (max d-ang @ t, dP)	-69.5@(10.00821,53.4)	28.0@(1.11666,-55.0)	28.3@(1.16666,-58.4)	22.9@(2.37499,-52.7)	15.8@(0.92500,-17.4)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.38333 sec / 0.18333 sec	247% / 411%	259% / 433%	295% / 494%	255% / 425%
63	G82R at Rugby/L20D at Drayton	999% / 539%	999% / 585%	999% / 603%	999% / 675%	999% / 636%
64	R50M / F3M	585% / 190%	746% / 299%	767% / 315%	878% / 324%	818% / 292%
65	B10T	214%	171%	189%	287%	117%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 3 | 3)	(4 | 4 | 4) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 3 | 3)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 2 | 1) / (0 | 1 | 1)	(1 | 2 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 2 | 2)	(1 | 2 | 2) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m3a-so15aa-pas	m3a-so15aa-pc0	m3a-so15aa-pcs	m3a-so15aa-pct	m3a-so15aa-pzs
Disturbance	pas	pc0	pcs	pct	pzs
System Response	OK	OK	OK	OK	OK
70% or 120% Violations	M	MM	MM		
ORWG Criteria Violations		7	7		
Line Tripping	(5T)(6T)				

Table C-4: TSR Study Case with Upgrade Option 3

	Case No.	21	22	23	24	25
2	**Case Name**	m3a-so15aa-pzt	m3a-so15aa-ya3	m3a-so15aa-yas	m3a-so15aa-yb3	m3a-so15aa-h13
3	**Disturbance**	pzt	ya3	yas	yb3	h13
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 28 2009 14:13	MAY 28 2009 14:15	MAY 28 2009 14:18	MAY 28 2009 14:21	MAY 28 2009 14:24
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2300 / 156	2300 / 156	2300 / 156	2300 / 156	2300 / 156
10	MHEX / L20D	1949 / 268	1949 / 268	1949 / 268	1949 / 268	1949 / 268
11	ECL-ARP / PRI-BYN	842 / 35	842 / 35	842 / 35	842 / 35	842 / 35
12	MWEX / AHD-SLK	1722 / 643	1722 / 643	1722 / 643	1722 / 643	1722 / 643
13	D602F / F601C	1582 / 1218	1582 / 1218	1582 / 1218	1582 / 1218	1582 / 1218
14	B10T / MH>SPC	161 / 57	161 / 57	161 / 57	161 / 57	161 / 57
15	OH E-W / OH>MH	190 / -194	190 / -194	190 / -194	190 / -194	190 / -194
16	R50M / OH>MP	134 / 149	134 / 149	134 / 149	134 / 149	134 / 149
17	G82R	-36	-36	-36	-36	-36
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	850 / 9	850 / 9	850 / 9	850 / 9	850 / 9
20	Forbes SVC / MSC	-21 / 600	-21 / 600	-21 / 600	-21 / 600	-21 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045
24	Roseau 500/Forbes 500	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974
26	Int Falls 115/Badoura 115	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044
27	Drayton 230/Groton 345	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	312% / 521%	312% / 521%	312% / 521%	312% / 521%	312% / 521%
30	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 764%	999% / 764%	999% / 764%	999% / 764%
31	R50M/F3M	999% / 324%	999% / 324%	999% / 324%	999% / 324%	999% / 324%
32	B10T	354%	354%	354%	354%	354%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.00	1.01 | 1.02	0.96 | 0.98	1.02 | 1.03	0.99 | 1.02
35	Boise 115	1.02 | 1.02	1.03 | 1.04	1.02 | 1.04	1.02 | 1.04	1.00 | 1.02
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.07	1.04 | 1.05	0.99 | 1.06
37	Forbes 230	1.03 | 1.03	1.03 | 1.04	1.02 | 1.05	1.03 | 1.04	1.02 | 1.04
38	Riverton 230	1.03 | 1.03	1.02 | 1.03	1.01 | 1.03	1.03 | 1.03	1.03 | 1.04
39	Coal Creek 230	1.03 | 1.04	1.02 | 1.04	1.00 | 1.05	1.02 | 1.04	1.02 | 1.06
40	Jamestown 345	0.99 | 0.99	0.98 | 1.00	0.97 | 1.00	0.98 | 1.00	0.96 | 1.00
41	Drayton 230	1.03 | 1.04	1.03 | 1.04	1.03 | 1.05	1.03 | 1.04	1.01 | 1.04
42	Groton 345	1.02 | 1.02	1.01 | 1.02	1.01 | 1.02	1.01 | 1.02	1.01 | 1.04
43	Minong 161	1.01 | 1.02	0.97 | 1.00	0.96 | 1.02	0.98 | 1.01	1.01 | 1.04
44	Wahpeton 115	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.03 | 1.05
45	Watertown 345	1.03 | 1.03	1.02 | 1.03	1.02 | 1.03	1.02 | 1.03	1.02 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	SHERC3 / 38.47%	SHERC3 / 26.10%	SHERC3 / 34.90%	KING 3 / 36.29%	SHERC3 / 60.40%
55	Dorsey SUVP / UdHold					/ 0.133
56	Forbes DC Red (DCAR)	466%	330%	399%	384%	462%
57	K22W (max +dP @ t, d-ang)	0.0@(0.10000,0.0)	4.8@(0.11667,0.7)	3.0@(0.11667,0.4)	3.1@(0.11667,0.6)	102.7@(0.15000,-2.1)
58	K22W (max -dP @ t, d-ang)	9.1@(2.05000,3.8)	36.7@(1.69166,17.1)	29.3@(1.64166,12.5)	24.8@(1.60833,11.0)	23.6@(2.96665,5.2)
59	K22W (max d-ang @ t, dP)	3.8@(2.23333,-8.7)	18.0@(2.04166,-33.8)	12.9@(1.91666,-24.8)	11.5@(1.93333,-22.0)	-9.2@(0.64166,3.3)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	309% / 517%	312% / 521%	311% / 519%	312% / 521%	294% / 490%
63	G82R at Rugby/L20D at Drayton	999% / 743%	999% / 682%	999% / 697%	999% / 706%	999% / 679%
64	R50M / F3M	999% / 324%	999% / 324%	999% / 324%	999% / 324%	924% / 261%
65	B10T	193%	277%	284%	295%	294%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m3a-so15aa-pzt	m3a-so15aa-ya3	m3a-so15aa-yas	m3a-so15aa-yb3	m3a-so15aa-h13
Disturbance	pzt	ya3	yas	yb3	h13
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					

Table C-4: TSR Study Case with Upgrade Option 3

	Case No.	26	27	28	29	30
2	**Case Name**	m3a-so15aa-h23	m3a-so15aa-h33	m3a-so15aa-h43	m3a-so15aa-hc9	m3a-so15aa-hd9
3	**Disturbance**	h23	h33	h43	hc9	hd9
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAY 28 2009 14:27	MAY 28 2009 14:31	MAY 28 2009 14:34	JUN 15 2009 9:15	JUN 15 2009 9:18
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2300 / 156	2300 / 156	2300 / 156	2300 / 156	2300 / 156
10	MHEX / L20D	1949 / 268	1949 / 268	1949 / 268	1949 / 268	1949 / 268
11	ECL-ARP / PRI-BYN	842 / 35	842 / 35	842 / 35	839 / 35	839 / 35
12	MWEX / AHD-SLK	1722 / 643	1722 / 643	1722 / 643	1724 / 647	1724 / 647
13	D602F / F601C	1582 / 1218	1582 / 1218	1582 / 1218	1583 / 1216	1583 / 1216
14	B10T / MH>SPC	161 / 57	161 / 57	161 / 57	161 / 57	161 / 57
15	OH E-W / OH>MH	190 / -194	190 / -194	190 / -194	190 / -194	190 / -194
16	R50M / OH>MP	134 / 149	134 / 149	134 / 149	134 / 149	134 / 149
17	G82R	-36	-36	-36	-36	-36
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	850 / 9	850 / 9	850 / 9	850 / 9	850 / 9
20	Forbes SVC / MSC	-21 / 600	-21 / 600	-21 / 600	-28 / 600	-28 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045
24	Roseau 500/Forbes 500	1.043 / 1.035	1.043 / 1.035	1.043 / 1.035	1.042 / 1.035	1.042 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.974	1.031 / 0.974	1.031 / 0.974	1.031 / 0.972	1.031 / 0.972
26	Int Falls 115/Badoura 115	1.021 / 1.044	1.021 / 1.044	1.021 / 1.044	1.021 / 1.043	1.021 / 1.043
27	Drayton 230/Groton 345	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	312% / 521%	312% / 521%	312% / 521%	312% / 521%	312% / 521%
30	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 764%	999% / 764%	999% / 764%	999% / 764%
31	R50M/F3M	999% / 324%	999% / 324%	999% / 324%	999% / 323%	999% / 323%
32	B10T	354%	354%	354%	354%	354%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.02 | 1.05	1.03 | 1.08	0.99 | 1.02	0.83 | 1.04	(0.77)0.77 | 1.07
35	Boise 115	1.01 | 1.03	0.96 | 1.00	1.00 | 1.02	0.96 | 1.08	0.96 | 1.11
36	Dorsey 230	1.02 | 1.07	1.04 | 1.07	0.99 | 1.04	1.00 | 1.07	1.01 | 1.06
37	Forbes 230	1.03 | 1.05	1.05 | 1.08	1.02 | 1.04	0.87 | 1.03	0.84 | 1.04
38	Riverton 230	1.03 | 1.05	1.03 | 1.06	1.02 | 1.04	0.95 | 1.04	0.91 | 1.07
39	Coal Creek 230	1.03 | 1.06	1.02 | 1.07	1.02 | 1.05	1.00 | 1.07	0.97 | 1.08
40	Jamestown 345	0.96 | 1.00	0.93 | 1.00	0.96 | 1.00	0.93 | 0.99	0.90 | 1.02
41	Drayton 230	1.03 | 1.06	1.01 | 1.05	1.01 | 1.03	0.93 | 1.05	0.94 | 1.06
42	Groton 345	1.01 | 1.04	1.00 | 1.04	1.01 | 1.03	0.96 | 1.03	0.93 | 1.06
43	Minong 161	1.03 | 1.08	1.04 | 1.10	1.01 | 1.04	0.89 | 1.08	0.82 | 1.11
44	Wahpeton 115	1.03 | 1.06	1.01 | 1.06	1.03 | 1.05	0.99 | 1.05	0.96 | 1.08
45	Watertown 345	1.02 | 1.04	1.02 | 1.04	1.02 | 1.04	0.98 | 1.04	0.96 | 1.06
46	**Dynamic Voltage Warnings**					
47		63061 [MIDCOMP] 1.24	63061 [MIDCOMP] 1.23	none	none	61615 [ARROWHD4] 0.80
48						61614 [98L TAP4] 0.80
49						61616 [HILLTOP4] 0.80
50						61686 [15TH AV7] 0.80
51						61672 [HILLTOP7] 0.81
52						61667 [POTLTCH7] 0.81
53						668 [CLOQUET7] 0.81 +m
54	Worst Case Angle Damping	KING 3 / -1.56%	KING 3 / 30.58%	SHERC3 / 60.85%	KING 3 / 59.95%	SHERC3 / 69.03%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	442%	507%	473%	-71%	-123%
57	K22W (max +dP @ t, d-ang)	102.7@(0.15000,-2.1)	97.2@(0.15000,-1.8)	97.2@(0.15000,-1.8)	195.0@(1.47500,14.2)	195.0@(1.22500,24.9)
58	K22W (max -dP @ t, d-ang)	0.0@(0.02500,0.0)	15.9@(0.24167,0.5)	35.1@(2.95832,8.1)	115.5@(1.47500,34.1)	110.8@(1.22500,44.5)
59	K22W (max d-ang @ t, dP)	-43.8@(10.00821,52.2)	-73.5@(10.00821,52.8)	8.6@(2.68332,-24.5)	-56.6@(9.29989,195.0)	-60.9@(3.27498,195.0)
60	**OS Rel Trip / Marg**					
61	MH - OH				1.47500 sec	1.22500 sec
62	D602F at Forbes/Dorsey	312% / 521%	0.18333 sec / 0.18333 sec	302% / 502%	45% / 75%	38% / 61%
63	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 710%	999% / 592%	999% / 229%	999% / 257%
64	R50M / F3M	999% / 240%	607% / 161%	765% / 259%	313% / 241%	149% / 268%
65	B10T	347%	255%	262%	121%	56%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 2 | 2)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 5 | 2) / (0 | 1 | 1)	(1 | 5 | 2) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 2 | 1) / (1 | 3 | 1)	(0 | 2 | 1) / (1 | 4 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 5 | 1) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m3a-so15aa-h23	m3a-so15aa-h33	m3a-so15aa-h43	m3a-so15aa-hc9	m3a-so15aa-hd9
Disturbance	h23	h33	h43	hc9	hd9
System Response	OK	OK	OK	OK	OK
70% or 120% Violations	M	M			A9H1HPC
ORWG Criteria Violations					3
Line Tripping		(5T)(6T)		2(1T)5	2(1T)5

Table C-4: TSR Study Case with Upgrade Option 3

1	**Case No.**	31	32	33
2	**Case Name**	m3a-so15aa-hfs	m3a-so15aa-his	m3a-so15aa-hna
3	**Disturbance**	hfs	his	hna
4	**Prior Outage**	None	None	None
5	**Date/Time**	JUN 15 2009 9:21	MAY 28 2009 14:46	JUN 15 2009 10:16
6	**Comments**			
7				
8	**Steady State Flows**			
9	NDEX / EAST BIAS	2300 / 156	2300 / 156	2300 / 156
10	MHEX / L20D	1949 / 268	1949 / 268	1949 / 268
11	ECL-ARP / PRI-BYN	839 / 35	842 / 35	839 / 35
12	MWEX / AHD-SLK	1724 / 647	1722 / 643	1724 / 647
13	D602F / F601C	1583 / 1216	1582 / 1218	1583 / 1216
14	B10T / MH>SPC	161 / 57	161 / 57	161 / 57
15	OH E-W / OH>MH	190 / -194	190 / -194	190 / -194
16	R50M / OH>MP	134 / 149	134 / 149	134 / 149
17	G82R	-36	-36	-36
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1104	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	850 / 9	850 / 9	850 / 9
20	Forbes SVC / MSC	-28 / 600	-21 / 600	-28 / 600
21	RCDC	0	0	0
22	**Steady State Vltgs**			
23	Dorsey 500/Dorsey 230	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045
24	Roseau 500/Forbes 500	1.042 / 1.035	1.043 / 1.035	1.042 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.972	1.031 / 0.974	1.031 / 0.972
26	Int Falls 115/Badoura 115	1.021 / 1.043	1.021 / 1.044	1.021 / 1.043
27	Drayton 230/Groton 345	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022
28	**SS OS Relay Margins**			
29	D602F at Forbes/Dorsey	312% / 521%	312% / 521%	312% / 521%
30	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 764%	999% / 764%
31	R50M/F3M	999% / 323%	999% / 324%	999% / 323%
32	B10T	354%	354%	354%
33	**Min/MaxTransientVltg**			
34	Arrowhd 230	0.92 | 1.03	0.85 | 0.99	0.84 | 1.04
35	Boise 115	0.95 | 1.04	1.01 | 1.05	0.94 | 1.08
36	Dorsey 230	1.02 | 1.08	1.03 | 1.12	0.99 | 1.07
37	Forbes 230	0.92 | 1.03	1.01 | 1.05	0.87 | 1.03
38	Riverton 230	0.97 | 1.04	1.01 | 1.05	0.96 | 1.05
39	Coal Creek 230	0.98 | 1.07	1.01 | 1.05	0.97 | 1.07
40	Jamestown 345	0.93 | 1.00	0.98 | 1.01	0.92 | 0.99
41	Drayton 230	1.00 | 1.06	1.02 | 1.08	0.95 | 1.05
42	Groton 345	0.98 | 1.03	1.00 | 1.03	0.96 | 1.03
43	Minong 161	0.96 | 1.08	(0.73)0.81 | 1.00	0.89 | 1.08
44	Wahpeton 115	1.00 | 1.05	1.04 | 1.06	0.99 | 1.06
45	Watertown 345	1.00 | 1.03	1.01 | 1.04	0.99 | 1.04
46	**Dynamic Voltage Warnings**			
47		none	61631 [MINONG 5] 0.81	none
48			63061 [MIDCOMP-] 1.21	
49				
50				
51				
52				
53				
54	Worst Case Angle Damping	KING 3 / 31.63%	ANTEL3 / 61.16%	KING 3 / 52.36%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	143%	226%	-123%
57	K22W (max +dP @ t, d-ang)	50.5@(0.13333,-0.7)	13.6@(3.44997,1.5)	195.0@(1.15000,12.1)
58	K22W (max -dP @ t, d-ang)	103.2@(0.45000,16.1)	67.5@(1.64166,27.8)	125.5@(1.15000,32.7)
59	K22W (max d-ang @ t, dP)	-26.2@(10.00821,-1.2)	30.2@(1.18333,-63.5)	-59.4@(10.00821,195.0)
60	**OS Rel Trip / Marg**			
61	MH - OH			1.15000 sec
62	D602F at Forbes/Dorsey	11% / 7%	252% / 421%	11% / 7%
63	G82R at Rugby/L20D at Drayton	999% / 223%	999% / 600%	999% / 208%
64	R50M / F3M	303% / 196%	754% / 302%	264% / 196%
65	B10T	118%	180%	81%
66	**FSCAPS (SS/Unav/Final)**			
67	Balta 230	(0 | 1 | 1)	(0 | 0 | 0)	(0 | 1 | 1)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 3 | 3)
69	Prairie 115 / Ramsey 230	(1 | 5 | 2) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 5 | 2) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 1 | 1) / (1 | 3 | 2)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 2 | 1) / (1 | 4 | 1)
71	Shey 115 / Split Rock 115	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 2 | 2)	(1 | 2 | 2) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A

Case	m3a-so15aa-hfs	m3a-so15aa-his	m3a-so15aa-hna
Disturbance	hfs	his	hna
System Response	OK	OK	OK
70% or 120% Violations		MM	
ORWG Criteria Violations		7	
Line Tripping	56		2(1T)56

Table C-5: Mitigation of Constraints for TSR Study Case with Upgrade Option 1

1	**Case No.**	1	2	3	4	5
2	**Case Name**	m1a-so15aa-h79	m1a-so15aa-h73	m1a-so15aa-h7z	m1a-so15aa-h7z	m1a-so15aa-h7d
3	**Disturbance**	h79	h73	h7z	h7z	h7d
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	JUN 12 2009 14:53	JUN 11 2009 10:54	JUN 11 2009 11:39	JUN 11 2009 12:33	JUN 11 2009 11:17
6	**Comments**		Block MH-OH	Forbes 400 MVAr Cap	Forbes 600 MVAr Cap	Trigger DC Reduction
7			Block DCAR			
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
12	MWEX / AHD-SLK	1645 / 647	1641 / 642	1641 / 642	1641 / 642	1641 / 642
13	D602F / F601C	1545 / 1247	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249
14	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
17	G82R	-61	-61	-61	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 28	717 / 29	717 / 29	717 / 29	717 / 29
20	Forbes SVC / MSC	-55 / 600	-45 / 600	-45 / 600	-45 / 600	-45 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.046	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
31	R50M/F3M	999% / 321%	999% / 322%	999% / 322%	999% / 322%	999% / 322%
32	B10T	347%	347%	347%	347%	347%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.91 | 1.01	0.90 | 1.02	0.95 | 1.01	0.97 | 1.01	1.01 | 1.05
35	Boise 115	0.96 | 1.07	0.96 | 1.02	0.96 | 1.01	0.96 | 1.01	1.00 | 1.02
36	Dorsey 230	1.00 | 1.04	1.00 | 1.04	1.00 | 1.04	1.00 | 1.04	1.04 | 1.07
37	Forbes 230	0.93 | 1.01	0.91 | 1.01	0.99 | 1.02	1.00 | 1.03	1.02 | 1.05
38	Riverton 230	0.99 | 1.03	0.98 | 1.04	1.01 | 1.03	1.01 | 1.03	1.03 | 1.05
39	Coal Creek 230	1.00 | 1.05	1.00 | 1.05	1.01 | 1.05	1.01 | 1.05	1.01 | 1.06
40	Jamestown 345	0.92 | 0.97	0.92 | 0.97	0.92 | 0.97	0.93 | 0.97	0.93 | 1.00
41	Drayton 230	0.93 | 1.00	0.92 | 1.02	0.94 | 1.00	0.94 | 0.98	1.02 | 1.05
42	Groton 345	0.99 | 1.03	0.99 | 1.03	1.00 | 1.03	1.00 | 1.03	1.00 | 1.05
43	Minong 161	0.95 | 1.05	0.94 | 1.05	0.98 | 1.04	0.99 | 1.04	1.03 | 1.08
44	Wahpeton 115	1.01 | 1.04	1.01 | 1.05	1.02 | 1.04	1.02 | 1.04	1.03 | 1.06
45	Watertown 345	1.01 | 1.04	1.01 | 1.04	1.02 | 1.04	1.02 | 1.04	1.02 | 1.05
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	MNTCE3 / 59.36%	MNTCE3 / 12.60%	MNTCE3 / 59.27%	SHERC3 / 67.90%	KING 3 / 34.35%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	39%	-66%	507%	507%	507%
57	K22W (max +dP @ t, d-ang)	196.0@(1.63333,6.4)	102.8@(0.15000,-2.0)	102.9@(0.15000,-2.0)	102.9@(0.15000,-2.0)	102.8@(0.15000,-2.0)
58	K22W (max -dP @ t, d-ang)	102.7@(1.63333,25.7)	117.0@(2.89165,36.2)	93.3@(2.88332,23.5)	88.7@(2.89998,20.3)	11.5@(0.25000,0.9)
59	K22W (max d-ang @ t, dP)	-35.6@(2.24166,196.0)	37.2@(2.53332,-108.1)	25.1@(2.40832,-81.9)	22.1@(2.36666,-75.7)	-66.4@(10.00821,55.9)
60	**OS Rel Trip / Marg**					
61	MH - OH	1.63333 sec				
62	D602F at Forbes/Dorsey	52% / 85%	48% / 78%	79% / 129%	81% / 133%	262% / 441%
63	G82R at Rugby/L20D at Drayton	999% / 194%	999% / 180%	999% / 221%	999% / 227%	999% / 640%
64	R50M / F3M	201% / 213%	381% / 213%	478% / 206%	480% / 205%	999% / 212%
65	B10T	66%	60%	78%	80%	164%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 4 | 4) / (0 | 1 | 1)	(1 | 5 | 4) / (0 | 1 | 1)	(1 | 3 | 3) / (0 | 1 | 1)	(1 | 3 | 2) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 2 | 2) / (1 | 3 | 2)	(0 | 2 | 1) / (1 | 3 | 3)	(0 | 2 | 2) / (1 | 2 | 2)	(0 | 2 | 2) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-h79	m1a-so15aa-h73	m1a-so15aa-h7z	m1a-so15aa-h7z	m1a-so15aa-h7d
Disturbance	h79	h73	h7z	h7z	h7d
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(1T)	25			

Table C-5: Mitigation of Constraints for TSR Study Case with Upgrade Option 1

1	**Case No.**	6	7
2	**Case Name**	m1a-so15aa-hec	m1a-so15aa-he0
3	**Disturbance**	hec	he0
4	**Prior Outage**	None	None
5	**Date/Time**	JUN 11 2009 11:07	JUN 11 2009 11:33
6	**Comments**		Trigger DC Reduction
7			
8	**Steady State Flows**		
9	NDEX / EAST BIAS	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27
12	MWEX / AHD-SLK	1641 / 642	1641 / 642
13	D602F / F601C	1545 / 1249	1545 / 1249
14	B10T / MH>SPC	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151
17	G82R	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 29	717 / 29
20	Forbes SVC / MSC	-45 / 600	-45 / 600
21	RCDC	0	0
22	**Steady State Vltgs**		
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.045	1.022 / 1.045
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**		
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%
31	R50M/F3M	999% / 322%	999% / 322%
32	B10T	347%	347%
33	**Min/MaxTransientVltg**		
34	Arrowhd 230	0.97 | 1.04	1.01 | 1.05
35	Boise 115	0.97 | 1.03	1.00 | 1.04
36	Dorsey 230	1.02 | 1.10	1.03 | 1.17
37	Forbes 230	0.97 | 1.03	1.03 | 1.06
38	Riverton 230	1.00 | 1.04	1.04 | 1.05
39	Coal Creek 230	1.00 | 1.07	1.03 | 1.06
40	Jamestown 345	0.92 | 0.99	0.95 | 1.00
41	Drayton 230	1.00 | 1.05	1.04 | 1.11
42	Groton 345	1.00 | 1.04	1.01 | 1.05
43	Minong 161	1.01 | 1.07	1.03 | 1.08
44	Wahpeton 115	1.02 | 1.06	1.04 | 1.06
45	Watertown 345	1.02 | 1.04	1.03 | 1.05
46	**Dynamic Voltage Warnings**		
47		none	none
48			
49			
50			
51			
52			
53			
54	Worst Case Angle Damping	KING 3 / 11.51%	KING 3 / 31.51%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	170%	445%
57	K22W (max +dP @ t, d-ang)	47.2@(0.13333,-0.6)	101.1@(1.53333,-34.6)
58	K22W (max -dP @ t, d-ang)	105.4@(0.44166,15.1)	66.3@(0.40000,7.6)
59	K22W (max d-ang @ t, dP)	-28.7@(10.00821,-1.0)	-65.1@(10.00821,54.9)
60	**OS Rel Trip / Marg**		
61	MH - OH		
62	D602F at Forbes/Dorsey	21% / 22%	76% / 113%
63	G82R at Rugby/L20D at Drayton	999% / 219%	999% / 360%
64	R50M / F3M	333% / 197%	544% / 200%
65	B10T	75%	131%
66	**FSCAPS (SS/Unav/Final)**		
67	Balta 230	(0 | 1 | 1)	(0 | 1 | 1)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 5 | 3) / (0 | 1 | 1)	(1 | 5 | 1) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 1 | 1) / (1 | 2 | 2)	(0 | 1 | 0) / (1 | 2 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A

Case	m1a-so15aa-hec	m1a-so15aa-he0
Disturbance	hec	he0
System Response	OK	OK
70% or 120% Violations		
ORWG Criteria Violations		
Line Tripping	56	

Table C-5: Mitigation of Constraints for TSR Study Case with Upgrade Option 1

1	**Case No.**	8	9	11	12	10
2	**Case Name**	m1a-so15aa-hlc	m1a-so15aa-hls	m1a-so15aa-hlz	m1a-so15aa-hlz	m1a-so15aa-hl0
3	**Disturbance**	hlc	hls	hlz	hlz	hl0
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	JUN 12 2009 16:13	JUN 11 2009 11:01	JUN 11 2009 11:45	JUN 11 2009 12:39	JUN 11 2009 11:24
6	**Comments**		Block MH-OH	Forbes 400 MVAr Cap	Forbes 600 MVAr Cap	Trigger DC Reduction
7				Block MH-OH		
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
12	MWEX / AHD-SLK	1645 / 647	1641 / 642	1641 / 642	1641 / 642	1641 / 642
13	D602F / F601C	1545 / 1247	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249
14	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
17	G82R	-61	-61	-61	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 28	717 / 29	717 / 29	717 / 29	717 / 29
20	Forbes SVC / MSC	-55 / 600	-45 / 600	-45 / 600	-45 / 600	-45 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.046	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
31	R50M/F3M	999% / 321%	999% / 322%	999% / 322%	999% / 322%	999% / 322%
32	B10T	347%	347%	347%	347%	347%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.90 | 1.00	0.90 | 1.01	0.95 | 1.01	0.97 | 1.00	1.01 | 1.05
35	Boise 115	0.95 | 1.08	0.95 | 1.03	0.95 | 1.02	0.96 | 1.01	1.00 | 1.04
36	Dorsey 230	0.98 | 1.06	0.98 | 1.06	0.98 | 1.07	0.99 | 1.08	1.03 | 1.17
37	Forbes 230	0.91 | 1.00	0.92 | 1.01	0.99 | 1.02	1.00 | 1.04	1.03 | 1.06
38	Riverton 230	0.99 | 1.03	0.99 | 1.04	1.01 | 1.03	1.02 | 1.03	1.04 | 1.05
39	Coal Creek 230	1.00 | 1.05	1.00 | 1.05	1.01 | 1.05	1.02 | 1.05	1.03 | 1.06
40	Jamestown 345	0.92 | 0.97	0.92 | 0.97	0.93 | 0.97	0.94 | 0.98	0.95 | 1.00
41	Drayton 230	0.93 | 1.00	0.94 | 1.01	0.95 | 1.01	0.96 | 1.01	1.04 | 1.11
42	Groton 345	0.99 | 1.02	0.99 | 1.02	1.00 | 1.02	1.00 | 1.03	1.01 | 1.05
43	Minong 161	0.95 | 1.04	0.95 | 1.04	0.98 | 1.04	1.00 | 1.03	1.03 | 1.08
44	Wahpeton 115	1.01 | 1.04	1.01 | 1.05	1.02 | 1.05	1.03 | 1.05	1.04 | 1.06
45	Watertown 345	1.01 | 1.03	1.01 | 1.03	1.02 | 1.03	1.02 | 1.03	1.03 | 1.05
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	SHERC3 / 60.24%	MNTCE3 / 21.99%	SHERC3 / 74.04%	SHERC3 / 73.98%	KING 3 / 31.58%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	55%	84%	507%	507%	445%
57	K22W (max +dP @ t, d-ang)	196.0@(1.21666,3.8)	47.2@(0.13333,-0.6)	47.2@(0.13333,-0.6)	47.2@(0.13333,-0.6)	102.0@(1.53333,-34.8)
58	K22W (max -dP @ t, d-ang)	116.5@(1.21666,23.9)	120.1@(1.29166,24.0)	102.3@(1.27500,16.0)	99.5@(0.44166,13.7)	66.6@(0.40000,7.6)
59	K22W (max d-ang @ t, dP)	-38.7@(1.79166,196.0)	33.2@(2.05833,-97.6)	21.1@(1.88333,-75.5)	19.0@(0.70833,-37.1)	-65.2@(10.00821,55.2)
60	**OS Rel Trip / Marg**					
61	MH - OH	1.21666 sec				
62	D602F at Forbes/Dorsey	21% / 23%	21% / 22%	15% / 13%	12% / 7%	76% / 113%
63	G82R at Rugby/L20D at Drayton	999% / 175%	999% / 186%	999% / 213%	999% / 222%	999% / 360%
64	R50M / F3M	180% / 204%	333% / 202%	339% / 198%	343% / 197%	544% / 200%
65	B10T	47%	45%	52%	55%	132%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 1 | 1)	(0 | 1 | 1)	(0 | 1 | 1)	(0 | 1 | 1)	(0 | 1 | 1)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 |11 | 5) / (0 | 1 | 1)	(1 |11 | 5) / (0 | 1 | 1)	(1 | 5 | 5) / (0 | 1 | 1)	(1 | 5 | 5) / (0 | 1 | 1)	(1 | 5 | 1) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 2 | 2) / (1 | 4 | 2)	(0 | 1 | 1) / (1 | 4 | 3)	(0 | 1 | 1) / (1 | 3 | 3)	(0 | 1 | 1) / (1 | 2 | 2)	(0 | 1 | 0) / (1 | 2 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-hlc	m1a-so15aa-hls	m1a-so15aa-hlz	m1a-so15aa-hlz	m1a-so15aa-hl0
Disturbance	hlc	hls	hlz	hlz	hl0
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(1T)56	56	56	56	

Table C-5: Mitigation of Constraints for TSR Study Case with Upgrade Option 1

1	**Case No.**	13	14	16	17	15
2	**Case Name**	m1a-so15aa-hoc	m1a-so15aa-hoa	m1a-so15aa-hoz	m1a-so15aa-hoz	m1a-so15aa-ho0
3	**Disturbance**	hoc	hoa	hoz	hoz	ho0
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	JUN 12 2009 15:02	JUN 11 2009 11:11	JUN 11 2009 11:48	JUN 11 2009 12:42	JUN 11 2009 11:27
6	**Comments**		Block MH-OH	Forbes 400 MVAr Cap	Forbes 600 MVAr Cap	Trigger DC Reduction
7			Block DCAR	Block MH-OH		
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
12	MWEX / AHD-SLK	1645 / 647	1641 / 642	1641 / 642	1641 / 642	1641 / 642
13	D602F / F601C	1545 / 1247	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249
14	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
17	G82R	-61	-61	-61	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 28	717 / 29	717 / 29	717 / 29	717 / 29
20	Forbes SVC / MSC	-55 / 600	-45 / 600	-45 / 600	-45 / 600	-45 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.046	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
31	R50M/F3M	999% / 321%	999% / 322%	999% / 322%	999% / 322%	999% / 322%
32	B10T	347%	347%	347%	347%	347%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.86 | 1.03	0.82 | 1.01	0.91 | 1.00	0.95 | 1.00	0.99 | 1.04
35	Boise 115	0.96 | 1.08	0.95 | 1.04	0.96 | 1.04	0.97 | 1.04	1.00 | 1.05
36	Dorsey 230	1.01 | 1.14	1.00 | 1.14	1.01 | 1.14	1.01 | 1.14	1.04 | 1.18
37	Forbes 230	0.89 | 1.04	0.82 | 1.04	0.95 | 1.06	0.99 | 1.07	1.02 | 1.06
38	Riverton 230	0.97 | 1.04	0.95 | 1.03	0.98 | 1.03	0.99 | 1.04	1.01 | 1.04
39	Coal Creek 230	0.99 | 1.06	0.99 | 1.06	1.00 | 1.04	1.01 | 1.04	1.02 | 1.05
40	Jamestown 345	0.94 | 0.98	0.92 | 0.98	0.94 | 0.98	0.95 | 0.98	0.95 | 0.98
41	Drayton 230	0.94 | 1.08	0.91 | 1.08	0.95 | 1.08	0.96 | 1.08	1.02 | 1.10
42	Groton 345	0.96 | 1.02	0.95 | 1.01	0.97 | 1.01	0.98 | 1.01	1.00 | 1.03
43	Minong 161	0.92 | 1.08	0.87 | 1.04	0.95 | 1.03	0.98 | 1.02	1.01 | 1.08
44	Wahpeton 115	1.00 | 1.05	0.98 | 1.04	1.01 | 1.05	1.02 | 1.05	1.02 | 1.05
45	Watertown 345	0.99 | 1.03	0.98 | 1.02	1.00 | 1.02	1.00 | 1.02	1.02 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	61564 [FORB4JCT] 0.80	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 53.41%	ANTEL3 / -23.74%	SHERC3 / 29.59%	SHERC3 / 52.00%	KING 3 / 39.12%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	-33%	-432%	427%	507%	507%
57	K22W (max +dP @ t, d-ang)	196.0@(1.46666,14.9)	10.3@(0.11667,0.2)	10.3@(0.11667,0.2)	10.3@(0.11667,0.2)	85.7@(2.17499,-34.1)
58	K22W (max -dP @ t, d-ang)	115.3@(1.46666,35.0)	142.3@(2.94165,49.8)	105.2@(1.65000,28.7)	95.8@(1.63333,24.8)	54.3@(0.40833,6.3)
59	K22W (max d-ang @ t, dP)	-53.9@(9.24989,196.0)	52.8@(9.09989,-134.7)	34.6@(2.26666,-94.4)	28.5@(2.18333,-81.5)	-59.5@(10.00821,48.4)
60	**OS Rel Trip / Marg**					
61	MH - OH	1.46666 sec				
62	D602F at Forbes/Dorsey	52% / 87%	0% / -3%	61% / 99%	76% / 124%	220% / 374%
63	G82R at Rugby/L20D at Drayton	999% / 242%	999% / 158%	999% / 275%	999% / 290%	999% / 646%
64	R50M / F3M	313% / 237%	269% / 237%	411% / 229%	459% / 227%	810% / 216%
65	B10T	78%	45%	84%	87%	199%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 3 | 3)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 4 | 3) / (0 | 1 | 1)	(1 | 8 | 6) / (0 | 1 | 1)	(1 | 3 | 2) / (0 | 1 | 1)	(1 | 3 | 2) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 2 | 1) / (1 | 3 | 1)	(0 | 2 | 2) / (1 | 6 | 4)	(0 | 1 | 1) / (1 | 3 | 3)	(0 | 1 | 1) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-hoc	m1a-so15aa-hoa	m1a-so15aa-hoz	m1a-so15aa-hoz	m1a-so15aa-ho0
Disturbance	hoc	hoa	hoz	hoz	ho0
System Response	OK	OK	OK	OK	OK
70% or 120% Violations		F			
ORWG Criteria Violations					
Line Tripping	2(1T)	2(5T)6			

Table C-5: Mitigation of Constraints for TSR Study Case with Upgrade Option 1

1	**Case No.**	18	19	20	21	22
2	**Case Name**	m1a-so15aa-hm9	m1a-so15aa-hm3	m1a-so15aa-hmz	m1a-so15aa-hmz	m1a-so15aa-hmd
3	**Disturbance**	hm9	hm3	hmz	hmz	hmd
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	JUN 12 2009 14:56	JUN 11 2009 10:57	JUN 11 2009 11:42	JUN 11 2009 12:36	JUN 11 2009 11:21
6	**Comments**		Block MH-OH	Forbes 400 MVAr Cap	Forbes 600 MVAr Cap	Trigger DC Reduction
7			Block DCAR	Block MH-OH		
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2287 / 186	2287 / 186	2287 / 186	2287 / 186	2287 / 186
10	MHEX / L20D	1849 / 236	1849 / 236	1849 / 236	1849 / 236	1849 / 236
11	ECL-ARP / PRI-BYN	810 / 27	810 / 27	810 / 27	810 / 27	810 / 27
12	MWEX / AHD-SLK	1645 / 647	1641 / 642	1641 / 642	1641 / 642	1641 / 642
13	D602F / F601C	1545 / 1247	1545 / 1249	1545 / 1249	1545 / 1249	1545 / 1249
14	B10T / MH>SPC	163 / 59	163 / 59	163 / 59	163 / 59	163 / 59
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	128 / 151	128 / 151	128 / 151	128 / 151	128 / 151
17	G82R	-61	-61	-61	-61	-61
18	Dorsey bipole / CU bipole	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104	3245 / 1104
19	Dorsey Reserve / Wtrtn SVC	717 / 28	717 / 29	717 / 29	717 / 29	717 / 29
20	Forbes SVC / MSC	-55 / 600	-45 / 600	-45 / 600	-45 / 600	-45 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035	1.050 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991	1.031 / 0.991
26	Int Falls 115/Badoura 115	1.022 / 1.046	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045	1.022 / 1.045
27	Drayton 230/Groton 345	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024	1.041 / 1.024
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	325% / 543%	325% / 543%	325% / 543%	325% / 543%	325% / 543%
30	G82R at Rugby/L20D at Drayton	999% / 912%	999% / 912%	999% / 912%	999% / 912%	999% / 912%
31	R50M/F3M	999% / 321%	999% / 322%	999% / 322%	999% / 322%	999% / 322%
32	B10T	347%	347%	347%	347%	347%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.91 | 1.05	0.88 | 1.02	0.94 | 1.01	0.95 | 1.01	0.98 | 1.05
35	Boise 115	0.96 | 1.09	0.96 | 1.03	0.96 | 1.02	0.97 | 1.02	0.99 | 1.02
36	Dorsey 230	1.01 | 1.06	1.01 | 1.04	1.01 | 1.04	1.01 | 1.04	1.04 | 1.07
37	Forbes 230	0.90 | 1.03	0.89 | 1.01	0.96 | 1.02	1.00 | 1.03	1.02 | 1.05
38	Riverton 230	0.98 | 1.05	0.98 | 1.04	0.99 | 1.03	1.00 | 1.03	1.01 | 1.06
39	Coal Creek 230	0.98 | 1.07	0.98 | 1.07	0.98 | 1.07	0.98 | 1.07	0.99 | 1.08
40	Jamestown 345	0.89 | 0.99	0.89 | 0.98	0.90 | 0.98	0.90 | 0.98	0.91 | 1.01
41	Drayton 230	0.91 | 1.04	0.91 | 1.02	0.93 | 1.01	0.93 | 0.99	1.01 | 1.07
42	Groton 345	0.98 | 1.04	0.97 | 1.03	0.98 | 1.03	0.99 | 1.03	0.99 | 1.05
43	Minong 161	0.94 | 1.09	0.93 | 1.05	0.97 | 1.04	0.97 | 1.04	1.00 | 1.08
44	Wahpeton 115	1.00 | 1.06	1.00 | 1.05	1.01 | 1.05	1.01 | 1.05	1.02 | 1.07
45	Watertown 345	1.01 | 1.04	1.00 | 1.04	1.01 | 1.03	1.01 | 1.03	1.02 | 1.05
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 38.95%	MNTCE3 / 35.38%	SHERC3 / 62.81%	KING 3 / 68.13%	KING 3 / 39.96%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	-37%	-111%	507%	507%	507%
57	K22W (max +dP @ t, d-ang)	196.0@(1.20000,12.9)	29.5@(0.11667,0.7)	29.5@(0.11667,0.7)	29.5@(0.11667,0.7)	105.1@(2.06666,-39.8)
58	K22W (max -dP @ t, d-ang)	113.8@(1.16666,33.4)	121.4@(1.35833,34.1)	102.9@(1.30000,25.7)	95.0@(1.28333,22.3)	67.5@(0.27500,7.6)
59	K22W (max d-ang @ t, dP)	-59.3@(10.00821,196.0)	37.1@(1.86666,-111.7)	28.5@(0.84166,-46.7)	26.9@(0.80833,-41.8)	-64.8@(10.00821,55.6)
60	**OS Rel Trip / Marg**					
61	MH - OH	1.20000 sec				
62	D602F at Forbes/Dorsey	44% / 72%	37% / 60%	58% / 94%	65% / 106%	200% / 341%
63	G82R at Rugby/L20D at Drayton	999% / 170%	999% / 159%	999% / 196%	999% / 214%	999% / 489%
64	R50M / F3M	331% / 238%	345% / 236%	384% / 226%	404% / 225%	732% / 210%
65	B10T	35%	35%	41%	44%	115%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 5 | 3) / (0 | 2 | 2)	(1 | 5 | 4) / (0 | 2 | 2)	(1 | 4 | 4) / (0 | 2 | 2)	(1 | 3 | 3) / (0 | 2 | 2)	(1 | 2 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 1 | 1) / (1 | 4 | 1)	(0 | 2 | 1) / (1 | 4 | 3)	(0 | 2 | 2) / (1 | 3 | 3)	(0 | 1 | 1) / (1 | 3 | 3)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 2 | 2) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 2 | 0) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1a-so15aa-hm9	m1a-so15aa-hm3	m1a-so15aa-hmz	m1a-so15aa-hmz	m1a-so15aa-hmd
Disturbance	hm9	hm3	hmz	hmz	hmd
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	2(1T)5	25			

Table C-6: Mitigation of Constraints for TSR Study Case with Upgrade Option 3

1	**Case No.**	1	2	3	4	5
2	**Case Name**	m3a-so15aa-hc9	m3a-so15aa-hc3	m3a-so15aa-hcz	m3a-so15aa-hcz	m3a-so15aa-hcd
3	**Disturbance**	hc9	hc3	hcz	hcz	hcd
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	JUN 15 2009 9:15	JUN 15 2009 10:59	JUN 15 2009 11:31	JUN 15 2009 12:52	JUN 15 2009 11:11
6	**Comments**		Block MH-OH	Forbes 400 MVAr Cap	Forbes 600 MVAr Cap	Trigger DC Reduction
7			Block DCAR	Block MH-OH	Block MH-OH	
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2300 / 156	2300 / 156	2300 / 156	2300 / 156	2300 / 156
10	MHEX / L20D	1949 / 268	1949 / 268	1949 / 268	1949 / 268	1949 / 268
11	ECL-ARP / PRI-BYN	839 / 35	839 / 35	839 / 35	839 / 35	839 / 35
12	MWEX / AHD-SLK	1724 / 647	1724 / 647	1724 / 647	1724 / 647	1724 / 647
13	D602F / F601C	1583 / 1216	1583 / 1216	1583 / 1216	1583 / 1216	1583 / 1216
14	B10T / MH>SPC	161 / 57	161 / 57	161 / 57	161 / 57	161 / 57
15	OH E-W / OH>MH	190 / -194	190 / -194	190 / -194	190 / -194	190 / -194
16	R50M / OH>MP	134 / 149	134 / 149	134 / 149	134 / 149	134 / 149
17	G82R	-36	-36	-36	-36	-36
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	850 / 9	850 / 9	850 / 9	850 / 9	850 / 9
20	Forbes SVC / MSC	-28 / 600	-28 / 600	-28 / 600	-28 / 600	-28 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045
24	Roseau 500/Forbes 500	1.042 / 1.035	1.042 / 1.035	1.042 / 1.035	1.042 / 1.035	1.042 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.972	1.031 / 0.972	1.031 / 0.972	1.031 / 0.972	1.031 / 0.972
26	Int Falls 115/Badoura 115	1.021 / 1.043	1.021 / 1.043	1.021 / 1.043	1.021 / 1.043	1.021 / 1.043
27	Drayton 230/Groton 345	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	312% / 521%	312% / 521%	312% / 521%	312% / 521%	312% / 521%
30	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 764%	999% / 764%	999% / 764%	999% / 764%
31	R50M/F3M	999% / 323%	999% / 323%	999% / 323%	999% / 323%	999% / 323%
32	B10T	354%	354%	354%	354%	354%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.83 | 1.04	(4.02)0.71 | 1.15	0.88 | 1.02	0.92 | 1.01	1.00 | 1.04
35	Boise 115	0.96 | 1.08	(5.69)0.25 | 0.98	0.97 | 1.03	0.97 | 1.03	1.00 | 1.02
36	Dorsey 230	1.00 | 1.07	(5.41)0.29 | 1.15	1.00 | 1.04	0.99 | 1.04	1.03 | 1.06
37	Forbes 230	0.87 | 1.03	(4.04)0.50 | 1.13	0.90 | 1.02	0.96 | 1.03	1.01 | 1.04
38	Riverton 230	0.95 | 1.04	0.77 | 1.18(5.72)	0.97 | 1.03	0.99 | 1.03	1.00 | 1.04
39	Coal Creek 230	1.00 | 1.07	0.83 | 1.22(5.72)	1.00 | 1.06	1.00 | 1.05	1.01 | 1.06
40	Jamestown 345	0.93 | 0.99	(4.55)0.30 | 1.22(5.72)	0.93 | 0.98	0.94 | 0.98	0.94 | 0.99
41	Drayton 230	0.93 | 1.05	(4.11)0.23 | 1.32(5.74)	0.93 | 1.03	0.94 | 1.01	1.01 | 1.05
42	Groton 345	0.96 | 1.03	(4.65)0.60 | 1.21(5.72)	0.96 | 1.01	0.97 | 1.01	0.99 | 1.03
43	Minong 161	0.89 | 1.08	(2.92)0.81 | 1.17	0.92 | 1.06	0.96 | 1.05	1.03 | 1.07
44	Wahpeton 115	0.99 | 1.05	(4.65)0.64 | 1.25(5.72)	1.00 | 1.05	1.01 | 1.04	1.01 | 1.05
45	Watertown 345	0.98 | 1.04	0.79 | 1.17	0.99 | 1.03	1.00 | 1.02	1.01 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	61615 [ARROWHD4] 0.80	none	none	none
48			61616 [HILLTOP4] 0.81			
49			61614 [98L TAP4] 0.81			
50			61686 [15TH AV7] 0.81			
51			61672 [HILLTOP7] 0.81			
52			61673 [ARROWHD7] 0.81			
53			687 [MIDWAY 7] 0.81 +mc			
54	Worst Case Angle Damping	KING 3 / 59.95%	STANT4 / -162.82%	MNTCE3 / 18.76%	SHERC3 / 36.95%	KING 3 / 28.81%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	-71%	-1969%	91%	507%	507%
57	K22W (max +dP @ t, d-ang)	195.0@(1.47500,14.2)	492.4@(7.51658,3508.8)	102.7@(0.15000,-2.1)	102.7@(0.15000,-2.1)	102.7@(0.15000,-2.1)
58	K22W (max -dP @ t, d-ang)	115.5@(1.47500,34.1)	165.9@(2.91665,66.2)	129.7@(2.91665,41.7)	110.7@(2.89165,32.4)	7.1@(0.25000,0.7)
59	K22W (max d-ang @ t, dP)	-56.6@(9.29989,195.0)	4649.2@(9.68321,112.9)	42.5@(2.59165,-118.6)	34.6@(2.47499,-99.6)	-58.2@(10.00821,47.9)
60	**OS Rel Trip / Marg**					
61	MH - OH	1.47500 sec				
62	D602F at Forbes/Dorsey	45% / 75%	-254% / -395%	31% / 50%	54% / 88%	233% / 392%
63	G82R at Rugby/L20D at Drayton	999% / 229%	-124% / -431%	999% / 212%	999% / 256%	999% / 746%
64	R50M / F3M	313% / 241%	-758% / -190%	346% / 230%	392% / 226%	950% / 217%
65	B10T	121%	4.08330 sec	83%	105%	264%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 3 | 1)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 0) / (0 | 3 | 3)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 5 | 2) / (0 | 1 | 1)	(1 | 0 | 0) / (0 | 2 | 0)	(1 | 5 | 4) / (0 | 1 | 1)	(1 | 4 | 3) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 2 | 1) / (1 | 3 | 1)	(0 | 2 | 2) / (1 | 6 | 6)	(0 | 2 | 1) / (1 | 4 | 3)	(0 | 2 | 2) / (1 | 3 | 3)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 5 | 0) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m3a-so15aa-hc9	m3a-so15aa-hc3	m3a-so15aa-hcz	m3a-so15aa-hcz	m3a-so15aa-hcd
Disturbance	hc9	hc3	hcz	hcz	hcd
System Response	OK	OK	OK	OK	OK
70% or 120% Violations		AH91HAM			
ORWG Criteria Violations		1235678BC			
Line Tripping	2(1T)5	234567(8T)9	5		

Table C-6: Mitigation of Constraints for TSR Study Case with Upgrade Option 3

1	**Case No.**	6	7	8	9	10
2	**Case Name**	m3a-so15aa-hd9	m3a-so15aa-hd3	m3a-so15aa-hdz	m3a-so15aa-hdz	m3a-so15aa-hdd
3	**Disturbance**	hd9	hd3	hdz	hdz	hdd
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	JUN 15 2009 9:18	JUN 15 2009 11:03	JUN 15 2009 11:34	JUN 15 2009 12:55	JUN 15 2009 11:14
6	**Comments**		Block MH-OH	Forbes 400 MVAr Cap	Forbes 600 MVAr Cap	Trigger DC Reduction
7			Block DCAR	Block MH-OH	Block MH-OH	
8	**Steady State Flows**			Block DCAR		
9	NDEX / EAST BIAS	2300 / 156	2300 / 156	2300 / 156	2300 / 156	2300 / 156
10	MHEX / L20D	1949 / 268	1949 / 268	1949 / 268	1949 / 268	1949 / 268
11	ECL-ARP / PRI-BYN	839 / 35	839 / 35	839 / 35	839 / 35	839 / 35
12	MWEX / AHD-SLK	1724 / 647	1724 / 647	1724 / 647	1724 / 647	1724 / 647
13	D602F / F601C	1583 / 1216	1583 / 1216	1583 / 1216	1583 / 1216	1583 / 1216
14	B10T / MH>SPC	161 / 57	161 / 57	161 / 57	161 / 57	161 / 57
15	OH E-W / OH>MH	190 / -194	190 / -194	190 / -194	190 / -194	190 / -194
16	R50M / OH>MP	134 / 149	134 / 149	134 / 149	134 / 149	134 / 149
17	G82R	-36	-36	-36	-36	-36
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	850 / 9	850 / 9	850 / 9	850 / 9	850 / 9
20	Forbes SVC / MSC	-28 / 600	-28 / 600	-28 / 600	-28 / 600	-28 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045
24	Roseau 500/Forbes 500	1.042 / 1.035	1.042 / 1.035	1.042 / 1.035	1.042 / 1.035	1.042 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.972	1.031 / 0.972	1.031 / 0.972	1.031 / 0.972	1.031 / 0.972
26	Int Falls 115/Badoura 115	1.021 / 1.043	1.021 / 1.043	1.021 / 1.043	1.021 / 1.043	1.021 / 1.043
27	Drayton 230/Groton 345	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	312% / 521%	312% / 521%	312% / 521%	312% / 521%	312% / 521%
30	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 764%	999% / 764%	999% / 764%	999% / 764%
31	R50M/F3M	999% / 323%	999% / 323%	999% / 323%	999% / 323%	999% / 323%
32	B10T	354%	354%	354%	354%	354%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	(0.77)0.77 | 1.07	(2.20)0.32 | 0.84	0.82 | 1.04	0.88 | 1.02	0.90 | 1.05
35	Boise 115	0.96 | 1.11	(2.20)0.66 | 0.98	0.95 | 1.04	0.96 | 1.03	0.99 | 1.02
36	Dorsey 230	1.01 | 1.06	0.93 | 1.03	1.00 | 1.05	1.01 | 1.04	1.04 | 1.07
37	Forbes 230	0.84 | 1.04	(2.20)0.25 | 0.91	0.83 | 1.03	0.90 | 1.03	0.98 | 1.04
38	Riverton 230	0.91 | 1.07	(2.20)0.58 | 0.94	0.94 | 1.05	0.95 | 1.04	0.97 | 1.04
39	Coal Creek 230	0.97 | 1.08	0.94 | 1.01	0.96 | 1.07	0.98 | 1.07	0.99 | 1.06
40	Jamestown 345	0.90 | 1.02	(2.20)0.55 | 0.93	0.91 | 1.00	0.92 | 0.99	0.93 | 0.99
41	Drayton 230	0.94 | 1.06	(2.20)0.63 | 0.97	0.89 | 1.03	0.91 | 1.03	1.01 | 1.05
42	Groton 345	0.93 | 1.06	(2.20)0.56 | 0.98	0.94 | 1.02	0.96 | 1.02	0.98 | 1.04
43	Minong 161	0.82 | 1.11	(2.20)0.53 | 0.88	0.88 | 1.08	0.92 | 1.07	0.93 | 1.09
44	Wahpeton 115	0.96 | 1.08	(2.20)0.62 | 0.99	0.98 | 1.07	0.98 | 1.06	1.00 | 1.05
45	Watertown 345	0.96 | 1.06	(2.20)0.66 | 0.99	0.98 | 1.04	0.98 | 1.03	1.00 | 1.04
46	**Dynamic Voltage Warnings**					
47		61615 [ARROWHD4] 0.80	61615 [ARROWHD4] 0.80	61564 [FORB4JCT] 0.80	none	none
48		61614 [98L TAP4] 0.80	61614 [98L TAP4] 0.80			
49		61616 [HILLTOP4] 0.80	61616 [HILLTOP4] 0.80			
50		61686 [15TH AV7] 0.80	61686 [15TH AV7] 0.80			
51		61672 [HILLTOP7] 0.81	61672 [HILLTOP7] 0.81			
52		61667 [POTLTCH7] 0.81	61667 [POTLTCH7] 0.81			
53		668 [CLOQUET7] 0.81 +m	668 [CLOQUET7] 0.81 +m			
54	Worst Case Angle Damping	SHERC3 / 69.03%	STANT4 / -162.82%	STANT4 / 54.93%	SHERC3 / 68.12%	KING 3 / 62.39%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	-123%	-5806%	-325%	222%	507%
57	K22W (max +dP @ t, d-ang)	195.0@(1.22500,24.9)	10.6@(0.11667,1.9)	10.6@(0.11667,1.9)	10.6@(0.11667,1.9)	94.8@(2.12499,-34.7)
58	K22W (max -dP @ t, d-ang)	110.8@(1.22500,44.5)	172.4@(1.80833,88.6)	146.9@(1.80000,54.2)	127.9@(1.37500,43.1)	74.0@(0.27500,9.7)
59	K22W (max d-ang @ t, dP)	-60.9@(3.27498,195.0)	106.9@(2.08333,-157.7)	54.2@(1.79166,-146.9)	44.0@(1.61666,-126.5)	-55.9@(10.00821,46.9)
60	**OS Rel Trip / Marg**					
61	MH - OH	1.22500 sec				
62	D602F at Forbes/Dorsey	38% / 61%	-116% / -203%	-4% / -11%	19% / 29%	185% / 310%
63	G82R at Rugby/L20D at Drayton	999% / 257%	157% / 34%	999% / 144%	999% / 185%	999% / 542%
64	R50M / F3M	149% / 268%	1% / 323%	260% / 222%	313% / 228%	725% / 210%
65	B10T	56%	40%	41%	47%	140%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 2 | 2)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 2) / (0 | 2 | 2)	(4 | 4 | 4) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 3 | 3)	(4 | 4 | 2) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 5 | 2) / (0 | 1 | 1)	(1 |12 |12) / (0 | 2 | 2)	(1 | 8 | 3) / (0 | 2 | 2)	(1 | 6 | 3) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 2 | 1) / (1 | 4 | 1)	(0 | 2 | 2) / (1 | 6 | 6)	(0 | 2 | 1) / (1 | 6 | 3)	(0 | 2 | 1) / (1 | 4 | 3)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 5 | 1) / (1 | 2 | 2)	(1 | 5 | 5) / (1 | 2 | 2)	(1 | 4 | 3) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m3a-so15aa-hd9	m3a-so15aa-hd3	m3a-so15aa-hdz	m3a-so15aa-hdz	m3a-so15aa-hdd
Disturbance	hd9	hd3	hdz	hdz	hdd
System Response	OK	OK	OK	OK	OK
70% or 120% Violations	A9H1HPC	A9H1HPC	F		
ORWG Criteria Violations	3	2345678ABC			
Line Tripping	2(1T)5	2567	256	56	

Table C-6: Mitigation of Constraints for TSR Study Case with Upgrade Option 3

1	**Case No.**	11	12
2	**Case Name**	m3a-so15aa-hfs	m3a-so15aa-hf0
3	**Disturbance**	hfs	hf0
4	**Prior Outage**	None	None
5	**Date/Time**	JUN 15 2009 9:21	JUN 15 2009 11:20
6	**Comments**		Trigger DC Reduction
7			
8	**Steady State Flows**		
9	NDEX / EAST BIAS	2300 / 156	2300 / 156
10	MHEX / L20D	1949 / 268	1949 / 268
11	ECL-ARP / PRI-BYN	839 / 35	839 / 35
12	MWEX / AHD-SLK	1724 / 647	1724 / 647
13	D602F / F601C	1583 / 1216	1583 / 1216
14	B10T / MH>SPC	161 / 57	161 / 57
15	OH E-W / OH>MH	190 / -194	190 / -194
16	R50M / OH>MP	134 / 149	134 / 149
17	G82R	-36	-36
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	850 / 9	850 / 9
20	Forbes SVC / MSC	-28 / 600	-28 / 600
21	RCDC	0	0
22	**Steady State Vltgs**		
23	Dorsey 500/Dorsey 230	1.044 / 1.045	1.044 / 1.045
24	Roseau 500/Forbes 500	1.042 / 1.035	1.042 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.972	1.031 / 0.972
26	Int Falls 115/Badoura 115	1.021 / 1.043	1.021 / 1.043
27	Drayton 230/Groton 345	1.034 / 1.022	1.034 / 1.022
28	**SS OS Relay Margins**		
29	D602F at Forbes/Dorsey	312% / 521%	312% / 521%
30	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 764%
31	R50M/F3M	999% / 323%	999% / 323%
32	B10T	354%	354%
33	**Min/MaxTransientVltg**		
34	Arrowhd 230	0.92 | 1.03	0.99 | 1.04
35	Boise 115	0.95 | 1.04	1.01 | 1.03
36	Dorsey 230	1.02 | 1.08	1.03 | 1.14
37	Forbes 230	0.92 | 1.03	1.02 | 1.04
38	Riverton 230	0.97 | 1.04	1.01 | 1.04
39	Coal Creek 230	0.98 | 1.07	1.00 | 1.06
40	Jamestown 345	0.93 | 1.00	0.95 | 0.99
41	Drayton 230	1.00 | 1.06	1.04 | 1.10
42	Groton 345	0.98 | 1.03	1.00 | 1.04
43	Minong 161	0.96 | 1.08	1.01 | 1.07
44	Wahpeton 115	1.00 | 1.05	1.02 | 1.05
45	Watertown 345	1.00 | 1.03	1.01 | 1.04
46	**Dynamic Voltage Warnings**		
47		none	none
48			
49			
50			
51			
52			
53			
54	Worst Case Angle Damping	KING 3 / 31.63%	KING 3 / 23.81%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	143%	409%
57	K22W (max +dP @ t, d-ang)	50.5@(0.13333,-0.7)	82.8@(1.55833,-28.1)
58	K22W (max -dP @ t, d-ang)	103.2@(0.45000,16.1)	66.0@(0.40833,8.3)
59	K22W (max d-ang @ t, dP)	-26.2@(10.00821,-1.2)	-58.0@(10.00821,45.3)
60	**OS Rel Trip / Marg**		
61	MH - OH		
62	D602F at Forbes/Dorsey	11% / 7%	60% / 88%
63	G82R at Rugby/L20D at Drayton	999% / 223%	999% / 359%
64	R50M / F3M	303% / 196%	487% / 206%
65	B10T	118%	188%
66	**FSCAPS (SS/Unav/Final)**		
67	Balta 230	(0 | 1 | 1)	(0 | 1 | 1)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 5 | 2) / (0 | 1 | 1)	(1 | 5 | 1) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 1 | 1) / (1 | 3 | 2)	(0 | 1 | 0) / (1 | 2 | 2)
71	Shey 115 / Split Rock 115	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A

Case	m3a-so15aa-hfs	m3a-so15aa-hf0
Disturbance	hfs	hf0
System Response	OK	OK
70% or 120% Violations		
ORWG Criteria Violations		
Line Tripping	56	

Table C-6: Mitigation of Constraints for TSR Study Case with Upgrade Option 3

1	**Case No.**	13	14	15	16	17
2	**Case Name**	m3a-so15aa-hna	m3a-so15aa-hns	m3a-so15aa-hnz	m3a-so15aa-hnz	m3a-so15aa-hn0
3	**Disturbance**	hna	hns	hnz	hnz	hn0
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	JUN 15 2009 10:16	JUN 15 2009 11:04	JUN 15 2009 11:37	JUN 15 2009 12:58	JUN 15 2009 11:17
6	**Comments**		Block MH-OH	Forbes 400 MVAr Cap	Forbes 600 MVAr Cap	Trigger DC Reduction
7			Block DCAR	Block MH-OH	Block MH-OH	
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2300 / 156	2300 / 156	2300 / 156	2300 / 156	2300 / 156
10	MHEX / L20D	1949 / 268	1949 / 268	1949 / 268	1949 / 268	1949 / 268
11	ECL-ARP / PRI-BYN	839 / 35	839 / 35	839 / 35	839 / 35	839 / 35
12	MWEX / AHD-SLK	1724 / 647	1724 / 647	1724 / 647	1724 / 647	1724 / 647
13	D602F / F601C	1583 / 1216	1583 / 1216	1583 / 1216	1583 / 1216	1583 / 1216
14	B10T / MH>SPC	161 / 57	161 / 57	161 / 57	161 / 57	161 / 57
15	OH E-W / OH>MH	190 / -194	190 / -194	190 / -194	190 / -194	190 / -194
16	R50M / OH>MP	134 / 149	134 / 149	134 / 149	134 / 149	134 / 149
17	G82R	-36	-36	-36	-36	-36
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	850 / 9	850 / 9	850 / 9	850 / 9	850 / 9
20	Forbes SVC / MSC	-28 / 600	-28 / 600	-28 / 600	-28 / 600	-28 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045	1.044 / 1.045
24	Roseau 500/Forbes 500	1.042 / 1.035	1.042 / 1.035	1.042 / 1.035	1.042 / 1.035	1.042 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 0.972	1.031 / 0.972	1.031 / 0.972	1.031 / 0.972	1.031 / 0.972
26	Int Falls 115/Badoura 115	1.021 / 1.043	1.021 / 1.043	1.021 / 1.043	1.021 / 1.043	1.021 / 1.043
27	Drayton 230/Groton 345	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022	1.034 / 1.022
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	312% / 521%	312% / 521%	312% / 521%	312% / 521%	312% / 521%
30	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 764%	999% / 764%	999% / 764%	999% / 764%
31	R50M/F3M	999% / 323%	999% / 323%	999% / 323%	999% / 323%	999% / 323%
32	B10T	354%	354%	354%	354%	354%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.84 | 1.04	(2.74)0.76 | 1.03	0.90 | 1.01	0.94 | 1.00	0.98 | 1.04
35	Boise 115	0.94 | 1.08	0.90 | 1.05	0.95 | 1.02	0.96 | 1.01	1.01 | 1.03
36	Dorsey 230	0.99 | 1.07	0.99 | 1.05	0.99 | 1.05	0.99 | 1.05	1.03 | 1.14
37	Forbes 230	0.87 | 1.03	(2.77)0.73 | 1.01	0.93 | 1.02	0.98 | 1.02	1.01 | 1.04
38	Riverton 230	0.96 | 1.05	0.92 | 1.05	0.98 | 1.03	0.99 | 1.02	1.01 | 1.04
39	Coal Creek 230	0.97 | 1.07	0.97 | 1.08	0.99 | 1.05	0.99 | 1.05	1.00 | 1.06
40	Jamestown 345	0.92 | 0.99	0.89 | 0.99	0.94 | 0.99	0.94 | 0.99	0.95 | 0.99
41	Drayton 230	0.95 | 1.05	0.86 | 1.03	0.96 | 1.02	0.97 | 1.02	1.04 | 1.10
42	Groton 345	0.96 | 1.03	0.92 | 1.02	0.97 | 1.01	0.98 | 1.01	1.00 | 1.04
43	Minong 161	0.89 | 1.08	0.84 | 1.08	0.94 | 1.05	0.98 | 1.04	1.01 | 1.07
44	Wahpeton 115	0.99 | 1.06	0.96 | 1.06	1.00 | 1.04	1.01 | 1.04	1.02 | 1.05
45	Watertown 345	0.99 | 1.04	0.97 | 1.03	1.00 | 1.02	1.01 | 1.02	1.01 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	61615 [ARROWHD4] 0.80	none	none	none
48			61616 [HILLTOP4] 0.80			
49			61614 [98L TAP4] 0.81			
50			61686 [15TH AV7] 0.81			
51			61672 [HILLTOP7] 0.81			
52			61673 [ARROWHD7] 0.81			
53			687 [MIDWAY 7] 0.81 +mo			
54	Worst Case Angle Damping	KING 3 / 52.36%	ANTEL3 / -19.50%	SHERC3 / 32.51%	SHERC3 / 54.40%	KING 3 / 23.87%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	-123%	-1062%	351%	507%	409%
57	K22W (max +dP @ t, d-ang)	195.0@(1.15000,12.1)	50.5@(0.13333,-0.7)	50.5@(0.13333,-0.7)	50.5@(0.13333,-0.7)	83.6@(1.55833,-28.3)
58	K22W (max -dP @ t, d-ang)	125.5@(1.15000,32.7)	160.6@(2.79165,58.5)	117.2@(1.27500,25.9)	108.1@(1.25833,21.1)	66.3@(0.40833,8.3)
59	K22W (max d-ang @ t, dP)	-59.4@(10.00821,195.0)	59.4@(8.89989,-142.4)	35.7@(2.05833,-101.9)	27.8@(1.89166,-90.2)	-58.2@(10.00821,45.7)
60	**OS Rel Trip / Marg**					
61	MH - OH	1.15000 sec				
62	D602F at Forbes/Dorsey	11% / 7%	-36% / -66%	5% / -3%	3% / -8%	60% / 88%
63	G82R at Rugby/L20D at Drayton	999% / 208%	160% / 88%	999% / 228%	999% / 231%	999% / 359%
64	R50M / F3M	264% / 196%	164% / 196%	307% / 196%	309% / 195%	487% / 206%
65	B10T	81%	28%	84%	88%	189%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 1 | 1)	(0 | 1 | 1)	(0 | 1 | 1)	(0 | 1 | 1)	(0 | 1 | 1)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 2) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 3 | 3)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 5 | 2) / (0 | 1 | 1)	(1 |12 | 6) / (0 | 2 | 2)	(1 | 5 | 4) / (0 | 1 | 1)	(1 | 5 | 4) / (0 | 1 | 1)	(1 | 5 | 1) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 2 | 1) / (1 | 4 | 1)	(0 | 2 | 1) / (1 | 6 | 3)	(0 | 2 | 2) / (1 | 3 | 3)	(0 | 1 | 1) / (1 | 3 | 3)	(0 | 1 | 0) / (1 | 2 | 2)
71	Shey 115 / Split Rock 115	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 5 | 4) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m3a-so15aa-hna	m3a-so15aa-hns	m3a-so15aa-hnz	m3a-so15aa-hnz	m3a-so15aa-hn0
Disturbance	hna	hns	hnz	hnz	hn0
System Response	OK	OK	OK	OK	OK
70% or 120% Violations		AH91HAM			
ORWG Criteria Violations		23			
Line Tripping	2(1T)56	256	56	56	