Report R164-08

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

Prepared for

Midwest ISO

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April 28, 2009

Siemens PTI Project P/21-113318

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Executive Summary

At the MH TSR Group Study meeting held on March 27, 2009, the study group provided comments on the power flow cases being developed for stability analysis and requested analysis of benchmark cases without and with CapX 2020 Group 1 projects. This report describes development and analysis of both benchmark cases and the TSR study cases.

Significant model changes since the previous set of models were released include the following:

- Load in North Dakota has been reduced to approximately 80% of summer peak; generation west of NDEX was reduced by a corresponding amount; generator reductions include coal-field generators dispatched above Pmax and wind generation in eastern North Dakota; wind generation in eastern North Dakota was selected based on discussions with the study group that dispatching wind generation in central and western North Dakota tends to stress the system more than dispatching generation further east
- Center-Harvey-Prairie 345 kV line, Center 345-230 kV xfmr #2 and Harvey 345-230 kV xfmr have been purged
- Amount of new transmission service modeled in the study cases has been reduced to 1130 MW; A340 has been granted 7 MW of service and A339 and A406 have been withdrawn

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.

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. Loading of the MHEX, MWEX and NDEX interfaces was reset in the pre-benchmark case (MHEX = 2175 MW, MWEX = 1525 MW, NDEX=2450 MW). All of the simulated disturbances result in acceptable system performance.

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 reset after adding the CapX projects. All of the simulated disturbances result in acceptable system performance.

Two TSR study cases were created by modeling the requested transmission service in the benchmark case along with one of the two transmission upgrade options. Both cases were analyzed assuming that outage of a new 500 kV facility will be accompanied by an HVDC automatic power order reduction at Dorsey.

With upgrade option 1, all of the simulated disturbances result in acceptable system performance. With upgrade option 3, all of the simulated disturbances result in acceptable system performance except for a steady-state voltage violation at the series capacitor on the new Dorsey-King 500 kV line. The new 500 kV line is modeled without shunt reactors and

with the series capacitor at the line midpoint. The pre-contingency voltage at the series capacitor is 1.19 per unit and the steady-state post-contingency voltage is as high as 1.26 per unit. Mitigation for the Option 3 voltage violation might include series compensating the line in two locations instead of at the midpoint, connecting shunt reactors at the line terminals or adding a substation and connection to the 230 kV system near the line's midpoint.

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. 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: Power Flow Cases

Case ID	Case Description	CapX Projects	Study TSRs and Associated Transmission Upgrades
MB0-so15aa	Pre-Benchmark Case	-	-
MHB-so15aa	Benchmark Case	Group 1 Projects	-
MH1-so15aa	TSR Study Case with Option 1	Group 1 Projects	1130 MW with Upgrade Option 1
MH3-so15aa	TSR Study Case with Option 3	Group 1 Projects	1130 MW with Upgrade Option 3

1.2.1 Pre-Benchmark Case "Mb0-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 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 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 TSR study cases.
9) Apply 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 2 shows the MTEP08 projects that were added to the pre-benchmark case using response files provided by Midwest ISO.

Table 2: MTEP Projects Added to the Stability Case

PrjID	TO	Project Name
56	XEL	La Crosse Area Capacitor banks
177	ATC LLC	Gardner Park-Highway 22 345 kV line projects
552	XEL/GRE	Mankato 115 kV loop
675	XEL	Eau Claire - Hydro Lane 161 kV Conversion
971	XEL	Convert/Relocate the 69 kV Rush River substation to existing 161 kV line from Pine Lake - Crystal Cave
1021	MP/GRE	Embarass to Tower 115 kV Line
1022	MP/GRE	Embarass to Tower 115 kV Line
1025	SMP	Lake City load serving upgrades
1033	XEL	Osceola - Sand Lake 69 Reconductor
1287	ITCM	Replace Salem 345/161 kV transformer with 448 MVA unit
1288	ATC LLC	Gardner Park-Highway 22 345 kV line projects
1289	OTP/MPC	Winger 230/115 kV Transformer Upgrade
1340	XEL	Rebuild Westgate to Scott County 69 kV to 115 kV
1341	GRE/OTP	Silver Lake 230/41.6 kV transformer
1342	ITCM	Replace Salem 345/161 kV transformer with 448 MVA unit
1345	GRE	Crooked Lake - Enterprise Park 115 kV line
1361	MP/GRE	Badoura-Long Lake 115 kV line
1367	XEL/GRE	Scott County - West Waconia 115
1368	XEL	Three Lakes 115/69 kV substation
1369	XEL	Osceola - Sand Lake 69 Reconductor
1370	XEL	Convert/Relocate the 69 kV Rush River substation to existing 161 kV line from Pine Lake - Crystal Cave
1371	XEL	G238, 37642-02, Increase of generating capacity at Riverside Generating Plant
1373	XEL	Ft. Ridgeley - Searles Jct 115 new line and Searles Jct - New Ulm 69 Reconductor
1380	ITCM	Hrn Lk-Lkfld 161kV Ckt 1 Rbld
1455	XEL	G287, 37642-03. Upgrades for G287
1457	XEL	G287, 37642-03. Upgrades for G287
1473	ITCM	Replace Hazleton 345/161 kV transformer #1 with 335 MVA unit

PrjID	TO	Project Name
1482	XEL	Three Lakes 115/69 kV substation
1487	ITCM	Mason City Armor - Emery North 69 kV line
1489	XEL	Woodbury - Tanners Lake upgrade
1522	ITCM	Marshalltown - Toledo - Belle Plaine - Stoney Point 115 kV line rebuild
1545	XEL/GRE	Mankato 115 kV loop
1548	XEL	La Crosse Area Capacitor banks
1549	XEL	Eau Claire - Hydro Lane 161 kV Conversion
1618	ITCM	Marshalltown - Toledo - Belle Plaine - Stoney Point 115 kV line rebuild
1619	GRE	Badoura - Birch Lake 115 lines
1641	ITCM	Hazleton - Lore - Salem 345 kV line with a Lore 345/161 kV 335 MVA transformer
1645	ATC LLC	Cranberry-Conover 115 kV and Conover-Plains conversion to 138 kV
1739	ITCM	Replace two Hazleton 161/69 kV transformers
1753	ITCM	Lewis Fields 161 kV substation which taps the SwampFX - Coggon 115 kV line
1755	ATC LLC	Morgan - Werner West 345 kV line (includes Clintonville-Werner West 138)
1756	ITCM	Lewis Fields 161 kV substation which taps the SwampFX - Coggon 115 kV line
1758	XEL	Chisago - Apple River
1761	ITCM	Readlyn-Tripoli 69kV Rebuild
1772	XEL	Ironwood 92/34.5 kV transformer #2
1953	MP	Pepin Lake 115/34.5 - Transformer 115/34.5 kV 39 MVA
1954	XEL	Somerset - Stanton 69 kV line 84 MVA
1958	ITCM	Hrn Lk-Lkfld 161kV Ckt 1 Rbld
1959	XEL	Yankee Doodle interconnection
1960	XEL	Woodbury - Tanners Lake upgrade
1961	ITCM	6th Street - Beverly
2091	XEL	Black Dog - Wilson 115 kV #2 Reconductor
2092	XEL	Ft. Ridgeley - Searles Jct 115 new line and Searles Jct - New Ulm 69 Reconductor

1.2.1.3 Miscellaneous Updates and Corrections

Table 3 shows miscellaneous model updates and corrections.

Table 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 4 were added to the pre-benchmark case.

Table 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 approximately 80% of summer peak. Generation west of NDEX was reduced by a corresponding amount:

- North Dakota coal field generation dispatched above Pmax was reduced to Pmax (90 MW reduction)
- Big Stone Unit 1 reduced to Pmax (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 "MHB-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 5 shows the CapX 2020 Group 1 projects that were added to the benchmark case using response files provided by Midwest ISO.

Table 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

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

1) Increase loading on MH bipoles 1 and 2 and make corresponding changes to MH generation schedule at Conawapa and Keeyask
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 6.

Table 6: MH to US TSR Sinks

Generator Bus	MW
Removed	

Generator Bus	MW
Removed	

1.2.3.2 Transmission Upgrade Options

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

Table 7: Transmission Upgrade Options

Project	1	2	3
Dorsey – Maple River 50% series compensated 500 kV line terminated via 500/345 kV transformer at Maple River. HVDC reduction for loss of the line or transformer.	X	X	
North LaCrosse – West Middleton 345 kV Line	X	X	X
Maple River – Helena 50% series compensated 500 kV line terminated via 500/345 kV transformer at Helena. HVDC reduction for loss of the line or transformer.	X		
Arrowhead – Chisago – King 345 kV line		X	
Maple River – Arrowhead 50% series compensated 500 kV line terminated via 500/345 kV transformer at Arrowhead. HVDC reduction for loss of the line or transformer.		X	
Dorsey – King 50% series compensated 500 kV line terminated via 500/345 kV transformer at King. HVDC reduction for loss of the line or transformer.			X

1.3 Contingency Criteria

The stability simulations performed as part of this study considered the contingencies listed in Table 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 8: Proposed Stability Disturbances

Pre-Benchmark MB0	Benchmark MHB	TSR Study Option 1 MH1	TSR Study Option 3 MH3	Description
ag1	ag1	ag1	ag1	SLG fault with breaker failure at Leland Olds on the Ft Thompson 345 kV line
ag3	ag3	ag3	ag3	3PH fault at Leland Olds on the Ft Thompson 345 kV line
		cts [1]	cts [1]	SLGBF fault at CHISAGO 345 TR10, Trips CHISAGO-FORBES, and CHISAGO TR; Cross-trip Forbes-Riel
ei2	ei2	ei2	ei2	CU DC permanent bipole fault with tripping of both Coal Creek units
		em3	em3	5.0 cy 3 ph flt @ letellier 230 on drayton line, clr letellier-drayton 230 kv line; dc 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	3PH fault at Square Butte on the Stanton 230 kV line
		mc3	mc3	5.0 cy 3 ph flt @ richer 230 on R50M, clr richer-roseau 230 kv line; dc reduction
		md3	md3	5.0 cy 3 ph flt @ glenboro 230 on G82R, clr glenboro-rugby 230 kv line; dc reduction
		mis	mis	Bipole 2 block in the Manitoba Hydro System, Cross trip Manitoba Ontario Ties @ t=0.35s
		mjs	mjs	SLGBF fault at CHISAGO, Trip CHISAGO-KOHLMAN LAKE, and CHISAGO TR
		mkd	mkd	4 cycle 3 phase fault at Chisago kv, clear the king-Chisago kv line
		mks	mks	SLGBF fault at CHISAGO, Trips CHISAGO-KING, and CHISAGO TR
nad [1]	nad [1]	nad [1]	nad [1]	3PH fault at Forbes on the M602F 500 kV line; dc reduction
nmz [1]	nmz [1]	nmz [1]	nmz [1]	3PH fault at Chisago on the Forbes D601C 500 kV line, xtrip M602F, 100% reduction, leave SVC on MP system
pas [1]	pas [1]	pas [1]	pas [1]	SLG fault with breaker failure at Forbes with 602L stuck, trip Riel-Forbes 500 kV line (M602F); dc reduction

Pre-Benchmark MB0	Benchmark MHB	TSR Study Option 1 MH1	TSR Study Option 3 MH3	Description
		pc0	pc0	SLG fault at King-Eau Claire line with a breaker failure at King, Trips King-ECL and ASK-CHI line
pcs	pcs	pcs	pcs	SLG fault with breaker failure at King with 8P6 stuck
pct	pct	pct	pct	Trip of King-Eau Claire-Arpin without a fault
pys	pzs [2]	pzs [2]	pzs [2]	SLG fault with breaker failure at Prairie Island with 8H9 stuck; Trips Prairie Island-N Rochester line
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 CY 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 3 phase fault at Arrowhead 345 kV, clear the Arrowhead - Stone Lake 345 kv 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; dc reduction
		h73		5 cycle 3PH fault at Dorsey 500 kV, trip the Dorsey-Maple River 500 kV line; dc reduction
			hc3	5 cycle 3PH fault at Dorsey 500 kV, trip Dorsey-King 500 kV line; dc reduction
		hes		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, dc reduction
			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, dc reduction
		h33	h33	5 cycle 3PH fault at Riel, trip Riel-Forbes 500 kV line; dc 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, cross trip the Dorsey-Maple River 500 kV line; dc reduction
		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, cross trip the Dorsey-Maple River 500 kV line, dc reduction
		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

Pre-Benchmark MB0	Benchmark MHB	TSR Study Option 1 MH1	TSR Study Option 3 MH3	Description
		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
			hd3	5 cycle 3PH fault at King 500 kV, trip Dorsey-King line, 100% reduction
			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

Existing 500 kV and 230 kV HVDC reduction Special Protection Schemes (SPS) were simulated in the stability analysis. HVDC reduction assumed for network upgrade options is summarized in Table 9.

Table 9: HVDC Reduction Assumed for Network Upgrade Options

Option	Initiating Event	Flow Measurement	% Reduction at Dorsey Based on Measured Flow
1	Dorsey-Maple River 500 kV line trip	Dorsey-Maple River	100%
1	Maple River 500/230 kV transformer trip	Dorsey-Maple River	None
1	Maple River-Helena 500 kV line trip	Dorsey-Maple River	100%
1	Helena 500/230 kV transformer trip	Dorsey-Maple River	100%
3	Dorsey-King 500 kV line trip	Dorsey-King	100%
3	King 500/230 kV transformer trip	Dorsey-King	100%

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 Simulation Results

1.5.1 Pre-Benchmark and 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.

1.5.2 TSR Study Cases

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

With upgrade option 1, all of the simulated disturbances result in acceptable system performance.

With upgrade option 3, all of the simulated disturbances result in acceptable system performance except for steady-state voltage violations at the series capacitor on the new Dorsey-King 500 kV line. The line is modeled without shunt reactors and with the series capacitor at the line midpoint. The pre-contingency voltage at the series capacitor is 1.19 per unit and the steady-state post-contingency voltage is as high as 1.26 per unit. Mitigation for the Option 3 voltage violation might include series compensating the line in two locations instead of at the midpoint, connecting shunt reactors at the line terminals or adding a substation and connection to the 230 kV system near the line's midpoint.

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

1.11 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
MHEB_Case\upgrades\N-LaCrosse--W-Middleton-345kV.idv
```

3.3.2 Option 3

```
MHEB_Case\upgrades\ Dorsey--King-500kV.idv
MHEB_Case\upgrades\N-LaCrosse--W-Middleton-345kV.idv
```

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:	2449 MW	ECL-ARP:	626 MW
MHEX:	2177 MW	PRI-BYN:	746 MW
MWEX:	1528 MW	AHD-SLK:	638 MW
KING-ECL:	888 MW	SLK-GPK:	444 MW
COOPER S:	1016 MW	WNE-WKS:	524 MW
FTCAL S:	562 MW	GGS:	1615 MW
GRIS-LNC:	679 MW	QC WEST:	184 MW
ALEX-WTPK:	0 MW	NROC-NLAX:	0 MW
DOR-MAP R:	0 MW	DOR-ASK:	0 MW

LOAD LEVELS AS PERCENT OF 2015 SUMMER PEAK:

NORTH DAKOTA	(ZONE 90,990)	2890.0 MW,	77.9% OF	3710.2 MW
NSP	(AREA 600)	8463.5 MW,	71.2% 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/ 243	MH total gross	4960	ATC West Import	1293
Ont. total	22150/ 478	Wpg River	568	ATC SW Import	620
NW	915/ 37	7 Sisters	170	ATC SE Import	-1599
Sask.	2150/ 82	OH total gross	21884	East Bias	220
MP	2342/ 164	northwest	717	SPC>WAPA (B10T)	164
NSP	8463/ 472	SPC total gross	2406	MH>SPC (3-230)	60
N. Dakota	2890/ 295	MP total gross	2861	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	152
NW	489 MVARS	NSP East gross	2552	OH E>W @Wawa	192
Sask.	502 MVARS	net	2420	OH>East USA	0
MP	669 MVARS	West gross	3057	F601C @Forbes	1606
NSP	1786 MVARS	net	2895	D602F @Riel	1804
N. Dakota	753 MVARS	Total net	6191	L20D @Letell	271
ATC	10757/ 303	WAPA SD Hydro	1497	R50M @Richer	137
ATC	3143 MVARS	Pleasant Valley	110	G82R @Glenboro	N/A
		LGS/Trimont	109		
		SW MN Wind	193		
		N DAK WIND	252		
		Swing Bus	1010		

Tfmrs	MVA/ Load	Ph Shifters	Deg/ MW	DC Lines	MW
Wshell #1 7-7	105/ 73%	Stinson	29/ 29	CU (1,2)	1103
Wshell #2 7-7	105/ 73%	Boundary Dam	4/ 165	SQ BU (3,4)	455
Drayton#1 4-7	47/ 34%	Whiteshell	97/ 199	MH Bipole 1	797
Drayton#2 4-7	60/ 32%	Int Falls	120/ 151	MH Bipole 2	903
Dorsey #1 2-4	469/ 39%	St. Lawrence	16/ 0	MH (BP1+BP2)	1700
Dorsey #2 2-4	550/ 45%	Arrowhead	0/ 639	Miles City E>W	-150
Forbes 2-4	50/ 7%			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	-115	600/ -330
SCE 1-3G	18.2 3	-94	480/ -240
SCA 4-6G	18.2 3	-94	480/ -240
Total		-304	1560/ -810
Margin		1864	

SVC's	MVAR	Qmax/ Qmin
Forbes	500 18	400/ -450
Fargo	13.2 -2	20/ -135
Watertown	20.0 30	125/ -86

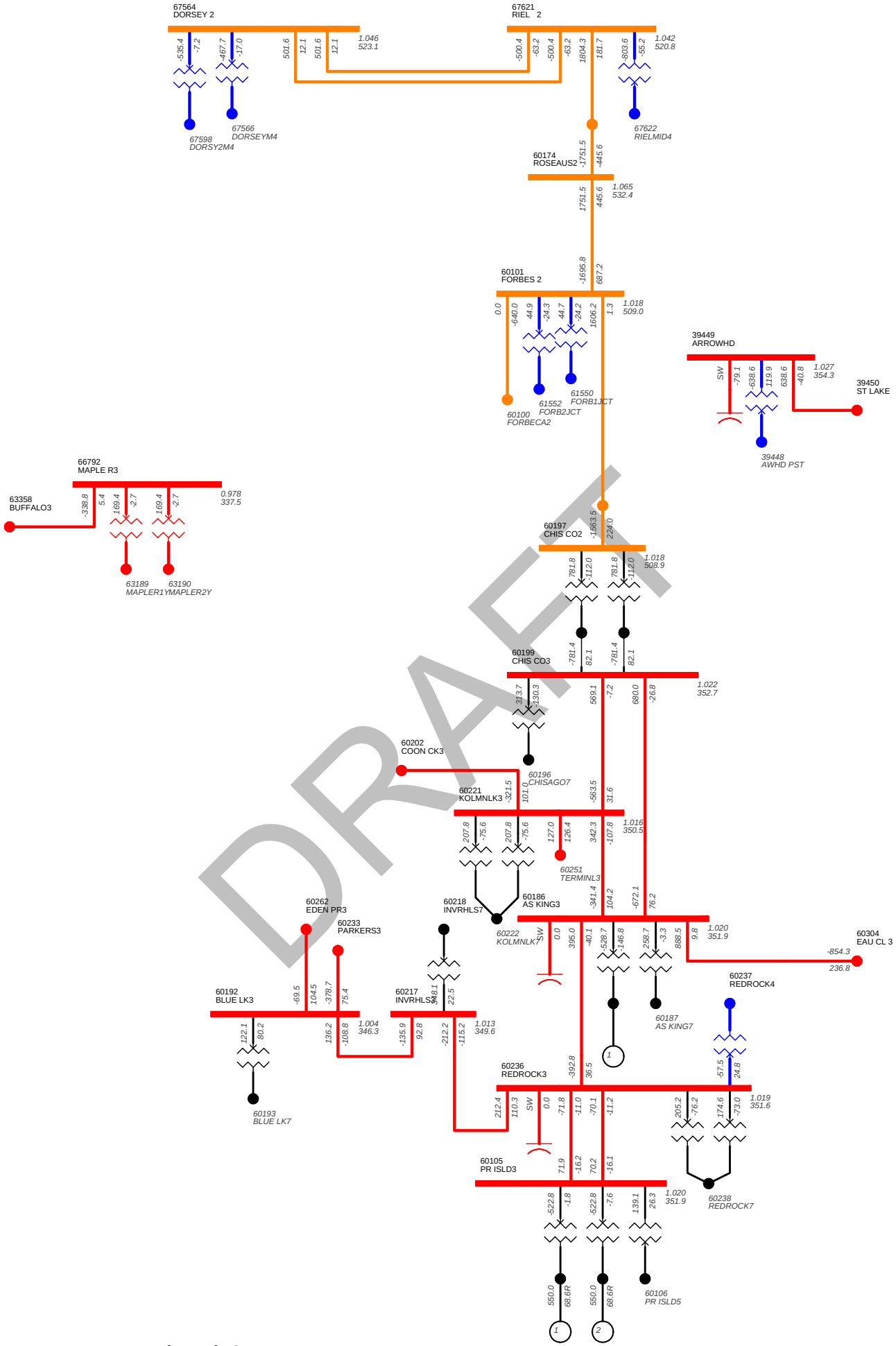
Series Caps	Num In Serv
Roseau	500 2 of 2
Chisago	500 1 of 1

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	75
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	1.008	Arrowhead 230	1.011	Whiteshell 110	118.9
Alexandria 115	1.022	Badoura 115	1.026	Kenora 220	246.5
Audubon 115	1.040	Blackberry 230	1.035	Dryden 220	250.7
Bemidji 115	1.015	Boise Cascade 13.8	1.051	Fort Frances 220	244.3
Byron 345	1.016	Boise Cascade 115	1.019	Mackenzie 220	253.6
Chisago Co. 345	1.022	ETCO 115	1.008	Lakehead 220	246.2
Chisago Co. 500	1.018	Forbes 230	1.022	Marathon 220	253.0
Drayton 230	1.028	Forbes 500	1.018	Wawa 220	254.7
Eau Claire 345	1.028	Hubbard 115	1.021	Mississagi 220	250.7
WEST FARIBAULT 115	1.020	Intl Falls 115	1.020	Fort Frances 118	118.7
LaPorte 115	1.013	Minntac 115	1.015	Lakehead 118	122.8
Maple River 230	1.031	Moranville 230	1.027	Birch 118	120.2
Marshall Tap 115	1.024	Riverton 230	1.019	Marathon 118	123.3
Owatonna 161	1.001	Running 230	1.028		0.000
Prairie 115	1.033	Shannon 230	1.029	Arrowhead 345	1.027
Prairie 230	1.027	Stinson MN 115	1.024	Stone Lake 345	1.037
Ramsey 230	1.005	Jamestown 345	0.983	Stone Lake 161	1.037
Roseau County 230	1.026	Groton 345	1.009	Gardner Park 345	1.035
Roseau County 500	1.065	Watertown 230	1.030	Weston 115	1.035
Sheyenne 230	1.032	Watertown 345	1.023	Arpin 345	1.023
Thief R Falls 115	1.028		0.000	Eau Claire 161	1.039
Tioga 230	1.034	Dorsey 230	1.045	Council Creek 161	0.975
Wahpeton 230	1.019	Dorsey 500	1.046	Hydro Lane 161	1.014
Winger 115	1.043		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	342%	N/A	N/A
2) -Tioga (North)	GE OST	SLLP	702%	N/A	N/A
3) -Tioga (Em North)	GE OST	SLLP		N/A	N/A
4) D602F-Dorsey	ATP ???	SLINOS	999999%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	240%	N/A	N/A
6) -Forbes (Em Nrth)	APT S-PRO	SLINOS		N/A	N/A
8) F3M-Intl Falls	APT S-PRO	SLINOS	315%	N/A	N/A
9) G82R-Rugby	APT	SLINOS	999999%	N/A	N/A
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	743%	N/A	N/A
11) -Drayton (Em Nrth)	ASEA RXZF2	SLINOS		N/A	N/A
12) R50M-Moranville (Norm)	APT, West	SLINOS	987%	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

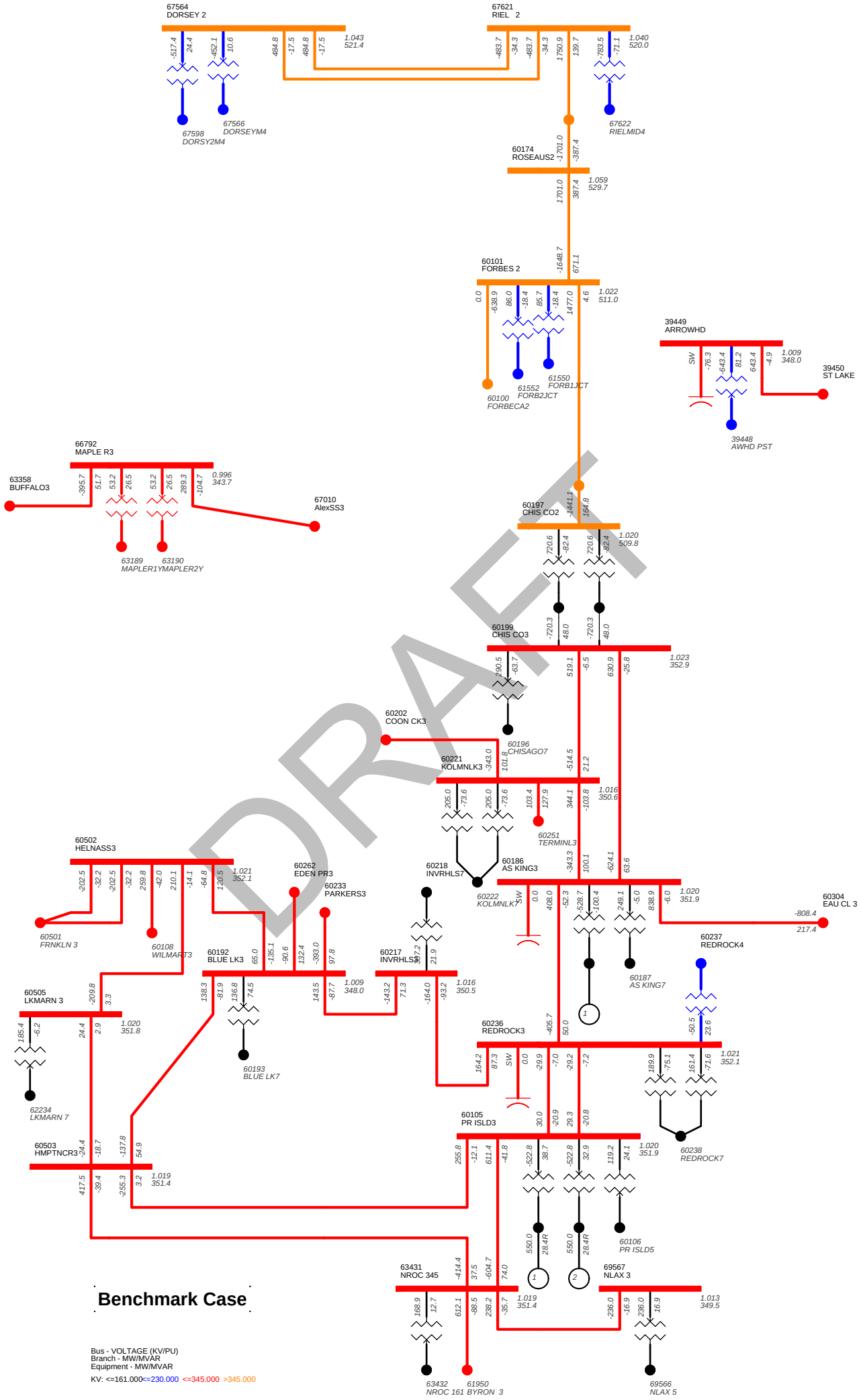
```
                    P O W E R   F L O W   S U M M A R Y
--------------------------------------------------------------------------------
               NDEX:      2316 MW         ECL-ARP:  639 MW
               MHEX:      2175 MW         PRI-BYN:  102 MW
               MWEX:      1483 MW         AHD-SLK:  643 MW
               KING-ECL:   838 MW         SLK-GPK:  450 MW
               COOPER S:  1011 MW         WNE-WKS:  520 MW
               FTCAL S:    556 MW         GGS:     1605 MW
               GRIS-LNC:   653 MW         QC WEST:  195 MW
               MAP R-ALEX: 289 MW         WIL-BOWS:-116 MW
               ALEX-WTPK:  206 MW         NROC-NLAX:238 MW
               DOR-MAP R:    0 MW         DOR-ASK:    0 MW

          LOAD LEVELS AS PERCENT OF 2015 SUMMER PEAK:
          NORTH DAKOTA (ZONE 90,990) 2890.0 MW,  77.9% OF  3710.2 MW
          NSP             (AREA 600) 8463.5 MW,  71.2% 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/ 245       MH total gross    4960     ATC West Import   1349
Ont. total   22150/ 478          Wpg River       568     ATC SW Import      603
     NW        915/  36          7 Sisters       170     ATC SE Import    -1628
Sask.         2150/  82       OH total gross   21884     East Bias          119
MP            2342/ 142          northwest        717     SPC>WAPA (B10T)    164
NSP           8463/ 429       SPC total gross   2406     MH>SPC  (3-230)     60
N. Dakota     2890/ 286       MP total gross    2861     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    2552     OH E>W @Wawa       190
Sask.          502 MVARS                net      2420     OH>East USA          0
MP             669 MVARS          West gross     3057     F601C  @Forbes    1476
NSP           1786 MVARS                net      2895     D602F  @Riel      1750
N. Dakota      753 MVARS          Total net      6191     L20D   @Letell     301
ATC          10757/ 310       WAPA SD Hydro     1497     R50M   @Richer     138
ATC           3143 MVARS      Pleasant Valley    110     G82R   @Glenboro   N/A
                              LGS/Trimont         109
                              SW MN Wind          193
                              N DAK WIND          252
                              Swing Bus           933


Tfmrs          MVA/ Load    Ph Shifters  Deg/  MW      DC Lines           MW
-------------- ---- -----   ------------ --- -----     --------------- ------
Wshell #1 7-7  105/  73%    Stinson       26/   26     CU (1,2)          1104
Wshell #2 7-7  105/  73%    Boundary Dam   1/  165     SQ BU (3,4)        455
Drayton#1 4-7   51/  36%    Whiteshell    94/  200     MH Bipole 1        797
Drayton#2 4-7   65/  34%    Int Falls    117/  150     MH Bipole 2        903
Dorsey #1 2-4  457/  38%    St. Lawrence  16/    0     MH (BP1+BP2)      1700
Dorsey #2 2-4  542/  45%    Arrowhead      0/  644     Miles City E>W    -149
Forbes    2-4   87/  13%                               RCDC (15)            0
Stone Lk  3-5  181/  53%                               Stegall (10)         0

Dorsey SC's       I/S  MVAR  Qmax/ Qmin   SVC's              MVAR  Qmax/ Qmin
----------------- --- -----  ---- -----   ----------------- -----  ---- -----
MIL 7-9G     17.0  2   -137   600/ -330   Forbes        500    12   400/ -450
SCE 1-3G     18.2  3   -112   480/ -240   Fargo       13.2    -3    20/ -135
SCA 4-6G     18.2  3   -112   480/ -240   Watertown   20.0    31   125/  -86
                         -----  ---- -----
       Total            -361  1560/ -810   Series Caps       Num In Serv
       Margin           1921               ----------------- -----------
                                           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	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	1.010	Arrowhead 230	1.005	Whiteshell 110	118.9
Alexandria 115	1.031	Badoura 115	1.041	Kenora 220	246.7
Audubon 115	1.053	Blackberry 230	1.035	Dryden 220	250.9
Bemidji 115	1.037	Boise Cascade 13.8	1.053	Fort Frances 220	244.8
Byron 345	1.020	Boise Cascade 115	1.021	Mackenzie 220	253.8
Chisago Co. 345	1.023	ETCO 115	1.009	Lakehead 220	246.3
Chisago Co. 500	1.020	Forbes 230	1.025	Marathon 220	253.1
Drayton 230	1.027	Forbes 500	1.022	Wawa 220	254.8
Eau Claire 345	1.030	Hubbard 115	1.037	Mississagi 220	250.7
WEST FARIBAULT 115	1.030	Intl Falls 115	1.022	Fort Frances 118	119.0
LaPorte 115	1.032	Minntac 115	1.017	Lakehead 118	122.8
Maple River 230	1.044	Moranville 230	1.027	Birch 118	120.2
Marshall Tap 115	1.030	Riverton 230	1.031	Marathon 118	123.3
Owatonna 161	1.005	Running 230	1.029		0.000
Prairie 115	1.038	Shannon 230	1.031	Arrowhead 345	1.009
Prairie 230	1.031	Stinson MN 115	1.017	Stone Lake 345	1.007
Ramsey 230	1.007	Jamestown 345	0.986	Stone Lake 161	1.015
Roseau County 230	1.027	Groton 345	1.015	Gardner Park 345	1.035
Roseau County 500	1.059	Watertown 230	1.030	Weston 115	1.035
Sheyenne 230	1.042	Watertown 345	1.028	Arpin 345	1.023
Thief R Falls 115	1.036		0.000	Eau Claire 161	1.038
Tioga 230	1.034	Dorsey 230	1.045	Council Creek 161	0.978
Wahpeton 230	1.030	Dorsey 500	1.043	Hydro Lane 161	1.012
Winger 115	1.056		0.000	Wien 115	1.031
	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	342%	N/A	N/A
2) -Tioga (North)	GE OST	SLLP	702%	N/A	N/A
3) -Tioga (Em North)	GE OST	SLLP		N/A	N/A
4) D602F-Dorsey	ATP ???	SLINOS	999999%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	254%	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	999999%	N/A	N/A
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	646%	N/A	N/A
11) -Drayton (Em Nrth)	ASEA RXZF2	SLINOS		N/A	N/A
12) R50M-Moranville (Norm)	APT, West	SLINOS	979%	N/A	N/A
13) -Moranville (Em N)	ASEA RXZF2	SLINOS		N/A	N/A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521.4
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DORSY2M4
67566
DORSEYM4
67621
RIEL 2
1.040
520.0
67622
RIELMID4
60174
ROSEAUS2
1.059
529.7
60101
FORBES 2
1.022
511.0
60100
FORBECA2
61552
FORB2JCT
61550
FORB1JCT
39449
ARROWHD
1.009
348.0
39450
ST LAKE
39448
AWHD PST
66792
MAPLE R3
0.996
343.7
63358
BUFFALO3
67010
AlexSS3
63189
MAPLER1Y
63190
MAPLER2Y
60197
CHIS CO2
1.020
509.8
60199
CHIS CO3
1.023
352.9
60196
CHISAGO7
60202
COON CK3
60221
KOLMNLK3
1.016
350.6
60251
TERMINL3
60186
AS KING3
60218
INVRHLS7
60222
KOLMNLK7
1.020
351.9
60304
EAU CL 3
60187
AS KING7
60237
REDROCK4
60502
HELNASS3
1.021
352.1
60501
FRNKLN 3
60108
WILMART3
60262
EDEN PR3
60233
PARKERS3
60192
BLUE LK3
1.009
348.0
60193
BLUE LK7
60217
INVRHLS3
1.016
350.5
60505
LKMARN 3
1.020
351.8
62234
LKMARN 7
60236
REDROCK3
1.021
352.1
60238
REDROCK7
60105
PR ISLD3
1.020
351.9
60106
PR ISLD5
60503
HMPTNCR3
1.019
351.4
63431
NROC 345
1.019
351.4
63432
NROC 161
61950
BYRON 3
69567
NLAX 3
1.013
349.5
69566
NLAX 5
Benchmark Case
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000<=230.000 <=345.000 >345.000
DRAFT

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

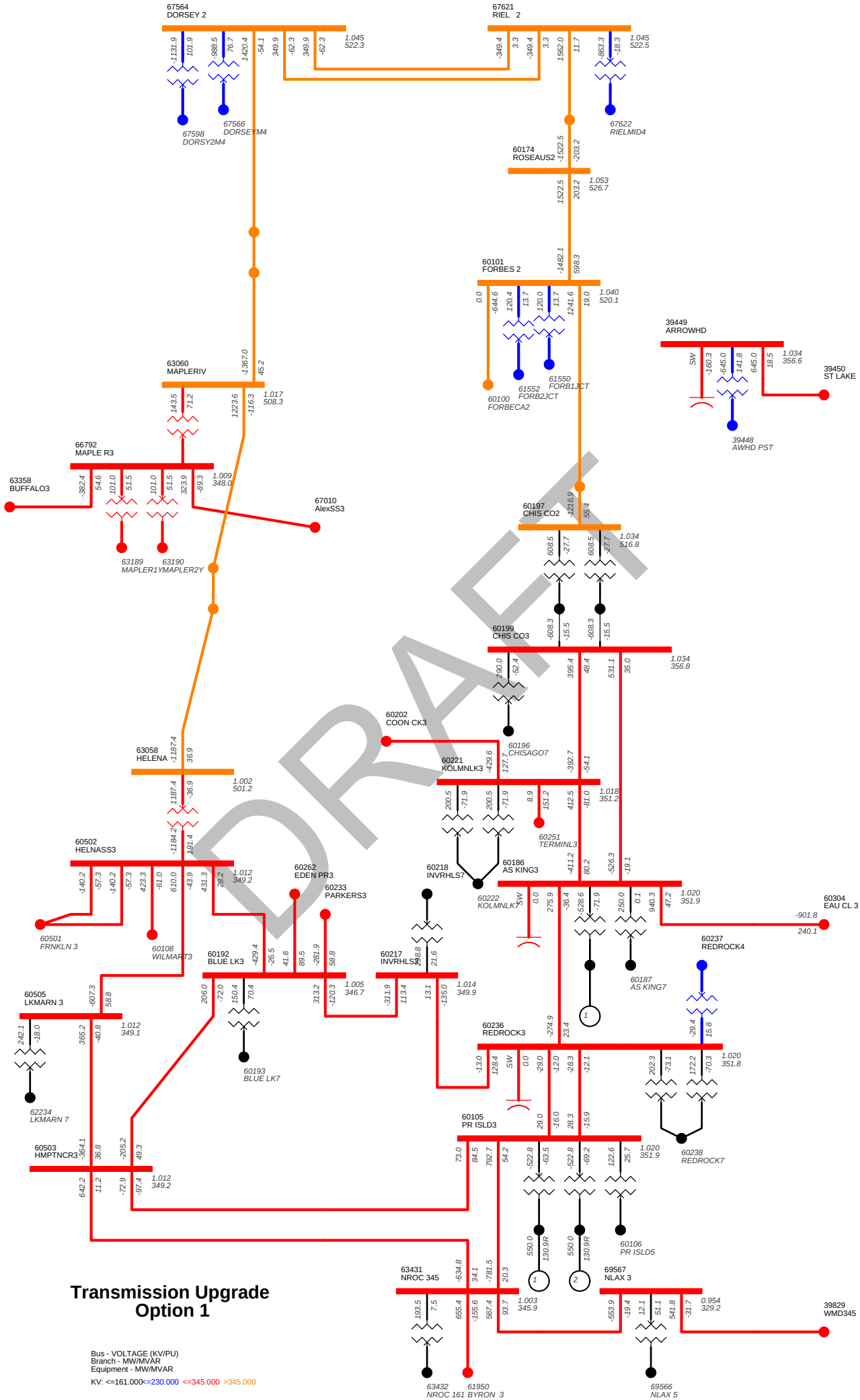
```
                    P O W E R   F L O W   S U M M A R Y
-------------------------------------------------------------------------------
               NDEX:      2400 MW         ECL-ARP:  692 MW
               MHEX:      1887 MW         PRI-BYN:  110 MW
               MWEX:      1586 MW         AHD-SLK:  644 MW
               KING-ECL:   940 MW         SLK-GPK:  470 MW
               COOPER S:  1013 MW         WNE-WKS:  520 MW
               FTCAL S:    569 MW         GGS:     1605 MW
               GRIS-LNC:   655 MW         QC WEST:  209 MW
               MAP R-ALEX: 323 MW         WIL-BOS:  -73 MW
               ALEX-WTPK:  229 MW         NROC-NLAX:567 MW
               DOR-MAP R: 1429 MW         DOR-ASK:    0 MW

          LOAD LEVELS AS PERCENT OF 2015 SUMMER PEAK:
          NORTH DAKOTA (ZONE 90,990) 2890.0 MW,  77.9% OF  3710.2 MW
          NSP             (AREA 600) 8463.5 MW,  71.2% 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/ 331      MH total gross    6179     ATC West Import   1387
Ont. total   22150/ 478         Wpg River       568     ATC SW Import      441
     NW        915/  36         7 Sisters       170     ATC SE Import    -1455
Sask.         2150/  82      OH total gross   21884     East Bias          173
MP            2342/ 134         northwest        717     SPC>WAPA (B10T)    164
NSP           8463/ 459      SPC total gross   2406     MH>SPC  (3-230)     60
N. Dakota     2890/ 277      MP total gross    2611     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    150
     NW        489 MVARS     NSP East gross    2552     OH E>W @Wawa       190
Sask.          502 MVARS             net       2420     OH>East USA          0
MP             669 MVARS           West gross  3027     F601C  @Forbes    1241
NSP           1786 MVARS             net       2865     D602F  @Riel      1562
N. Dakota      753 MVARS           Total net    6111     L20D   @Letell     245
ATC           10757/ 312      WAPA SD Hydro    1497     R50M   @Richer     130
ATC            3143 MVARS     Pleasant Valley     0     G82R   @Glenboro   N/A
                              LGS/Trimont        19
                              SW MN Wind        193
                              N DAK WIND        252
                              Swing Bus        1020


Tfmrs          MVA/ Load     Ph Shifters  Deg/  MW      DC Lines          MW
------------ ---- -----     ----------- --- -----     -------------- ------
Wshell #1 7-7  105/  73%     Stinson      24/   33     CU (1,2)         1104
Wshell #2 7-7  105/  73%     Boundary Dam  7/  165     SQ BU (3,4)       454
Drayton#1 4-7   44/  32%     Whiteshell   87/  199     MH Bipole 1      1522
Drayton#2 4-7   57/  30%     Int Falls   110/  150     MH Bipole 2      1723
Dorsey #1 2-4  990/  82%     St. Lawrence 16/    0     MH (BP1+BP2)     3245
Dorsey #2 2-4 1141/  95%     Arrowhead     1/  646     Miles City E>W   -150
Forbes    2-4  120/  17%                               RCDC (15)           0
Stone Lk  3-5  162/  48%                               Stegall (10)        0

Dorsey SC's       I/S  MVAR  Qmax/ Qmin    SVC's             MVAR  Qmax/ Qmin
---------------- --- -----  ---- -----    ---------------- -----  ---- -----
MIL 7-9G     17.0  2    312   600/ -330    Forbes            500    -4   400/ -450
SCE 1-3G     18.2  3    254   480/ -240    Fargo            13.2   -16    20/ -135
SCA 4-6G     18.2  3    254   480/ -240    Watertown        20.0    17   125/  -86
                          -----  ---- -----
       Total              821  1560/ -810    Series Caps       Num In Serv
       Margin             739                ---------------- -----------
                                             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	0	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	1.002	Arrowhead 230	1.012	Whiteshell 110	118.9
Alexandria 115	1.035	Badoura 115	1.044	Kenora 220	247.0
Audubon 115	1.056	Blackberry 230	1.035	Dryden 220	251.1
Bemidji 115	1.039	Boise Cascade 13.8	1.055	Fort Frances 220	245.3
Byron 345	1.007	Boise Cascade 115	1.023	Mackenzie 220	254.1
Chisago Co. 345	1.034	ETCO 115	1.017	Lakehead 220	246.3
Chisago Co. 500	1.034	Forbes 230	1.038	Marathon 220	253.1
Drayton 230	1.038	Forbes 500	1.040	Wawa 220	254.8
Eau Claire 345	1.019	Hubbard 115	1.039	Mississagi 220	250.7
WEST FARIBAULT 115	1.026	Intl Falls 115	1.024	Fort Frances 118	119.3
LaPorte 115	1.034	Minntac 115	1.025	Lakehead 118	122.8
Maple River 230	1.053	Moranville 230	1.034	Birch 118	120.2
Marshall Tap 115	1.030	Riverton 230	1.034	Marathon 118	123.3
Owatonna 161	1.002	Running 230	1.037		0.000
Prairie 115	1.044	Shannon 230	1.035	Arrowhead 345	1.034
Prairie 230	1.038	Stinson MN 115	1.018	Stone Lake 345	1.021
Ramsey 230	1.010	Jamestown 345	0.997	Stone Lake 161	1.025
Roseau County 230	1.034	Groton 345	1.018	Gardner Park 345	1.035
Roseau County 500	1.053	Watertown 230	1.030	Weston 115	1.035
Sheyenne 230	1.046	Watertown 345	1.029	Arpin 345	1.018
Thief R Falls 115	1.041		0.000	Eau Claire 161	1.032
Tioga 230	1.034	Dorsey 230	1.045	Council Creek 161	0.982
Wahpeton 230	1.033	Dorsey 500	1.045	Hydro Lane 161	1.006
Winger 115	1.056		0.000	Wien 115	1.027
	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	342%	N/A	N/A
2) -Tioga (North)	GE OST	SLLP	702%	N/A	N/A
3) -Tioga (Em North)	GE OST	SLLP		N/A	N/A
4) D602F-Dorsey	ATP ???	SLINOS	999999%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	321%	N/A	N/A
6) -Forbes (Em Nrth)	APT S-PRO	SLINOS		N/A	N/A
8) F3M-Intl Falls	APT S-PRO	SLINOS	325%	N/A	N/A
9) G82R-Rugby	APT	SLINOS	999999%	N/A	N/A
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	864%	N/A	N/A
11) -Drayton (Em Nrth)	ASEA RXZF2	SLINOS		N/A	N/A
12) R50M-Moranville (Norm)	APT, West	SLINOS	1076%	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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DORSEYM4
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60101
FORBES 2
60100
FORBECA2
61552
FORB2JCT
61550
FORB1JCT
39449
ARROWHD
39450
ST LAKE
39448
AWHD PST
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MAPLE R3
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BUFFALO3
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AlexSS3
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MAPLER1Y
63190
MAPLER2Y
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CHIS CO2
60199
CHIS CO3
60196
CHISAGO7
60202
COON CK3
63058
HELENA
60221
KOLMNLK3
60251
TERMINL3
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INVRHLS7
60186
AS KING3
60222
KOLMNLK7
60304
EAU CL 3
60237
REDROCK4
60187
AS KING7
60502
HELNASS3
60501
FRNKLN 3
60108
WILMART3
60262
EDEN PR3
60233
PARKERS3
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BLUE LK3
60217
INVRHLS3
60193
BLUE LK7
60505
LKMARN 3
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LKMARN 7
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REDROCK3
60238
REDROCK7
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PR ISLD3
60106
PR ISLD5
60503
HMPTNCR3
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NROC 345
63432
NROC 161
61950
BYRON 3
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NLAX 5
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1.012
349.2
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345.9
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329.2
SW
1
2
DRAFT
Transmission Upgrade
Option 1
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000<=230.000 <=345.000 >345.000

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

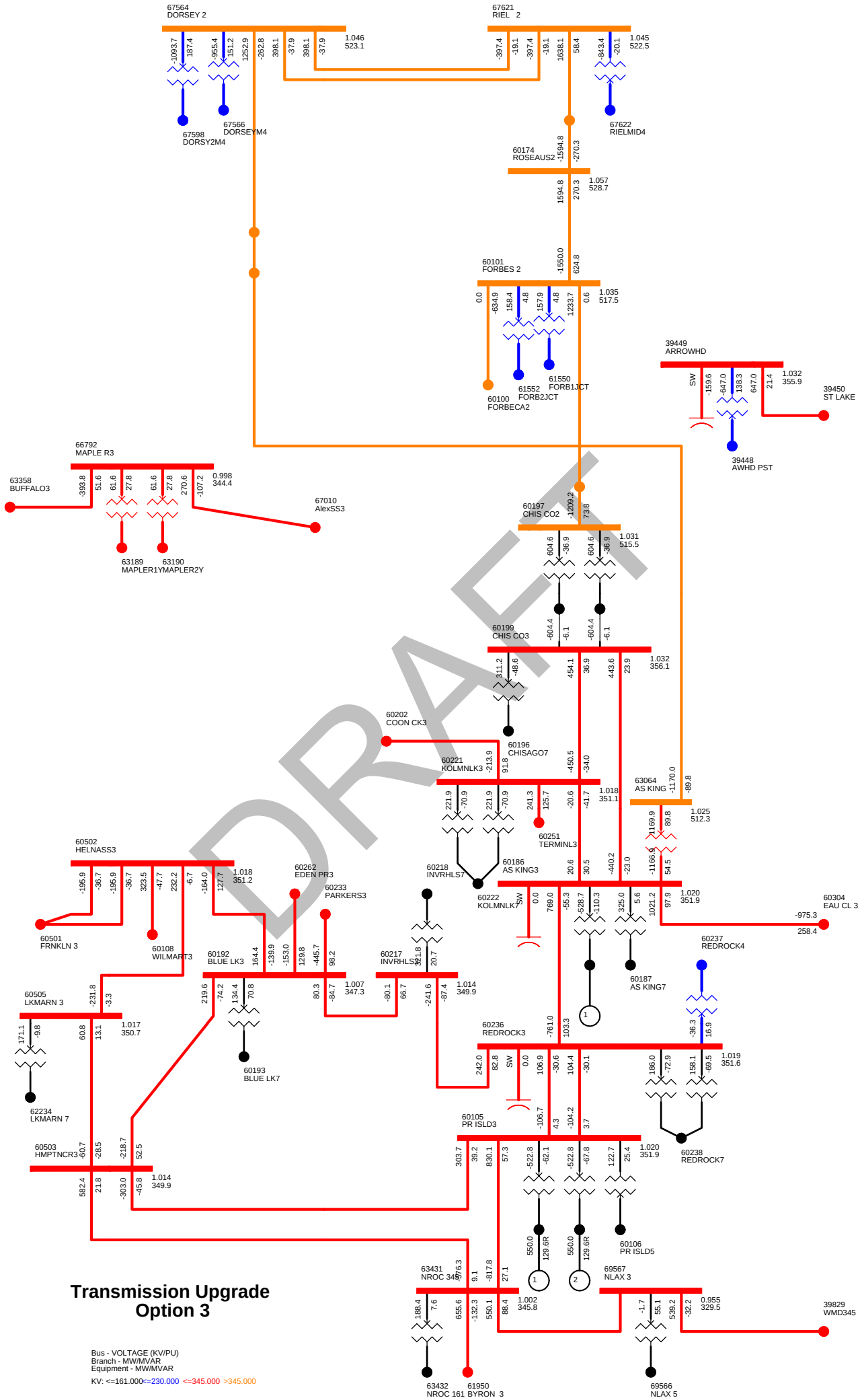
```
                    P O W E R   F L O W   S U M M A R Y
-------------------------------------------------------------------------------
               NDEX:      2329 MW          ECL-ARP:  726 MW
               MHEX:      2052 MW          PRI-BYN:  119 MW
               MWEX:      1669 MW          AHD-SLK:  647 MW
               KING-ECL:  1021 MW          SLK-GPK:  476 MW
               COOPER S:   994 MW          WNE-WKS:  517 MW
               FTCAL S:    547 MW          GGS:     1605 MW
               GRIS-LNC:   654 MW          QC WEST:  224 MW
               MAP R-ALEX: 270 MW          WIL-BOWS: -98 MW
               ALEX-WTPK:  179 MW          NROC-NLAX:550 MW
               DOR-MAP R:    0 MW          DOR-ASK: 1257 MW

          LOAD LEVELS AS PERCENT OF 2015 SUMMER PEAK:
          NORTH DAKOTA (ZONE 90,990) 2890.0 MW,  77.9% OF  3710.2 MW
          NSP              (AREA 600) 8463.5 MW,  71.2% 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/ 333      MH total gross    6179     ATC West Import   1424
Ont. total   22150/ 478         Wpg River       568     ATC SW Import      430
     NW        915/  36         7 Sisters       170     ATC SE Import    -1475
Sask.         2150/  82      OH total gross   21884     East Bias          130
MP            2342/ 136         northwest       717     SPC>WAPA (B10T)    165
NSP           8463/ 531      SPC total gross   2406     MH>SPC  (3-230)     60
N. Dakota     2890/ 284      MP total gross    2611     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    150
     NW        489 MVARS     NSP East gross    2552     OH E>W @Wawa       190
Sask.          502 MVARS              net       2420     OH>East USA          0
MP             669 MVARS           West gross   3027     F601C  @Forbes    1233
NSP           1786 MVARS              net       2865     D602F  @Riel      1638
N. Dakota      753 MVARS            Total net    6111     L20D   @Letell     293
ATC           10757/ 315      WAPA SD Hydro     1497     R50M   @Richer     138
ATC            3143 MVARS     Pleasant Valley      0     G82R   @Glenboro   N/A
                              LGS/Trimont         19
                              SW MN Wind         193
                              N DAK WIND         252
                              Swing Bus         1036


Tfmrs          MVA/ Load      Ph Shifters  Deg/  MW      DC Lines           MW
-------------- ---- -----     ------------ --- -----     ---------------- ------
Wshell #1 7-7  105/  73%      Stinson       26/   30     CU (1,2)         1104
Wshell #2 7-7  105/  73%      Boundary Dam   1/  165     SQ BU (3,4)       455
Drayton#1 4-7   50/  35%      Whiteshell    92/  199     MH Bipole 1      1522
Drayton#2 4-7   63/  34%      Int Falls    114/  150     MH Bipole 2      1723
Dorsey #1 2-4  964/  80%      St. Lawrence  16/    0     MH (BP1+BP2)     3245
Dorsey #2 2-4 1119/  93%      Arrowhead      2/  648     Miles City E>W    -149
Forbes    2-4  157/  23%                                 RCDC (15)           0
Stone Lk  3-5  158/  47%                                 Stegall (10)        0

Dorsey SC's       I/S  MVAR  Qmax/ Qmin    SVC's              MVAR  Qmax/ Qmin
----------------- --- -----  ---- -----    ----------------- -----  ---- -----
MIL 7-9G     17.0  2    250   600/ -330    Forbes        500    -7   400/ -450
SCE 1-3G     18.2  3    204   480/ -240    Fargo        13.2    -9    20/ -135
SCA 4-6G     18.2  3    204   480/ -240    Watertown    20.0   -48   125/  -86
                          -----  ---- -----
       Total              660  1560/ -810    Series Caps       Num In Serv
       Margin             900               ----------------- -----------
                                            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	76
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	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	1.002	Arrowhead 230	1.011	Whiteshell 110	118.9
Alexandria 115	1.034	Badoura 115	1.044	Kenora 220	246.9
Audubon 115	1.056	Blackberry 230	1.035	Dryden 220	251.0
Bemidji 115	1.039	Boise Cascade 13.8	1.054	Fort Frances 220	245.1
Byron 345	1.006	Boise Cascade 115	1.023	Mackenzie 220	254.0
Chisago Co. 345	1.032	ETCO 115	1.014	Lakehead 220	246.3
Chisago Co. 500	1.031	Forbes 230	1.034	Marathon 220	253.1
Drayton 230	1.029	Forbes 500	1.035	Wawa 220	254.8
Eau Claire 345	1.009	Hubbard 115	1.040	Mississagi 220	250.7
WEST FARIBAULT 115	1.027	Intl Falls 115	1.023	Fort Frances 118	119.2
LaPorte 115	1.035	Minntac 115	1.021	Lakehead 118	122.8
Maple River 230	1.046	Moranville 230	1.028	Birch 118	120.2
Marshall Tap 115	1.029	Riverton 230	1.034	Marathon 118	123.3
Owatonna 161	1.000	Running 230	1.031		0.000
Prairie 115	1.039	Shannon 230	1.033	Arrowhead 345	1.032
Prairie 230	1.033	Stinson MN 115	1.017	Stone Lake 345	1.019
Ramsey 230	1.008	Jamestown 345	0.988	Stone Lake 161	1.021
Roseau County 230	1.028	Groton 345	1.015	Gardner Park 345	1.035
Roseau County 500	1.057	Watertown 230	1.030	Weston 115	1.035
Sheyenne 230	1.043	Watertown 345	1.028	Arpin 345	1.013
Thief R Falls 115	1.038		0.000	Eau Claire 161	1.030
Tioga 230	1.034	Dorsey 230	1.045	Council Creek 161	0.980
Wahpeton 230	1.031	Dorsey 500	1.046	Hydro Lane 161	1.005
Winger 115	1.058		0.000	Wien 115	1.043
	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	341%	N/A	N/A
2) -Tioga (North)	GE OST	SLLP	701%	N/A	N/A
3) -Tioga (Em North)	GE OST	SLLP		N/A	N/A
4) D602F-Dorsey	ATP ???	SLINOS	999999%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	295%	N/A	N/A
6) -Forbes (Em Nrth)	APT S-PRO	SLINOS		N/A	N/A
8) F3M-Intl Falls	APT S-PRO	SLINOS	324%	N/A	N/A
9) G82R-Rugby	APT	SLINOS	999999%	N/A	N/A
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	672%	N/A	N/A
11) -Drayton (Em Nrth)	ASEA RXZF2	SLINOS		N/A	N/A
12) R50M-Moranville (Norm)	APT, West	SLINOS	978%	N/A	N/A
13) -Moranville (Em N)	ASEA RXZF2	SLINOS		N/A	N/A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512.3
60251
TERMINL3
60218
INVRHLS7
60186
AS KING3
60222
KOLMNLK7
1.020
351.9
60304
EAU CL 3
60502
HELNASS3
1.018
351.2
60501
FRNKLN 3
60108
WILMART3
60262
EDEN PR3
60233
PARKERS3
60192
BLUE LK3
60217
INVRHLS1
1.007
347.3
1.014
349.9
60193
BLUE LK7
60237
REDROCK4
60187
AS KING7
60505
LKMARN 3
1.017
350.7
62234
LKMARN 7
60236
REDROCK3
1.019
351.6
60238
REDROCK7
60503
HMPTNCR3
1.014
349.9
60105
PR ISLD3
1.020
351.9
60106
PR ISLD5
63431
NROC 345
1.002
345.8
69567
NLAX 3
0.955
329.5
39829
WMD345
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
DRAFT

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Appendix

C

Transient Stability Summary Tables

Table C-1: Pre-Benchmark Case MB0

Table C-2: Benchmark Case MHB

Table C-3: TSR Study Case MH1 with Upgrade Option 1

Table C-4: TSR Study Case MH3 with Upgrade Option 3

Table C-1: Pre-Benchmark Case

	Case No.	1	2	3	4	5
	Case Name	Mb0-so15aa-ag1	Mb0-so15aa-ag3	Mb0-so15aa-ei2	Mb0-so15aa-eq1	Mb0-so15aa-fds
	Disturbance	ag1	ag3	ei2	eq1	fds
	Prior Outage	None	None	None	None	None
	Date/Time	APR 15 2009 17:19	APR 15 2009 17:40	APR 15 2009 18:00	APR 15 2009 18:20	APR 15 2009 18:44
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2449 / 220	2449 / 220	2449 / 220	2449 / 220	2449 / 220
	MHEX / L20D	2177 / 271	2177 / 271	2177 / 271	2177 / 271	2177 / 271
	ECL-ARP / PRI-BYN	626 / 746	626 / 746	626 / 746	626 / 746	626 / 746
	MWEX / AHD-SLK	1528 / 638	1528 / 638	1528 / 638	1528 / 638	1528 / 638
	D602F / F601C	0 / 1606	0 / 1606	0 / 1606	0 / 1606	0 / 1606
	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60	164 / 60
	OH E-W / OH>MH	192 / -195	192 / -195	192 / -195	192 / -195	192 / -195
	R50M / OH>MP	137 / 152	137 / 152	137 / 152	137 / 152	137 / 152
	G82R	N/A	N/A	N/A	N/A	N/A
	Dorsey bipole / CU bipole	1700 / 1104	1700 / 1104	1700 / 1104	1700 / 1104	1700 / 1104
	Dorsey Reserve / Wtrtn SVC	1864 / 30	1864 / 30	1864 / 30	1864 / 30	1864 / 30
	Forbes SVC / MSC	18 / 600	18 / 600	18 / 600	18 / 600	18 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045
	Roseau 500/Forbes 500	1.032 / 1.018	1.032 / 1.018	1.032 / 1.018	1.032 / 1.018	1.032 / 1.018
	Chisago 500/EauClaire 345	1.018 / 1.028	1.018 / 1.028	1.018 / 1.028	1.018 / 1.028	1.018 / 1.028
	Int Falls 115/Badoura 115	1.020 / 1.026	1.020 / 1.026	1.020 / 1.026	1.020 / 1.026	1.020 / 1.026
	Drayton 230/Groton 345	1.028 / 1.009	1.028 / 1.009	1.028 / 1.009	1.028 / 1.009	1.028 / 1.009
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	240% / 999%	240% / 999%	240% / 999%	240% / 999%	240% / 999%
	G82R at Rugby/L20D at Drayton	999% / 744%	999% / 744%	999% / 744%	999% / 744%	999% / 744%
	R50M/F3M	988% / 315%	988% / 315%	988% / 315%	988% / 315%	988% / 315%
	B10T	344%	344%	344%	344%	344%
	Min/MaxTransientVltg					
	Arrowhd 230	0.99 | 1.02	0.99 | 1.02	0.98 | 1.04	0.99 | 1.04	0.98 | 1.03
	Boise 115	1.00 | 1.03	1.00 | 1.03	0.99 | 1.01	1.00 | 1.02	1.01 | 1.03
	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05
	Forbes 230	1.01 | 1.03	1.01 | 1.03	0.99 | 1.03	1.00 | 1.03	1.01 | 1.03
	Riverton 230	0.99 | 1.03	0.99 | 1.04	0.95 | 1.04	0.98 | 1.04	0.98 | 1.04
	Coal Creek 230	0.97 | 1.11	0.97 | 1.11	1.02 | 1.11	1.00 | 1.16	0.97 | 1.13
	Jamestown 345	0.91 | 1.03	0.89 | 1.04	0.86 | 1.04	0.89 | 1.05	0.82 | 1.06
	Drayton 230	1.01 | 1.06	1.00 | 1.07	0.98 | 1.07	1.02 | 1.08	1.00 | 1.07
	Groton 345	0.89 | 1.03	0.88 | 1.03	0.89 | 1.06	0.92 | 1.06	0.93 | 1.05
	Minong 161	1.01 | 1.04	1.01 | 1.04	1.02 | 1.07	1.03 | 1.06	1.01 | 1.04
	Wahpeton 115	0.99 | 1.07	0.97 | 1.07	0.93 | 1.08	0.98 | 1.08	0.96 | 1.08
	Watertown 345	0.96 | 1.04	0.96 | 1.04	0.94 | 1.06	0.97 | 1.05	0.97 | 1.05
	Dynamic Voltage Warnings					
		none	none	none	none	none
	Worst Case Angle Damping	KING 3 / 77.88%	KING 3 / 77.39%	SHERC3 / 22.12%	KING 3 / 30.00%	MNTCE3 / 71.80%
	Dorsey SUVP / UdHold					
	Forbes DC Red (DCAR)	463%	464%	507%	507%	452%
	K22W (max +dP @ t, d-ang)	9.9@(2.44999,2.0)	13.8@(2.40832,0.8)	57.6@(2.40832,-28.0)	40.5@(2.34166,-17.1)	13.3@(2.49166,-1.1)
	K22W (max -dP @ t, d-ang)	19.2@(0.79166,5.0)	20.3@(0.74166,5.7)	3.1@(0.46666,0.1)	3.1@(0.30833,0.1)	12.8@(0.73333,2.2)
	K22W (max d-ang @ t, dP)	7.3@(1.05833,-7.3)	8.0@(1.00000,-8.9)	-65.6@(20.00806,31.8)	-36.2@(20.00806,18.3)	4.5@(1.04166,-3.9)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	198% / -0.01667 sec	195% / -0.01667 sec	158% / -0.01667 sec	188% / -0.01667 sec	207% / -0.01667 sec
	G82R at Rugby/L20D at Drayton	-0.01667 sec / 621%	-0.01667 sec / 602%	-0.01667 sec / 536%	-0.01667 sec / 578%	-0.01667 sec / 601%
	R50M / F3M	846% / 277%	837% / 274%	790% / 226%	859% / 255%	859% / 281%
	B10T	199%	182%	106%	127%	172%
	FSCAPS (SS/Unav/Final)					
	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 0)	(0 | 0 | 0)
	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)
	Prairie 115 / Ramsey 230	(1 | 2 | 1) / (0 | 1 | 1)	(1 | 3 | 1) / (0 | 2 | 2)	(1 | 3 | 1) / (0 | 1 | 1)	(1 | 3 | 1) / (0 | 1 | 1)	(1 | 3 | 1) / (0 | 2 | 2)
	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 | 2 | 2) / (1 | 1 | 1)	(1 | 3 | 2) / (1 | 2 | 2)	(1 | 4 | 2) / (1 | 1 | 1)	(1 | 4 | 2) / (1 | 1 | 1)	(1 | 4 | 1) / (1 | 1 | 1)

Case	Mb0-so15aa-ag1	Mb0-so15aa-ag3	Mb0-so15aa-ei2	Mb0-so15aa-eq1	Mb0-so15aa-fds
Disturbance	ag1	ag3	ei2	eq1	fds
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(4T)(6T)	(4T)(6T)	(4T)(6T)	(4T)(6T)	(4T)(6T)

Table C-1: Pre-Benchmark Case

	Case No.	6	7	8	9	10
2	**Case Name**	mb0-so15aa-nad	mb0-so15aa-nad	mb0-so15aa-nad	Mb0-so15aa-pcs	Mb0-so15aa-pct
3	**Disturbance**	nad	nmz	pas	pcs	pct
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 22 2009 13:08	APR 22 2009 13:13	APR 22 2009 13:18	APR 15 2009 20:46	APR 15 2009 21:07
6	**Comments**	Dorsey tertiary capacitors off	Dorsey tertiary capacitors off	Dorsey tertiary capacitors off		
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2449 / 220	2449 / 220	2449 / 220	2449 / 220	2449 / 220
10	MHEX / L20D	2177 / 271	2177 / 271	2177 / 271	2177 / 271	2177 / 271
11	ECL-ARP / PRI-BYN	626 / 746	626 / 746	626 / 746	626 / 746	626 / 746
12	MWEX / AHD-SLK	1528 / 638	1528 / 638	1528 / 638	1528 / 638	1528 / 638
13	D602F / F601C	0 / 1606	0 / 1606	0 / 1606	0 / 1606	0 / 1606
14	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60	164 / 60
15	OH E-W / OH>MH	192 / -195	192 / -195	192 / -195	192 / -195	192 / -195
16	R50M / OH>MP	137 / 152	137 / 152	137 / 152	137 / 152	137 / 152
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	1700 / 1104	1700 / 1104	1700 / 1104	1700 / 1104	1700 / 1104
19	Dorsey Reserve / Wtrtn SVC	1617 / 30	1617 / 30	1617 / 30	1864 / 30	1864 / 30
20	Forbes SVC / MSC	15 / 600	15 / 600	15 / 600	18 / 600	18 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.048 / 1.045	1.048 / 1.045	1.048 / 1.045	1.046 / 1.045	1.046 / 1.045
24	Roseau 500/Forbes 500	1.032 / 1.018	1.032 / 1.018	1.032 / 1.018	1.032 / 1.018	1.032 / 1.018
25	Chisago 500/EauClaire 345	1.018 / 1.028	1.018 / 1.028	1.018 / 1.028	1.018 / 1.028	1.018 / 1.028
26	Int Falls 115/Badoura 115	1.020 / 1.026	1.020 / 1.026	1.020 / 1.026	1.020 / 1.026	1.020 / 1.026
27	Drayton 230/Groton 345	1.028 / 1.009	1.028 / 1.009	1.028 / 1.009	1.028 / 1.009	1.028 / 1.009
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	240% / 999%	240% / 999%	240% / 999%	240% / 999%	240% / 999%
30	G82R at Rugby/L20D at Drayton	999% / 745%	999% / 745%	999% / 745%	999% / 744%	999% / 744%
31	R50M/F3M	989% / 315%	989% / 315%	989% / 315%	988% / 315%	988% / 315%
32	B10T	344%	344%	344%	344%	344%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.01 | 1.06	0.93 | 1.08	1.00 | 1.06	0.91 | 0.99	0.95 | 0.98
35	Boise 115	0.90 | 1.03	0.94 | 1.03	0.97 | 1.03	1.00 | 1.04	1.02 | 1.03
36	Dorsey 230	1.04 | 1.07	1.05 | 1.07	1.05 | 1.07	1.04 | 1.07	1.04 | 1.05
37	Forbes 230	1.01 | 1.03	1.00 | 1.04	0.99 | 1.04	1.01 | 1.05	1.01 | 1.02
38	Riverton 230	0.98 | 1.04	0.91 | 1.04	0.97 | 1.02	1.00 | 1.03	1.01 | 1.02
39	Coal Creek 230	1.00 | 1.08	0.95 | 1.08	1.00 | 1.08	0.97 | 1.08	1.02 | 1.04
40	Jamestown 345	0.92 | 1.00	0.86 | 1.02	0.93 | 0.99	0.93 | 1.00	0.98 | 0.99
41	Drayton 230	0.97 | 1.06	0.98 | 1.09	0.99 | 1.06	1.01 | 1.04	1.02 | 1.03
42	Groton 345	0.96 | 1.03	0.89 | 1.05	0.95 | 1.02	0.96 | 1.02	1.00 | 1.02
43	Minong 161	1.04 | 1.08	0.99 | 1.11	1.03 | 1.09	0.90 | 1.00	0.95 | 0.99
44	Wahpeton 115	0.97 | 1.04	0.93 | 1.07	0.97 | 1.04	1.01 | 1.05	1.03 | 1.04
45	Watertown 345	0.99 | 1.03	0.93 | 1.05	0.98 | 1.03	0.99 | 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 / 38.29%	KING 3 / 34.47%	KING 3 / 44.93%	SHERC3 / 74.21%	SHERC3 / 65.96%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.150		
56	Forbes DC Red (DCAR)	507%	507%	507%	230%	315%
57	K22W (max +dP @ t, d-ang)	83.0@(2.04166,-41.1)	119.5@(2.14166,-50.2)	70.0@(2.07500,-35.8)	0.7@(0.10000,0.4)	0.0@(0.10000,0.0)
58	K22W (max -dP @ t, d-ang)	91.8@(0.27500,10.3)	66.5@(0.24167,6.3)	62.7@(0.27500,5.7)	41.1@(1.66666,12.3)	31.0@(1.90000,12.8)
59	K22W (max d-ang @ t, dP)	-105.1@(20.00806,30.9)	-113.0@(20.00806,57.0)	-98.8@(20.00806,33.1)	21.7@(1.04166,-33.2)	12.8@(1.95000,-31.0)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.16667 sec / -0.01667 sec	0.18333 sec / -0.01667 sec	0.38333 sec / -0.01667 sec	199% / -0.01667 sec	240% / -0.01667 sec
63	G82R at Rugby/L20D at Drayton	-0.01667 sec / 378%	-0.01667 sec / 495%	-0.01667 sec / 462%	-0.01667 sec / 565%	-0.01667 sec / 670%
64	R50M / F3M	305% / 99%	462% / 147%	449% / 174%	744% / 315%	903% / 315%
65	B10T	125%	95%	151%	162%	275%
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 | 2) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 3 | 2) / (0 | 1 | 1)	(1 | 2 | 1) / (0 | 1 | 1)	(1 | 2 | 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 | 3 | 3) / (1 | 1 | 1)	(1 | 4 | 3) / (1 | 2 | 2)	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)

Case	mb0-so15aa-nad	mb0-so15aa-nad	mb0-so15aa-nad	Mb0-so15aa-pcs	Mb0-so15aa-pct
Disturbance	nad	nmz	pas	pcs	pct
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(4T)(5T)(6T)	(4T)(5T)(6T)	(4T)(5T)(6T)	(4T)(6T)	(4T)(6T)

Table C-1: Pre-Benchmark Case

1	**Case No.**	11	12
2	**Case Name**	Mb0-so15aa-pys	Mb0-so15aa-pyt
3	**Disturbance**	pys	pyt
4	**Prior Outage**	None	None
5	**Date/Time**	APR 15 2009 21:26	APR 15 2009 21:46
	Comments		
6			
7			
8	**Steady State Flows**		
9	NDEX / EAST BIAS	2449 / 220	2449 / 220
10	MHEX / L20D	2177 / 271	2177 / 271
11	ECL-ARP / PRI-BYN	626 / 746	626 / 746
12	MWEX / AHD-SLK	1528 / 638	1528 / 638
13	D602F / F601C	0 / 1606	0 / 1606
14	B10T / MH>SPC	164 / 60	164 / 60
15	OH E-W / OH>MH	192 / -195	192 / -195
16	R50M / OH>MP	137 / 152	137 / 152
17	G82R	N/A	N/A
18	Dorsey bipole / CU bipole	1700 / 1104	1700 / 1104
19	Dorsey Reserve / Wtrtn SVC	1864 / 30	1864 / 30
20	Forbes SVC / MSC	18 / 600	18 / 600
21	RCDC	0	0
22	**Steady State Vltgs**		
23	Dorsey 500/Dorsey 230	1.046 / 1.045	1.046 / 1.045
24	Roseau 500/Forbes 500	1.032 / 1.018	1.032 / 1.018
25	Chisago 500/EauClaire 345	1.018 / 1.028	1.018 / 1.028
26	Int Falls 115/Badoura 115	1.020 / 1.026	1.020 / 1.026
27	Drayton 230/Groton 345	1.028 / 1.009	1.028 / 1.009
28	**SS OS Relay Margins**		
29	D602F at Forbes/Dorsey	240% / 999%	240% / 999%
30	G82R at Rugby/L20D at Drayton	999% / 744%	999% / 744%
31	R50M/F3M	988% / 315%	988% / 315%
32	B10T	344%	344%
33	**Min/MaxTransientVltg**		
34	Arrowhd 230	0.98 | 1.02	0.99 | 1.01
35	Boise 115	1.00 | 1.04	1.02 | 1.03
36	Dorsey 230	1.04 | 1.06	1.04 | 1.05
37	Forbes 230	1.02 | 1.06	1.02 | 1.03
38	Riverton 230	1.01 | 1.03	1.02 | 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	1.02 | 1.03
42	Groton 345	0.97 | 1.02	1.00 | 1.01
43	Minong 161	0.98 | 1.04	1.00 | 1.02
44	Wahpeton 115	1.01 | 1.05	1.03 | 1.04
45	Watertown 345	1.00 | 1.03	1.01 | 1.02
46	**Dynamic Voltage Warnings**		
47		none	none
48			
49			
50			
51			
52			
53			
54	Worst Case Angle Damping	KING 3 / 74.32%	SHERC3 / 65.46%
55	Dorsey SUVP / UdHold		
56	Forbes DC Red (DCAR)	276%	368%
57	K22W (max +dP @ t, d-ang)	11.2@(2.42499,1.7)	0.0@(0.10000,0.0)
58	K22W (max -dP @ t, d-ang)	29.9@(0.66666,10.9)	21.3@(1.79166,8.2)
59	K22W (max d-ang @ t, dP)	17.1@(1.02500,-21.0)	8.6@(2.12499,-19.0)
60	**OS Rel Trip / Marg**		
61	MH - OH		
62	D602F at Forbes/Dorsey	194% / -0.01667 sec	240% / -0.01667 sec
63	G82R at Rugby/L20D at Drayton	-0.01667 sec / 596%	-0.01667 sec / 685%
64	R50M / F3M	780% / 294%	957% / 315%
65	B10T	175%	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 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)

Case	Mb0-so15aa-pys	Mb0-so15aa-pyt
Disturbance	pys	pyt
System Response	OK	OK
70% or 120% Violations		
ORWG Criteria Violations		
Line Tripping	(4T)(6T)	(4T)(6T)

Table C-2: Benchmark Case

1	**Case No.**	1	2	3	4	5
2	**Case Name**	Mhb-so15aa-ag1	Mhb-so15aa-ag3	Mhb-so15aa-ei2	Mhb-so15aa-eq1	Mhb-so15aa-fds
3	**Disturbance**	ag1	ag3	ei2	eq1	fds
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 16 2009 8:47	APR 16 2009 9:05	APR 16 2009 9:23	APR 16 2009 9:41	APR 16 2009 9:59
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2318 / 116	2318 / 116	2318 / 116	2318 / 116	2318 / 116
10	MHEX / L20D	2174 / 301	2174 / 301	2174 / 301	2174 / 301	2174 / 301
11	ECL-ARP / PRI-BYN	648 / 100	648 / 100	648 / 100	648 / 100	648 / 100
12	MWEX / AHD-SLK	1450 / 599	1450 / 599	1450 / 599	1450 / 599	1450 / 599
13	D602F / F601C	0 / 1494	0 / 1494	0 / 1494	0 / 1494	0 / 1494
14	B10T / MH>SPC	165 / 61	165 / 61	165 / 61	165 / 61	165 / 61
15	OH E-W / OH>MH	190 / -196	190 / -196	190 / -196	190 / -196	190 / -196
16	R50M / OH>MP	137 / 151	137 / 151	137 / 151	137 / 151	137 / 151
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	1700 / 1104	1700 / 1104	1700 / 1104	1700 / 1104	1700 / 1104
19	Dorsey Reserve / Wtrtn SVC	1922 / -47	1922 / -47	1922 / -47	1922 / -47	1922 / -47
20	Forbes SVC / MSC	11 / 600	11 / 600	11 / 600	11 / 600	11 / 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	1.042 / 1.022	1.042 / 1.022	1.042 / 1.022	1.042 / 1.022	1.042 / 1.022
25	Chisago 500/EauClaire 345	1.019 / 1.028	1.019 / 1.028	1.019 / 1.028	1.019 / 1.028	1.019 / 1.028
26	Int Falls 115/Badoura 115	1.022 / 1.041	1.022 / 1.041	1.022 / 1.041	1.022 / 1.041	1.022 / 1.041
27	Drayton 230/Groton 345	1.027 / 1.014	1.027 / 1.014	1.027 / 1.014	1.027 / 1.014	1.027 / 1.014
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	255% / 999%	255% / 999%	255% / 999%	255% / 999%	255% / 999%
30	G82R at Rugby/L20D at Drayton	999% / 645%	999% / 645%	999% / 645%	999% / 645%	999% / 645%
31	R50M/F3M	988% / 320%	988% / 320%	988% / 320%	988% / 320%	988% / 320%
32	B10T	342%	342%	342%	342%	342%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.02	0.99 | 1.02	0.99 | 1.04	0.99 | 1.04	0.98 | 1.03
35	Boise 115	1.01 | 1.03	1.01 | 1.03	1.00 | 1.02	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	1.00 | 1.04	1.01 | 1.03	1.01 | 1.03
38	Riverton 230	1.01 | 1.04	1.00 | 1.04	0.98 | 1.05	1.00 | 1.05	1.00 | 1.05
39	Coal Creek 230	0.97 | 1.11	0.97 | 1.11	1.02 | 1.11	1.00 | 1.16	0.97 | 1.12
40	Jamestown 345	0.91 | 1.02	0.90 | 1.03	0.85 | 1.04	0.87 | 1.05	0.82 | 1.05
41	Drayton 230	1.01 | 1.05	1.00 | 1.04	0.98 | 1.06	1.02 | 1.07	1.00 | 1.05
42	Groton 345	0.91 | 1.04	0.91 | 1.04	0.92 | 1.07	0.94 | 1.07	0.95 | 1.06
43	Minong 161	1.00 | 1.03	1.00 | 1.03	1.01 | 1.06	1.01 | 1.05	1.00 | 1.03
44	Wahpeton 115	1.00 | 1.07	0.99 | 1.07	0.96 | 1.08	0.99 | 1.08	0.98 | 1.08
45	Watertown 345	0.99 | 1.04	0.99 | 1.04	0.98 | 1.06	0.99 | 1.06	1.00 | 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 / 73.75%	KING 3 / 76.69%	SHERC3 / 30.25%	KING 3 / 32.97%	MNTCE3 / 70.29%
55	Dorsey SUVP / UdHold					
56	Forbes DC Red (DCAR)	457%	451%	507%	507%	453%
57	K22W (max +dP @ t, d-ang)	9.4@(2.40832,1.8)	11.3@(2.38332,1.4)	57.6@(2.39166,-26.2)	39.7@(2.31666,-16.2)	10.5@(2.45832,-0.6)
58	K22W (max -dP @ t, d-ang)	16.8@(0.79166,4.5)	18.8@(0.74166,5.4)	2.2@(0.38333,0.1)	2.9@(0.29167,0.2)	11.9@(0.74166,2.3)
59	K22W (max d-ang @ t, dP)	6.4@(1.04166,-6.8)	7.6@(1.00000,-8.6)	-64.1@(20.00806,30.7)	-35.0@(20.00806,17.4)	4.2@(1.01666,-4.1)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	214% / -0.01667 sec	211% / -0.01667 sec	186% / -0.01667 sec	212% / -0.01667 sec	225% / -0.01667 sec
63	G82R at Rugby/L20D at Drayton	-0.01667 sec / 558%	-0.01667 sec / 549%	-0.01667 sec / 489%	-0.01667 sec / 510%	-0.01667 sec / 558%
64	R50M / F3M	865% / 284%	852% / 282%	838% / 232%	893% / 256%	878% / 288%
65	B10T	206%	199%	108%	127%	102%
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 | 1 | 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 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 1) / (1 | 1 | 1)	(1 | 4 | 1) / (1 | 1 | 1)	(1 | 3 | 1) / (1 | 1 | 1)	(1 | 2 | 0) / (1 | 1 | 1)

Case	Mhb-so15aa-ag1	Mhb-so15aa-ag3	Mhb-so15aa-ei2	Mhb-so15aa-eq1	Mhb-so15aa-fds
Disturbance	ag1	ag3	ei2	eq1	fds
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(4T)(6T)	(4T)(6T)	(4T)(6T)	(4T)(6T)	(4T)(6T)

Table C-2: Benchmark Case

	Case No.	6	7	8	9	10
2	**Case Name**	mhb-so15aa-nad	mhb-so15aa-nad	mhb-so15aa-nad	Mhb-so15aa-pcs	Mhb-so15aa-pct
3	**Disturbance**	nad	nmz	pas	pcs	pct
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 22 2009 12:51	APR 22 2009 12:57	APR 22 2009 13:02	APR 16 2009 11:46	APR 16 2009 12:04
6	**Comments**	Dorsey tertiary capacitors off	Dorsey tertiary capacitors off	Dorsey tertiary capacitors off		
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2316 / 119	2316 / 119	2316 / 119	2318 / 116	2318 / 116
10	MHEX / L20D	2175 / 300	2175 / 300	2175 / 300	2174 / 301	2174 / 301
11	ECL-ARP / PRI-BYN	639 / 102	639 / 102	639 / 102	648 / 100	648 / 100
12	MWEX / AHD-SLK	1483 / 643	1483 / 643	1483 / 643	1450 / 599	1450 / 599
13	D602F / F601C	0 / 1477	0 / 1477	0 / 1477	0 / 1494	0 / 1494
14	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	165 / 61	165 / 61
15	OH E-W / OH>MH	190 / -196	190 / -196	190 / -196	190 / -196	190 / -196
16	R50M / OH>MP	138 / 151	138 / 151	138 / 151	137 / 151	137 / 151
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	1700 / 1103	1700 / 1103	1700 / 1103	1700 / 1104	1700 / 1104
19	Dorsey Reserve / Wtrtn SVC	1674 / 31	1674 / 31	1674 / 31	1922 / -47	1922 / -47
20	Forbes SVC / MSC	9 / 600	9 / 600	9 / 600	11 / 600	11 / 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	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.042 / 1.022	1.042 / 1.022	1.042 / 1.022	1.042 / 1.022	1.042 / 1.022
25	Chisago 500/EauClaire 345	1.020 / 1.030	1.020 / 1.030	1.020 / 1.030	1.019 / 1.028	1.019 / 1.028
26	Int Falls 115/Badoura 115	1.022 / 1.041	1.022 / 1.041	1.022 / 1.041	1.022 / 1.041	1.022 / 1.041
27	Drayton 230/Groton 345	1.027 / 1.015	1.027 / 1.015	1.027 / 1.015	1.027 / 1.014	1.027 / 1.014
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	255% / 999%	255% / 999%	255% / 999%	255% / 999%	255% / 999%
30	G82R at Rugby/L20D at Drayton	999% / 647%	999% / 647%	999% / 647%	999% / 645%	999% / 645%
31	R50M/F3M	980% / 321%	980% / 321%	980% / 321%	988% / 320%	988% / 320%
32	B10T	344%	344%	344%	342%	342%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.00 | 1.06	0.95 | 1.07	1.01 | 1.06	0.94 | 1.00	0.96 | 1.00
35	Boise 115	0.92 | 1.03	0.96 | 1.03	0.97 | 1.03	1.01 | 1.04	1.02 | 1.03
36	Dorsey 230	1.04 | 1.07	1.05 | 1.07	1.05 | 1.07	1.04 | 1.08	1.04 | 1.05
37	Forbes 230	1.01 | 1.03	1.00 | 1.04	1.00 | 1.05	1.02 | 1.06	1.02 | 1.03
38	Riverton 230	1.00 | 1.05	0.96 | 1.06	1.00 | 1.05	1.01 | 1.04	1.03 | 1.03
39	Coal Creek 230	1.00 | 1.07	0.96 | 1.07	0.99 | 1.07	0.97 | 1.08	1.02 | 1.04
40	Jamestown 345	0.92 | 0.99	0.85 | 1.02	0.92 | 0.99	0.93 | 1.01	0.99 | 1.00
41	Drayton 230	0.96 | 1.06	0.97 | 1.08	0.98 | 1.06	1.01 | 1.05	1.02 | 1.03
42	Groton 345	0.97 | 1.03	0.91 | 1.05	0.97 | 1.03	0.98 | 1.03	1.01 | 1.02
43	Minong 161	1.02 | 1.07	0.98 | 1.09	1.04 | 1.08	0.93 | 1.01	0.95 | 1.01
44	Wahpeton 115	1.00 | 1.05	0.95 | 1.08	1.00 | 1.05	1.02 | 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 / 38.18%	KING 3 / 36.01%	KING 3 / 42.18%	SHERC3 / 77.78%	SHERC3 / 73.12%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.150		
56	Forbes DC Red (DCAR)	507%	507%	507%	239%	355%
57	K22W (max +dP @ t, d-ang)	93.0@(2.03333,-41.6)	119.0@(2.09999,-50.3)	79.9@(2.07500,-38.2)	2.2@(2.35832,3.1)	0.0@(0.10000,0.0)
58	K22W (max -dP @ t, d-ang)	89.1@(0.27500,10.0)	63.8@(0.24167,6.0)	60.2@(0.27500,5.5)	34.6@(0.39166,6.2)	24.4@(1.88333,9.6)
59	K22W (max d-ang @ t, dP)	-101.2@(20.00806,33.4)	-109.0@(20.00806,58.5)	-98.4@(20.00806,36.3)	18.9@(0.99166,-26.9)	9.7@(1.76666,-24.3)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.16667 sec / -0.01667 sec	0.18333 sec / -0.01667 sec	0.38333 sec / -0.01667 sec	213% / -0.01667 sec	253% / -0.01667 sec
63	G82R at Rugby/L20D at Drayton	-0.01667 sec / 320%	-0.01667 sec / 424%	-0.01667 sec / 392%	-0.01667 sec / 499%	-0.01667 sec / 606%
64	R50M / F3M	376% / 121%	534% / 165%	465% / 177%	760% / 314%	909% / 320%
65	B10T	109%	84%	133%	162%	284%
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 | 3) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 4 | 2) / (0 | 1 | 1)	(1 | 3 | 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 | 1 | 0) / (1 | 5 | 3)	(0 | 0 | 0) / (1 | 2 | 1)	(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 | 1 | 1) / (1 | 1 | 1)	(1 | 4 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)

Case	mhb-so15aa-nad	mhb-so15aa-nad	mhb-so15aa-nad	Mhb-so15aa-pcs	Mhb-so15aa-pct
Disturbance	nad	nmz	pas	pcs	pct
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(4T)(5T)(6T)	(4T)(5T)(6T)	(4T)(5T)(6T)	(4T)(6T)	(4T)(6T)

Table C-2: Benchmark Case

1	**Case No.**	11	12
2	**Case Name**	Mhb-so15aa-pzs	Mhb-so15aa-pzt
3	**Disturbance**	pzs	pzt
4	**Prior Outage**	None	None
5	**Date/Time**	APR 16 2009 12:22	APR 16 2009 12:40
	Comments		
6			
7			
8	**Steady State Flows**		
9	NDEX / EAST BIAS	2318 / 116	2318 / 116
10	MHEX / L20D	2174 / 301	2174 / 301
11	ECL-ARP / PRI-BYN	648 / 100	648 / 100
12	MWEX / AHD-SLK	1450 / 599	1450 / 599
13	D602F / F601C	0 / 1494	0 / 1494
14	B10T / MH>SPC	165 / 61	165 / 61
15	OH E-W / OH>MH	190 / -196	190 / -196
16	R50M / OH>MP	137 / 151	137 / 151
17	G82R	N/A	N/A
18	Dorsey bipole / CU bipole	1700 / 1104	1700 / 1104
19	Dorsey Reserve / Wtrtn SVC	1922 / -47	1922 / -47
20	Forbes SVC / MSC	11 / 600	11 / 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	1.042 / 1.022	1.042 / 1.022
25	Chisago 500/EauClaire 345	1.019 / 1.028	1.019 / 1.028
26	Int Falls 115/Badoura 115	1.022 / 1.041	1.022 / 1.041
27	Drayton 230/Groton 345	1.027 / 1.014	1.027 / 1.014
28	**SS OS Relay Margins**		
29	D602F at Forbes/Dorsey	255% / 999%	255% / 999%
30	G82R at Rugby/L20D at Drayton	999% / 645%	999% / 645%
31	R50M/F3M	988% / 320%	988% / 320%
32	B10T	342%	342%
33	**Min/MaxTransientVltg**		
34	Arrowhd 230	1.00 | 1.03	1.01 | 1.01
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 | 1.03
38	Riverton 230	1.02 | 1.04	1.03 | 1.03
39	Coal Creek 230	0.98 | 1.08	1.03 | 1.03
40	Jamestown 345	0.93 | 1.01	0.99 | 0.99
41	Drayton 230	1.02 | 1.04	1.03 | 1.03
42	Groton 345	0.98 | 1.03	1.01 | 1.01
43	Minong 161	1.01 | 1.05	1.01 | 1.02
44	Wahpeton 115	1.02 | 1.06	1.04 | 1.05
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 / 72.51%	SHERC3 / 58.30%
55	Dorsey SUVP / UdHold		
56	Forbes DC Red (DCAR)	373%	475%
57	K22W (max +dP @ t, d-ang)	22.7@(2.36666,-4.3)	0.0@(0.10000,0.0)
58	K22W (max -dP @ t, d-ang)	22.6@(0.60833,7.8)	5.3@(1.70000,2.1)
59	K22W (max d-ang @ t, dP)	11.4@(0.91666,-12.8)	2.3@(20.00806,-3.4)
60	**OS Rel Trip / Marg**		
61	MH - OH		
62	D602F at Forbes/Dorsey	204% / -0.01667 sec	255% / -0.01667 sec
63	G82R at Rugby/L20D at Drayton	-0.01667 sec / 538%	-0.01667 sec / 637%
64	R50M / F3M	806% / 282%	976% / 320%
65	B10T	171%	327%
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)

Case	Mhb-so15aa-pzs	Mhb-so15aa-pzt
Disturbance	pzs	pzt
System Response	OK	OK
70% or 120% Violations		
ORWG Criteria Violations		
Line Tripping	(4T)(6T)	(4T)(6T)

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

1	**Case No.**	1	2	3	4	5
2	**Case Name**	mh1-so15aa-ag1	mh1-so15aa-ag3	mh1-so15aa-cts	mh1-so15aa-ei2	mh1-so15aa-em3
3	**Disturbance**	ag1	ag3	cts	ei2	em3
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 23 2009 18:17	APR 23 2009 18:19	APR 23 2009 18:22	APR 23 2009 18:26	APR 23 2009 18:29
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2401 / 173	2401 / 173	2401 / 173	2401 / 173	2401 / 173
10	MHEX / L20D	1887 / 245	1887 / 245	1887 / 245	1887 / 245	1887 / 245
11	ECL-ARP / PRI-BYN	691 / 110	691 / 110	691 / 110	691 / 110	691 / 110
12	MWEX / AHD-SLK	1586 / 644	1586 / 644	1586 / 644	1586 / 644	1586 / 644
13	D602F / F601C	0 / 1241	0 / 1241	0 / 1241	0 / 1241	0 / 1241
14	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60	164 / 60
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	130 / 150	130 / 150	130 / 150	130 / 150	130 / 150
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	739 / 17	739 / 17	739 / 17	739 / 17	739 / 17
20	Forbes SVC / MSC	-4 / 600	-4 / 600	-4 / 600	-4 / 600	-4 / 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	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040
25	Chisago 500/EauClaire 345	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019
26	Int Falls 115/Badoura 115	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044
27	Drayton 230/Groton 345	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	321% / 536%	321% / 536%	321% / 536%	321% / 536%	321% / 536%
30	G82R at Rugby/L20D at Drayton	999% / 865%	999% / 865%	999% / 865%	999% / 865%	999% / 865%
31	R50M/F3M	999% / 326%	999% / 326%	999% / 326%	999% / 326%	999% / 326%
32	B10T	344%	344%	344%	344%	344%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.02	0.99 | 1.02	0.93 | 1.08	0.99 | 1.04	1.01 | 1.02
35	Boise 115	1.01 | 1.03	1.01 | 1.03	0.98 | 1.02	1.00 | 1.02	1.02 | 1.02
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.12	1.04 | 1.05	1.03 | 1.05
37	Forbes 230	1.03 | 1.05	1.03 | 1.05	0.96 | 1.05	1.01 | 1.05	1.04 | 1.04
38	Riverton 230	1.01 | 1.04	1.01 | 1.04	0.94 | 1.07	0.99 | 1.05	1.03 | 1.04
39	Coal Creek 230	0.97 | 1.11	0.97 | 1.11	0.88 | 1.08	1.02 | 1.10	1.03 | 1.04
40	Jamestown 345	0.93 | 1.02	0.93 | 1.02	0.80 | 1.05	0.88 | 1.03	0.99 | 1.00
41	Drayton 230	1.02 | 1.05	1.01 | 1.05	0.97 | 1.09	1.00 | 1.06	1.04 | 1.04
42	Groton 345	0.92 | 1.04	0.92 | 1.04	0.85 | 1.07	0.93 | 1.06	1.02 | 1.03
43	Minong 161	1.00 | 1.03	1.00 | 1.03	0.98 | 1.10	1.01 | 1.06	1.02 | 1.03
44	Wahpeton 115	1.01 | 1.06	1.01 | 1.06	0.92 | 1.09	0.98 | 1.07	1.05 | 1.05
45	Watertown 345	0.98 | 1.04	0.98 | 1.04	0.92 | 1.06	0.98 | 1.05	1.03 | 1.03
46	**Dynamic Voltage Warnings**					
47		none	none		none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 69.45%	KING 3 / 72.78%	KING 3 / 38.83%	SHERC3 / 32.45%	KING 3 / 34.80%
55	Dorsey SUVP / UdHold					/ 0.133
56	Forbes DC Red (DCAR)	470%	470%	507%	496%	494%
57	K22W (max +dP @ t, d-ang)	10.6@(2.34166,1.8)	12.9@(2.30833,0.9)	103.7@(2.36666,-43.9)	60.0@(2.36666,-26.1)	31.4@(0.13333,-0.3)
58	K22W (max -dP @ t, d-ang)	18.1@(1.74166,0.2)	18.2@(0.69166,4.8)	47.0@(0.41666,6.8)	0.4@(0.42500,-0.3)	20.9@(0.26667,1.8)
59	K22W (max d-ang @ t, dP)	6.4@(1.00000,-5.6)	6.8@(0.94166,-7.1)	-63.5@(10.00821,47.6)	-43.5@(10.00821,31.4)	-10.4@(10.00821,9.0)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	281% / 469%	278% / 464%	0.36667 sec / 0.36667 sec	242% / 404%	291% / 487%
63	G82R at Rugby/L20D at Drayton	999% / 777%	999% / 771%	999% / 682%	999% / 725%	999% / 0.18333 sec
64	R50M / F3M	954% / 288%	950% / 287%	697% / 206%	920% / 240%	958% / 300%
65	B10T	212%	208%	75%	136%	278%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 2 | 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 | 2) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 5 | 1) / (0 | 2 | 1)	(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)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 4 | 0) / (1 | 2 | 2)	(0 | 1 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)

Case	mh1-so15aa-ag1	mh1-so15aa-ag3	mh1-so15aa-cts	mh1-so15aa-ei2	mh1-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

1	**Case No.**	6	7	8	9	10
2	**Case Name**	mh1-so15aa-eq1	mh1-so15aa-fds	mh1-so15aa-mc3	mh1-so15aa-md3	mh1-so15aa-mis
3	**Disturbance**	eq1	fds	mc3	md3	mis
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 23 2009 18:32	APR 23 2009 18:34	APR 23 2009 18:37	APR 23 2009 18:40	APR 23 2009 18:42
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2401 / 173	2401 / 173	2401 / 173	2401 / 173	2401 / 173
10	MHEX / L20D	1887 / 245	1887 / 245	1887 / 245	1887 / 245	1887 / 245
11	ECL-ARP / PRI-BYN	691 / 110	691 / 110	691 / 110	691 / 110	691 / 110
12	MWEX / AHD-SLK	1586 / 644	1586 / 644	1586 / 644	1586 / 644	1586 / 644
13	D602F / F601C	0 / 1241	0 / 1241	0 / 1241	0 / 1241	0 / 1241
14	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60	164 / 60
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	130 / 150	130 / 150	130 / 150	130 / 150	130 / 150
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	739 / 17	739 / 17	739 / 17	739 / 17	739 / 17
20	Forbes SVC / MSC	-4 / 600	-4 / 600	-4 / 600	-4 / 600	-4 / 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	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040
25	Chisago 500/EauClaire 345	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019
26	Int Falls 115/Badoura 115	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044
27	Drayton 230/Groton 345	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	321% / 536%	321% / 536%	321% / 536%	321% / 536%	321% / 536%
30	G82R at Rugby/L20D at Drayton	999% / 865%	999% / 865%	999% / 865%	999% / 865%	999% / 865%
31	R50M/F3M	999% / 326%	999% / 326%	999% / 326%	999% / 326%	999% / 326%
32	B10T	344%	344%	344%	344%	344%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.04	0.97 | 1.03	1.01 | 1.02	1.01 | 1.01	1.01 | 1.02
35	Boise 115	1.01 | 1.02	1.01 | 1.03	1.01 | 1.02	1.02 | 1.03	1.05 | 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 | 1.05	1.02 | 1.05	1.04 | 1.04	1.03 | 1.04	1.04 | 1.04
38	Riverton 230	1.01 | 1.05	1.00 | 1.05	1.03 | 1.04	1.03 | 1.03	1.03 | 1.04
39	Coal Creek 230	0.99 | 1.16	0.98 | 1.12	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04
40	Jamestown 345	0.89 | 1.04	0.85 | 1.04	0.99 | 1.00	0.99 | 1.00	1.00 | 1.00
41	Drayton 230	1.02 | 1.07	1.00 | 1.05	1.03 | 1.04	1.03 | 1.04	1.04 | 1.04
42	Groton 345	0.95 | 1.06	0.95 | 1.05	1.02 | 1.02	1.01 | 1.02	1.02 | 1.02
43	Minong 161	1.01 | 1.05	0.99 | 1.03	1.02 | 1.03	1.02 | 1.02	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 | 1.05	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 / 29.74%	MNTCE3 / 73.56%	KING 3 / 35.22%	ANTEL3 / 80.36%	MNTCE3 / 23.64%
55	Dorsey SUVP / UdHold			/ 0.133	/ 0.133	
56	Forbes DC Red (DCAR)	493%	451%	491%	498%	484%
57	K22W (max +dP @ t, d-ang)	42.1@(2.29166,-16.2)	12.4@(2.37499,-1.0)	28.2@(0.12500,0.4)	20.6@(0.12500,-0.4)	196.0@(0.35000,-11.8)
58	K22W (max -dP @ t, d-ang)	2.5@(0.30833,0.0)	15.0@(0.57500,1.7)	22.7@(0.96666,-4.1)	10.5@(0.24167,0.6)	0.0@(0.35000,0.0)
59	K22W (max d-ang @ t, dP)	-24.6@(10.00821,17.5)	4.1@(0.94166,-3.0)	-7.5@(10.00821,-14.2)	-0.6@(2.32499,1.2)	-42.6@(0.95833,196.0)
60	**OS Rel Trip / Marg**					
61	MH - OH					0.35000 sec
62	D602F at Forbes/Dorsey	268% / 447%	272% / 454%	302% / 505%	320% / 532%	309% / 516%
63	G82R at Rugby/L20D at Drayton	62% / 714%	999% / 781%	999% / 814%	999% / 865%	999% / 829%
64	R50M / F3M	965% / 264%	923% / 293%	999% / 215%	999% / 322%	663% / 326%
65	B10T	147%	199%	329%	332%	336%
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 | 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	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 1 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)

Case	mh1-so15aa-eq1	mh1-so15aa-fds	mh1-so15aa-mc3	mh1-so15aa-md3	mh1-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

1	**Case No.**	11	12	13	14	15
2	**Case Name**	mh1-so15aa-mjs	mh1-so15aa-mkd	mh1-so15aa-mks	mh1-so15aa-nad	mh1-so15aa-nmz
3	**Disturbance**	mjs	mkd	mks	nad	nmz
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 23 2009 18:45	APR 23 2009 18:48	APR 23 2009 18:51	APR 23 2009 18:54	APR 23 2009 18:57
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2401 / 173	2401 / 173	2401 / 173	2401 / 173	2401 / 173
10	MHEX / L20D	1887 / 245	1887 / 245	1887 / 245	1887 / 245	1887 / 245
11	ECL-ARP / PRI-BYN	691 / 110	691 / 110	691 / 110	691 / 110	691 / 110
12	MWEX / AHD-SLK	1586 / 644	1586 / 644	1586 / 644	1586 / 644	1586 / 644
13	D602F / F601C	0 / 1241	0 / 1241	0 / 1241	0 / 1241	0 / 1241
14	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60	164 / 60
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	130 / 150	130 / 150	130 / 150	130 / 150	130 / 150
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	739 / 17	739 / 17	739 / 17	739 / 17	739 / 17
20	Forbes SVC / MSC	-4 / 600	-4 / 600	-4 / 600	-4 / 600	-4 / 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	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040
25	Chisago 500/EauClaire 345	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019
26	Int Falls 115/Badoura 115	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044
27	Drayton 230/Groton 345	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	321% / 536%	321% / 536%	321% / 536%	321% / 536%	321% / 536%
30	G82R at Rugby/L20D at Drayton	999% / 865%	999% / 865%	999% / 865%	999% / 865%	999% / 865%
31	R50M/F3M	999% / 326%	999% / 326%	999% / 326%	999% / 326%	999% / 326%
32	B10T	344%	344%	344%	344%	344%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.01	0.95 | 1.01	0.98 | 1.02	1.00 | 1.06	0.97 | 1.06
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	1.05 | 1.08
37	Forbes 230	1.03 | 1.05	1.03 | 1.05	1.03 | 1.05	1.02 | 1.04	1.02 | 1.04
38	Riverton 230	1.01 | 1.04	0.99 | 1.03	1.01 | 1.04	1.00 | 1.05	0.98 | 1.06
39	Coal Creek 230	0.98 | 1.07	0.98 | 1.07	0.97 | 1.08	1.00 | 1.06	0.97 | 1.06
40	Jamestown 345	0.94 | 1.01	0.93 | 1.01	0.93 | 1.01	0.95 | 1.01	0.90 | 1.03
41	Drayton 230	1.02 | 1.04	1.01 | 1.04	1.02 | 1.05	1.01 | 1.05	1.00 | 1.07
42	Groton 345	0.98 | 1.03	0.97 | 1.03	0.97 | 1.03	0.99 | 1.03	0.94 | 1.05
43	Minong 161	1.00 | 1.02	0.96 | 1.03	1.00 | 1.04	1.02 | 1.08	1.00 | 1.08
44	Wahpeton 115	1.02 | 1.05	1.01 | 1.05	1.01 | 1.06	1.01 | 1.06	0.99 | 1.08
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 / 84.78%	KING 3 / 76.24%	SHERC3 / 80.02%	KING 3 / 38.63%	KING 3 / 37.83%
55	Dorsey SUVP / UdHold		/ 0.133		/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	462%	327%	390%	507%	507%
57	K22W (max +dP @ t, d-ang)	2.9@(0.11667,0.3)	11.7@(0.10833,1.4)	8.6@(2.29166,0.5)	75.0@(2.03333,-36.0)	91.2@(2.11666,-40.6)
58	K22W (max -dP @ t, d-ang)	17.0@(0.35833,2.7)	26.6@(0.21667,3.3)	28.0@(0.37500,5.2)	59.3@(0.25000,6.6)	45.2@(0.22500,4.3)
59	K22W (max d-ang @ t, dP)	4.8@(0.80000,-5.2)	11.9@(0.78333,-10.2)	8.7@(0.72500,-7.7)	-61.2@(10.00821,35.0)	-65.0@(10.00821,49.5)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	307% / 521%	321% / 536%	292% / 509%	0.16667 sec / 0.16667 sec	0.18333 sec / 0.18333 sec
63	G82R at Rugby/L20D at Drayton	999% / 793%	999% / 729%	999% / 764%	999% / 610%	999% / 756%
64	R50M / F3M	995% / 326%	955% / 326%	956% / 320%	578% / 179%	746% / 200%
65	B10T	245%	197%	209%	192%	154%
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 | 3) / (0 | 0 | 0)	(4 | 4 | 3) / (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 | 1 | 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	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 1 | 0) / (1 | 2 | 2)

Case	mh1-so15aa-mjs	mh1-so15aa-mkd	mh1-so15aa-mks	mh1-so15aa-nad	mh1-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**	mh1-so15aa-pas	mh1-so15aa-pc0	mh1-so15aa-pcs	mh1-so15aa-pct	mh1-so15aa-pzs
3	**Disturbance**	pas	pc0	pcs	pct	pzs
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 23 2009 19:00	APR 23 2009 19:03	APR 23 2009 19:06	APR 23 2009 19:09	APR 23 2009 19:12
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2401 / 173	2401 / 173	2401 / 173	2401 / 173	2401 / 173
10	MHEX / L20D	1887 / 245	1887 / 245	1887 / 245	1887 / 245	1887 / 245
11	ECL-ARP / PRI-BYN	691 / 110	691 / 110	691 / 110	691 / 110	691 / 110
12	MWEX / AHD-SLK	1586 / 644	1586 / 644	1586 / 644	1586 / 644	1586 / 644
13	D602F / F601C	0 / 1241	0 / 1241	0 / 1241	0 / 1241	0 / 1241
14	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60	164 / 60
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	130 / 150	130 / 150	130 / 150	130 / 150	130 / 150
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	739 / 17	739 / 17	739 / 17	739 / 17	739 / 17
20	Forbes SVC / MSC	-4 / 600	-4 / 600	-4 / 600	-4 / 600	-4 / 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	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040
25	Chisago 500/EauClaire 345	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019
26	Int Falls 115/Badoura 115	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044
27	Drayton 230/Groton 345	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	321% / 536%	321% / 536%	321% / 536%	321% / 536%	321% / 536%
30	G82R at Rugby/L20D at Drayton	999% / 865%	999% / 865%	999% / 865%	999% / 865%	999% / 865%
31	R50M/F3M	999% / 326%	999% / 326%	999% / 326%	999% / 326%	999% / 326%
32	B10T	344%	344%	344%	344%	344%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.06	0.89 | 0.99	0.89 | 0.98	0.95 | 0.97	0.99 | 1.03
35	Boise 115	0.98 | 1.01	1.01 | 1.04	1.01 | 1.04	1.02 | 1.03	1.01 | 1.04
36	Dorsey 230	1.05 | 1.07	1.03 | 1.08	1.03 | 1.08	1.04 | 1.05	1.03 | 1.07
37	Forbes 230	0.99 | 1.04	1.03 | 1.06	1.02 | 1.06	1.03 | 1.03	1.03 | 1.06
38	Riverton 230	1.00 | 1.05	1.01 | 1.04	1.01 | 1.04	1.03 | 1.04	1.02 | 1.05
39	Coal Creek 230	1.00 | 1.06	0.97 | 1.08	0.97 | 1.08	1.02 | 1.04	0.98 | 1.08
40	Jamestown 345	0.96 | 1.01	0.95 | 1.02	0.95 | 1.01	0.99 | 1.01	0.95 | 1.02
41	Drayton 230	1.02 | 1.06	1.03 | 1.05	1.03 | 1.05	1.03 | 1.04	1.03 | 1.05
42	Groton 345	0.99 | 1.03	0.98 | 1.03	0.98 | 1.03	1.01 | 1.02	0.99 | 1.03
43	Minong 161	1.02 | 1.07	0.87 | 1.01	0.87 | 0.99	0.94 | 0.98	0.99 | 1.05
44	Wahpeton 115	1.02 | 1.06	1.03 | 1.06	1.03 | 1.06	1.04 | 1.06	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		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 42.23%	SHERC3 / 74.48%	SHERC3 / 73.51%	SHERC3 / 58.84%	KING 3 / 68.28%
55	Dorsey SUVP / UdHold	/ 0.150				
56	Forbes DC Red (DCAR)	394%	279%	264%	364%	362%
57	K22W (max +dP @ t, d-ang)	73.7@(2.03333,-33.7)	8.3@(3.28331,0.5)	2.6@(0.10833,0.4)	0.0@(0.10000,0.0)	20.1@(2.32499,-2.4)
58	K22W (max -dP @ t, d-ang)	41.0@(0.25833,3.7)	38.6@(0.39166,6.8)	38.7@(0.39166,6.8)	29.6@(1.94166,12.4)	29.0@(0.39166,4.7)
59	K22W (max d-ang @ t, dP)	-57.8@(10.00821,39.6)	20.2@(0.96666,-24.3)	20.7@(0.99166,-26.4)	12.4@(1.93333,-29.6)	12.6@(0.86666,-11.4)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.38333 sec / 0.18333 sec	281% / 466%	286% / 474%	321% / 535%	269% / 447%
63	G82R at Rugby/L20D at Drayton	999% / 670%	999% / 709%	999% / 718%	999% / 814%	999% / 748%
64	R50M / F3M	642% / 208%	852% / 316%	859% / 326%	985% / 326%	892% / 299%
65	B10T	221%	171%	181%	286%	182%
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 | 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 | 1 | 1)	(1 | 1 | 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 | 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	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 1 | 1) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 2 | 2)

Case	mh1-so15aa-pas	mh1-so15aa-pc0	mh1-so15aa-pcs	mh1-so15aa-pct	mh1-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
	Case Name	mh1-so15aa-pzt	mh1-so15aa-ya3	mh1-so15aa-yas	mh1-so15aa-yb3	mh1-so15aa-h13
	Disturbance	pzt	ya3	yas	yb3	h13
	Prior Outage	None	None	None	None	None
	Date/Time	APR 23 2009 19:14	APR 23 2009 20:08	APR 23 2009 20:10	APR 23 2009 20:13	APR 23 2009 19:32
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2401 / 173	2401 / 173	2401 / 173	2401 / 173	2401 / 173
	MHEX / L20D	1887 / 245	1887 / 245	1887 / 245	1887 / 245	1887 / 245
	ECL-ARP / PRI-BYN	691 / 110	691 / 110	691 / 110	691 / 110	691 / 110
	MWEX / AHD-SLK	1586 / 644	1586 / 644	1586 / 644	1586 / 644	1586 / 644
	D602F / F601C	0 / 1241	0 / 1241	0 / 1241	0 / 1241	0 / 1241
	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60	164 / 60
	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
	R50M / OH>MP	130 / 150	130 / 150	130 / 150	130 / 150	130 / 150
	G82R	N/A	N/A	N/A	N/A	N/A
	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
	Dorsey Reserve / Wtrtn SVC	739 / 17	739 / 17	739 / 17	739 / 17	739 / 17
	Forbes SVC / MSC	-4 / 600	-4 / 600	-4 / 600	-4 / 600	-4 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.045 / 1.045	1.045 / 1.045	1.045 / 1.045	1.045 / 1.045	1.045 / 1.045
	Roseau 500/Forbes 500	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040
	Chisago 500/EauClaire 345	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019
	Int Falls 115/Badoura 115	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044
	Drayton 230/Groton 345	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	321% / 536%	321% / 536%	321% / 536%	321% / 536%	321% / 536%
	G82R at Rugby/L20D at Drayton	999% / 865%	999% / 865%	999% / 865%	999% / 865%	999% / 865%
	R50M/F3M	999% / 326%	999% / 326%	999% / 326%	999% / 326%	999% / 326%
	B10T	344%	344%	344%	344%	344%
	Min/MaxTransientVltg					
	Arrowhd 230	1.00 | 1.01	1.01 | 1.02	0.96 | 0.99	1.03 | 1.05	1.00 | 1.03
	Boise 115	1.02 | 1.03	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04	1.01 | 1.03
	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.07	1.04 | 1.05	1.01 | 1.05
	Forbes 230	1.04 | 1.04	1.03 | 1.04	1.03 | 1.05	1.04 | 1.04	1.03 | 1.04
	Riverton 230	1.03 | 1.04	1.02 | 1.03	1.02 | 1.03	1.03 | 1.03	1.03 | 1.04
	Coal Creek 230	1.03 | 1.04	1.02 | 1.04	1.00 | 1.05	1.03 | 1.04	1.02 | 1.06
	Jamestown 345	1.00 | 1.00	0.99 | 1.00	0.99 | 1.01	0.99 | 1.00	0.98 | 1.01
	Drayton 230	1.04 | 1.04	1.03 | 1.05	1.03 | 1.05	1.03 | 1.04	1.02 | 1.05
	Groton 345	1.01 | 1.02	1.01 | 1.02	1.01 | 1.02	1.01 | 1.02	1.01 | 1.04
	Minong 161	1.01 | 1.02	0.97 | 0.99	0.97 | 1.04	0.98 | 1.00	1.01 | 1.04
	Wahpeton 115	1.05 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.06
	Watertown 345	1.03 | 1.03	1.02 | 1.03	1.02 | 1.03	1.02 | 1.03	1.02 | 1.04
	Dynamic Voltage Warnings					
		none	none		none	none
	Worst Case Angle Damping	SHERC3 / 56.31%	SHERC3 / 53.94%	ANTEL3 / 71.81%	KING 3 / 56.12%	MNTCE3 / 70.97%
	Dorsey SUVP / UdHold					/ 0.133
	Forbes DC Red (DCAR)	467%	391%	439%	418%	473%
	K22W (max +dP @ t, d-ang)	0.0@(0.10000,0.0)	5.2@(0.11667,0.7)	3.1@(0.11667,0.3)	3.5@(0.11667,0.5)	102.8@(0.15000,-2.1)
	K22W (max -dP @ t, d-ang)	8.2@(1.69166,3.3)	23.5@(1.63333,11.2)	19.0@(1.56666,8.6)	17.1@(1.60000,8.0)	17.0@(2.94165,3.5)
	K22W (max d-ang @ t, dP)	3.4@(2.05000,-7.8)	11.4@(1.85000,-21.6)	9.3@(1.00833,-11.8)	8.1@(1.83333,-15.3)	-7.7@(0.65833,0.3)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	321% / 536%	321% / 536%	321% / 536%	321% / 536%	305% / 509%
	G82R at Rugby/L20D at Drayton	999% / 850%	999% / 812%	999% / 820%	999% / 826%	999% / 787%
	R50M / F3M	999% / 326%	999% / 326%	999% / 326%	999% / 326%	966% / 268%
	B10T	324%	279%	286%	294%	194%
	FSCAPS (SS/Unav/Final)					
	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 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 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
	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)
	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	(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 | 2 | 2)

Case	mh1-so15aa-pzt	mh1-so15aa-ya3	mh1-so15aa-yas	mh1-so15aa-yb3	mh1-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**	mh1-so15aa-h23	mh1-so15aa-h33	mh1-so15aa-h43	mh1-so15aa-h53	mh1-so15aa-h63
3	**Disturbance**	h23	h33	h43	h53	h63
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 23 2009 19:35	APR 23 2009 19:38	APR 23 2009 19:41	APR 23 2009 19:44	APR 23 2009 19:47
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2401 / 173	2401 / 173	2401 / 173	2401 / 173	2401 / 173
10	MHEX / L20D	1887 / 245	1887 / 245	1887 / 245	1887 / 245	1887 / 245
11	ECL-ARP / PRI-BYN	691 / 110	691 / 110	691 / 110	691 / 110	691 / 110
12	MWEX / AHD-SLK	1586 / 644	1586 / 644	1586 / 644	1586 / 644	1586 / 644
13	D602F / F601C	0 / 1241	0 / 1241	0 / 1241	0 / 1241	0 / 1241
14	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60	164 / 60
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	130 / 150	130 / 150	130 / 150	130 / 150	130 / 150
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	739 / 17	739 / 17	739 / 17	739 / 17	739 / 17
20	Forbes SVC / MSC	-4 / 600	-4 / 600	-4 / 600	-4 / 600	-4 / 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	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040
25	Chisago 500/EauClaire 345	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019
26	Int Falls 115/Badoura 115	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044
27	Drayton 230/Groton 345	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	321% / 536%	321% / 536%	321% / 536%	321% / 536%	321% / 536%
30	G82R at Rugby/L20D at Drayton	999% / 865%	999% / 865%	999% / 865%	999% / 865%	999% / 865%
31	R50M/F3M	999% / 326%	999% / 326%	999% / 326%	999% / 326%	999% / 326%
32	B10T	344%	344%	344%	344%	344%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.02 | 1.05	1.02 | 1.07	1.00 | 1.03	0.98 | 1.05	0.97 | 1.03
35	Boise 115	1.01 | 1.03	0.97 | 1.00	1.00 | 1.02	1.00 | 1.02	1.01 | 1.03
36	Dorsey 230	1.03 | 1.06	1.04 | 1.07	1.00 | 1.04	1.04 | 1.07	1.03 | 1.05
37	Forbes 230	1.04 | 1.05	1.05 | 1.07	1.03 | 1.04	1.03 | 1.05	1.03 | 1.04
38	Riverton 230	1.04 | 1.05	1.03 | 1.05	1.03 | 1.04	1.01 | 1.04	1.02 | 1.04
39	Coal Creek 230	1.02 | 1.06	1.02 | 1.07	1.02 | 1.06	1.00 | 1.05	1.01 | 1.07
40	Jamestown 345	0.99 | 1.02	0.97 | 1.01	0.98 | 1.00	0.95 | 0.99	0.98 | 1.01
41	Drayton 230	1.04 | 1.06	1.02 | 1.05	1.02 | 1.04	1.02 | 1.05	1.02 | 1.04
42	Groton 345	1.01 | 1.05	1.00 | 1.03	1.01 | 1.03	0.99 | 1.03	1.00 | 1.03
43	Minong 161	1.02 | 1.07	1.03 | 1.08	1.01 | 1.04	0.99 | 1.07	0.98 | 1.06
44	Wahpeton 115	1.06 | 1.07	1.03 | 1.06	1.04 | 1.05	1.02 | 1.05	1.04 | 1.06
45	Watertown 345	1.03 | 1.05	1.02 | 1.04	1.02 | 1.04	1.01 | 1.04	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 / 26.66%	KING 3 / 34.84%	MNTCE3 / 70.83%	KING 3 / 45.08%	KING 3 / 77.16%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	454%	507%	478%	507%	380%
57	K22W (max +dP @ t, d-ang)	102.8@(0.15000,-2.1)	96.6@(0.15000,-1.8)	96.6@(0.15000,-1.8)	80.7@(2.08333,-30.7)	21.6@(2.22499,-2.6)
58	K22W (max -dP @ t, d-ang)	0.0@(0.01667,0.0)	17.9@(0.25000,0.6)	30.1@(2.93332,7.1)	60.2@(0.26667,6.1)	38.4@(0.26667,5.3)
59	K22W (max d-ang @ t, dP)	-36.7@(10.00821,41.6)	-62.2@(10.00821,36.4)	7.7@(2.64165,-22.9)	-52.7@(10.00821,41.0)	14.2@(0.76666,-11.7)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	321% / 536%	0.18333 sec / 0.18333 sec	312% / 517%	232% / 392%	248% / 414%
63	G82R at Rugby/L20D at Drayton	999% / 865%	999% / 765%	999% / 674%	999% / 616%	999% / 751%
64	R50M / F3M	999% / 259%	610% / 173%	792% / 266%	829% / 232%	843% / 285%
65	B10T	286%	235%	264%	167%	194%
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 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 3) / (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	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 2 | 2)

Case	mh1-so15aa-h23	mh1-so15aa-h33	mh1-so15aa-h43	mh1-so15aa-h53	mh1-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

1	**Case No.**	31	32	33	34	35
2	**Case Name**	mh1-so15aa-h73	mh1-so15aa-h83	mh1-so15aa-h93	mh1-so15aa-hes	mh1-so15aa-hgs
3	**Disturbance**	h73	h83	h93	hes	hgs
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 23 2009 19:50	APR 23 2009 19:53	APR 23 2009 19:56	APR 23 2009 19:58	APR 23 2009 20:01
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2401 / 173	2401 / 173	2401 / 173	2401 / 173	2401 / 173
10	MHEX / L20D	1887 / 245	1887 / 245	1887 / 245	1887 / 245	1887 / 245
11	ECL-ARP / PRI-BYN	691 / 110	691 / 110	691 / 110	691 / 110	691 / 110
12	MWEX / AHD-SLK	1586 / 644	1586 / 644	1586 / 644	1586 / 644	1586 / 644
13	D602F / F601C	0 / 1241	0 / 1241	0 / 1241	0 / 1241	0 / 1241
14	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60	164 / 60
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	130 / 150	130 / 150	130 / 150	130 / 150	130 / 150
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	739 / 17	739 / 17	739 / 17	739 / 17	739 / 17
20	Forbes SVC / MSC	-4 / 600	-4 / 600	-4 / 600	-4 / 600	-4 / 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	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040
25	Chisago 500/EauClaire 345	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019
26	Int Falls 115/Badoura 115	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044
27	Drayton 230/Groton 345	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	321% / 536%	321% / 536%	321% / 536%	321% / 536%	321% / 536%
30	G82R at Rugby/L20D at Drayton	999% / 865%	999% / 865%	999% / 865%	999% / 865%	999% / 865%
31	R50M/F3M	999% / 326%	999% / 326%	999% / 326%	999% / 326%	999% / 326%
32	B10T	344%	344%	344%	344%	344%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.01 | 1.04	0.99 | 1.02	0.99 | 1.01	1.02 | 1.07	0.97 | 1.06
35	Boise 115	1.00 | 1.02	1.02 | 1.03	1.02 | 1.03	0.99 | 1.06	0.99 | 1.03
36	Dorsey 230	1.04 | 1.07	1.03 | 1.05	1.03 | 1.05	1.05 | 1.19	1.05 | 1.07
37	Forbes 230	1.02 | 1.05	1.03 | 1.05	1.03 | 1.04	1.04 | 1.08	1.02 | 1.05
38	Riverton 230	1.02 | 1.04	1.02 | 1.04	1.01 | 1.03	1.03 | 1.05	1.00 | 1.05
39	Coal Creek 230	1.02 | 1.06	1.00 | 1.07	0.99 | 1.07	1.02 | 1.06	0.99 | 1.06
40	Jamestown 345	0.94 | 0.99	0.96 | 1.00	0.96 | 1.01	0.96 | 1.00	0.95 | 1.01
41	Drayton 230	1.02 | 1.05	1.02 | 1.04	1.03 | 1.05	1.05 | 1.15	1.02 | 1.06
42	Groton 345	0.99 | 1.03	1.00 | 1.03	0.99 | 1.03	0.99 | 1.04	0.97 | 1.04
43	Minong 161	1.03 | 1.06	0.99 | 1.03	0.99 | 1.02	1.03 | 1.08	0.98 | 1.08
44	Wahpeton 115	1.02 | 1.05	1.03 | 1.06	1.03 | 1.05	1.03 | 1.06	1.01 | 1.07
45	Watertown 345	1.02 | 1.04	1.02 | 1.04	1.02 | 1.03	1.02 | 1.04	1.00 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	none	none		none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 35.33%	KING 3 / 70.25%	KING 3 / 72.88%	KING 3 / 35.46%	KING 3 / 52.90%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.158
56	Forbes DC Red (DCAR)	507%	452%	471%	378%	507%
57	K22W (max +dP @ t, d-ang)	102.8@(0.15000,-2.1)	28.9@(0.11667,0.6)	20.3@(0.11667,0.6)	154.4@(1.51666,-45.6)	91.7@(2.19999,-33.6)
58	K22W (max -dP @ t, d-ang)	12.1@(0.25000,0.9)	37.4@(0.28333,5.1)	31.8@(0.26667,4.0)	58.5@(0.39166,6.6)	48.5@(0.27500,5.0)
59	K22W (max d-ang @ t, dP)	-53.8@(10.00821,40.6)	7.2@(0.54166,-3.0)	7.0@(0.62500,-4.4)	-84.1@(10.00821,87.7)	-52.1@(10.00821,39.1)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	259% / 437%	261% / 437%	268% / 448%	61% / 85%	200% / 335%
63	G82R at Rugby/L20D at Drayton	999% / 749%	999% / 693%	999% / 803%	999% / 387%	999% / 628%
64	R50M / F3M	999% / 234%	868% / 309%	916% / 307%	524% / 195%	821% / 217%
65	B10T	214%	231%	241%	201%	109%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 1)	(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 | 3) / (0 | 0 | 0)	(4 | 4 | 3) / (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 | 5 | 1) / (0 | 1 | 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 | 1 | 0) / (1 | 2 | 0)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 0 | 0) / (1 | 2 | 2)	(0 | 1 | 1) / (1 | 1 | 1)	(0 | 2 | 2) / (1 | 2 | 2)

Case	mh1-so15aa-h73	mh1-so15aa-h83	mh1-so15aa-h93	mh1-so15aa-hes	mh1-so15aa-hgs
Disturbance	h73	h83	h93	hes	hgs
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.**	36	37	38	39
2	**Case Name**	mh1-so15aa-hhs	mh1-so15aa-hjs	mh1-so15aa-hks	m1a-so15aa-he3
3	**Disturbance**	hhs	hjs	hks	he3
4	**Prior Outage**	None	None	None	None
5	**Date/Time**	APR 23 2009 20:04	APR 23 2009 20:15	APR 23 2009 20:18	APR 23 2009 20:21
6	**Comments**				
7					
8	**Steady State Flows**				
9	NDEX / EAST BIAS	2401 / 173	2401 / 173	2401 / 173	2401 / 173
10	MHEX / L20D	1887 / 245	1887 / 245	1887 / 245	1887 / 245
11	ECL-ARP / PRI-BYN	691 / 110	691 / 110	691 / 110	691 / 110
12	MWEX / AHD-SLK	1586 / 644	1586 / 644	1586 / 644	1586 / 644
13	D602F / F601C	0 / 1241	0 / 1241	0 / 1241	0 / 1241
14	B10T / MH>SPC	164 / 60	164 / 60	164 / 60	164 / 60
15	OH E-W / OH>MH	190 / -195	190 / -195	190 / -195	190 / -195
16	R50M / OH>MP	130 / 150	130 / 150	130 / 150	130 / 150
17	G82R	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	739 / 17	739 / 17	739 / 17	739 / 17
20	Forbes SVC / MSC	-4 / 600	-4 / 600	-4 / 600	-4 / 600
21	RCDC	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
24	Roseau 500/Forbes 500	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040	1.046 / 1.040
25	Chisago 500/EauClaire 345	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019	1.034 / 1.019
26	Int Falls 115/Badoura 115	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044	1.024 / 1.044
27	Drayton 230/Groton 345	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018	1.038 / 1.018
28	**SS OS Relay Margins**				
29	D602F at Forbes/Dorsey	321% / 536%	321% / 536%	321% / 536%	321% / 536%
30	G82R at Rugby/L20D at Drayton	999% / 865%	999% / 865%	999% / 865%	999% / 865%
31	R50M/F3M	999% / 326%	999% / 326%	999% / 326%	999% / 326%
32	B10T	344%	344%	344%	344%
33	**Min/MaxTransientVltg**				
34	Arrowhd 230	0.99 | 1.04	0.98 | 1.03	0.99 | 1.04	0.97 | 1.03
35	Boise 115	1.00 | 1.02	1.01 | 1.04	1.00 | 1.05	1.01 | 1.03
36	Dorsey 230	1.05 | 1.07	1.03 | 1.09	1.04 | 1.17	1.03 | 1.05
37	Forbes 230	1.03 | 1.04	1.03 | 1.07	1.02 | 1.06	1.03 | 1.04
38	Riverton 230	1.01 | 1.04	1.03 | 1.04	1.02 | 1.04	1.02 | 1.04
39	Coal Creek 230	0.97 | 1.07	1.01 | 1.06	0.99 | 1.06	1.01 | 1.06
40	Jamestown 345	0.94 | 1.00	0.99 | 1.02	0.96 | 1.00	0.98 | 1.01
41	Drayton 230	1.05 | 1.09	1.03 | 1.09	1.04 | 1.14	1.02 | 1.04
42	Groton 345	0.96 | 1.03	1.00 | 1.03	0.98 | 1.03	1.00 | 1.03
43	Minong 161	1.00 | 1.06	0.99 | 1.05	1.00 | 1.06	0.98 | 1.05
44	Wahpeton 115	1.02 | 1.05	1.05 | 1.07	1.03 | 1.05	1.04 | 1.06
45	Watertown 345	1.00 | 1.04	1.01 | 1.04	1.01 | 1.03	1.01 | 1.04
46	**Dynamic Voltage Warnings**				
47		none	none		none
48					
49					
50					
51					
52					
53					
54	Worst Case Angle Damping	KING 3 / 41.38%	KING 3 / 73.44%	KING 3 / 41.48%	KING 3 / 76.99%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.158	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	507%	379%	507%	379%
57	K22W (max +dP @ t, d-ang)	73.2@(2.11666,-30.5)	18.5@(2.29999,-1.6)	77.0@(2.19166,-30.1)	19.3@(2.23333,-1.9)
58	K22W (max -dP @ t, d-ang)	42.4@(0.26667,3.8)	43.2@(0.39166,6.9)	53.7@(0.40833,6.3)	38.9@(0.26667,5.4)
59	K22W (max d-ang @ t, dP)	-52.2@(10.00821,38.5)	14.0@(0.83333,-12.5)	-51.8@(10.00821,38.5)	14.6@(0.77500,-12.3)
60	**OS Rel Trip / Marg**				
61	MH - OH				
62	D602F at Forbes/Dorsey	228% / 391%	247% / 413%	214% / 363%	249% / 415%
63	G82R at Rugby/L20D at Drayton	999% / 416%	999% / 747%	999% / 654%	999% / 752%
64	R50M / F3M	839% / 237%	843% / 291%	791% / 231%	843% / 289%
65	B10T	155%	186%	173%	194%
66	**FSCAPS (SS/Unav/Final)**				
67	Balta 230	(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 | 3) / (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 | 5 | 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)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(0 | 2 | 2) / (1 | 1 | 1)	(0 | 2 | 1) / (1 | 2 | 2)	(0 | 2 | 2) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 2 | 2)

Case	mh1-so15aa-hhs	mh1-so15aa-hjs	mh1-so15aa-hks	m1a-so15aa-he3
Disturbance	hhs	hjs	hks	he3
System Response	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.	1	2	3	4	5
	Case Name	mh3-so15aa-ag1	mh3-so15aa-ag3	mh3-so15aa-cts	mh3-so15aa-ei2	mh3-so15aa-em3
	Disturbance	ag1	ag3	cts	ei2	em3
	Prior Outage	None	None	None	None	None
	Date/Time	APR 23 2009 20:24	APR 23 2009 20:27	APR 23 2009 20:29	APR 23 2009 20:33	APR 23 2009 20:36
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2329 / 130	2329 / 130	2329 / 130	2329 / 130	2329 / 130
	MHEX / L20D	2052 / 293	2052 / 293	2052 / 293	2052 / 293	2052 / 293
	ECL-ARP / PRI-BYN	726 / 119	726 / 119	726 / 119	726 / 119	726 / 119
	MWEX / AHD-SLK	1669 / 647	1669 / 647	1669 / 647	1669 / 647	1669 / 647
	D602F / F601C	0 / 1233	0 / 1233	0 / 1233	0 / 1233	0 / 1233
	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
	OH E-W / OH>MH	190 / -196	190 / -196	190 / -196	190 / -196	190 / -196
	R50M / OH>MP	138 / 150	138 / 150	138 / 150	138 / 150	138 / 150
	G82R	N/A	N/A	N/A	N/A	N/A
	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
	Dorsey Reserve / Wtrtn SVC	900 / -48	900 / -48	900 / -48	900 / -48	900 / -48
	Forbes SVC / MSC	-7 / 600	-7 / 600	-7 / 600	-7 / 600	-7 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 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 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009
	Int Falls 115/Badoura 115	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044
	Drayton 230/Groton 345	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	295% / 494%	295% / 494%	295% / 494%	295% / 494%	295% / 494%
	G82R at Rugby/L20D at Drayton	999% / 673%	999% / 673%	999% / 673%	999% / 673%	999% / 673%
	R50M/F3M	979% / 324%	979% / 324%	979% / 324%	979% / 324%	979% / 324%
	B10T	343%	343%	343%	343%	343%
	Min/MaxTransientVltg					
	Arrowhd 230	0.99 | 1.02	0.99 | 1.02	0.93 | 1.08	0.99 | 1.04	1.01 | 1.02
	Boise 115	1.01 | 1.03	1.01 | 1.03	0.98 | 1.03	1.00 | 1.02	1.01 | 1.02
	Dorsey 230	1.03 | 1.05	1.03 | 1.05	1.05 | 1.14	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	0.93 | 1.08	0.99 | 1.05	1.04 | 1.04
	Coal Creek 230	0.97 | 1.11	0.97 | 1.11	0.88 | 1.09	1.02 | 1.11	1.03 | 1.05
	Jamestown 345	0.92 | 1.03	0.91 | 1.02	0.75 | 1.04	0.85 | 1.04	0.99 | 0.99
	Drayton 230	1.01 | 1.06	1.00 | 1.04	0.96 | 1.09	0.99 | 1.06	1.03 | 1.04
	Groton 345	0.91 | 1.04	0.91 | 1.04	0.84 | 1.09	0.93 | 1.07	1.02 | 1.03
	Minong 161	0.99 | 1.03	0.99 | 1.03	0.98 | 1.10	1.01 | 1.06	1.02 | 1.03
	Wahpeton 115	1.00 | 1.07	1.00 | 1.07	0.90 | 1.10	0.97 | 1.08	1.05 | 1.05
	Watertown 345	0.99 | 1.04	0.99 | 1.04	0.92 | 1.08	0.98 | 1.06	1.03 | 1.03
	Dynamic Voltage Warnings					
		none	none	63061 [MIDCOMP] 1.24	63061 [MIDCOMP] 1.22	63061 [MIDCOMP] 1.21
	Worst Case Angle Damping	KING 3 / 73.19%	KING 3 / 76.49%	KING 3 / 37.76%	SHERC3 / 32.01%	KING 3 / 28.97%
	Dorsey SUVP / UdHold			/ 0.150		/ 0.133
	Forbes DC Red (DCAR)	463%	460%	507%	507%	499%
	K22W (max +dP @ t, d-ang)	10.4@(2.39166,1.9)	13.2@(2.35832,1.0)	108.3@(2.31666,-49.7)	60.2@(2.43332,-26.5)	31.9@(0.13333,-0.3)
	K22W (max -dP @ t, d-ang)	17.3@(1.79166,0.2)	17.9@(0.74166,5.3)	51.5@(0.41666,7.5)	0.0@(0.01667,0.0)	25.2@(0.26667,2.2)
	K22W (max d-ang @ t, dP)	6.3@(1.04166,-5.7)	7.4@(0.99166,-7.5)	-68.7@(10.00821,56.8)	-43.9@(10.00821,32.7)	-12.3@(10.00821,10.2)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	252% / 421%	248% / 414%	0.36667 sec / 0.36667 sec	234% / 392%	257% / 432%
	G82R at Rugby/L20D at Drayton	999% / 587%	999% / 578%	999% / 494%	999% / 529%	999% / 0.18333 sec
	R50M / F3M	865% / 286%	853% / 284%	622% / 190%	873% / 232%	838% / 291%
	B10T	210%	203%	62%	121%	252%
	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 | 2 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 6 | 1) / (0 | 2 | 1)	(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)

Case	mh3-so15aa-ag1	mh3-so15aa-ag3	mh3-so15aa-cts	mh3-so15aa-ei2	mh3-so15aa-em3
Disturbance	ag1	ag3	cts	ei2	em3
System Response	OK	OK	OK	OK	OK
70% or 120% Violations			M	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**	mh3-so15aa-eq1	mh3-so15aa-fds	mh3-so15aa-mc3	mh3-so15aa-md3	mh3-so15aa-mis
3	**Disturbance**	eq1	fds	mc3	md3	mis
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 23 2009 20:38	APR 23 2009 20:41	APR 23 2009 20:44	APR 23 2009 20:47	APR 23 2009 20:49
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2329 / 130	2329 / 130	2329 / 130	2329 / 130	2329 / 130
10	MHEX / L20D	2052 / 293	2052 / 293	2052 / 293	2052 / 293	2052 / 293
11	ECL-ARP / PRI-BYN	726 / 119	726 / 119	726 / 119	726 / 119	726 / 119
12	MWEX / AHD-SLK	1669 / 647	1669 / 647	1669 / 647	1669 / 647	1669 / 647
13	D602F / F601C	0 / 1233	0 / 1233	0 / 1233	0 / 1233	0 / 1233
14	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
15	OH E-W / OH>MH	190 / -196	190 / -196	190 / -196	190 / -196	190 / -196
16	R50M / OH>MP	138 / 150	138 / 150	138 / 150	138 / 150	138 / 150
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	900 / -48	900 / -48	900 / -48	900 / -48	900 / -48
20	Forbes SVC / MSC	-7 / 600	-7 / 600	-7 / 600	-7 / 600	-7 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 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 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009
26	Int Falls 115/Badoura 115	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044
27	Drayton 230/Groton 345	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	295% / 494%	295% / 494%	295% / 494%	295% / 494%	295% / 494%
30	G82R at Rugby/L20D at Drayton	999% / 673%	999% / 673%	999% / 673%	999% / 673%	999% / 673%
31	R50M/F3M	979% / 324%	979% / 324%	979% / 324%	979% / 324%	979% / 324%
32	B10T	343%	343%	343%	343%	343%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.04	0.97 | 1.02	1.01 | 1.02	1.01 | 1.01	1.01 | 1.02
35	Boise 115	1.00 | 1.02	1.01 | 1.03	1.01 | 1.02	1.02 | 1.03	1.05 | 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	1.01 | 1.06	1.00 | 1.05	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04
39	Coal Creek 230	1.00 | 1.16	0.97 | 1.12	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04
40	Jamestown 345	0.87 | 1.05	0.83 | 1.05	0.99 | 0.99	0.99 | 0.99	0.99 | 0.99
41	Drayton 230	1.02 | 1.07	1.00 | 1.05	1.02 | 1.03	1.02 | 1.03	1.03 | 1.03
42	Groton 345	0.95 | 1.07	0.95 | 1.05	1.01 | 1.02	1.01 | 1.02	1.01 | 1.02
43	Minong 161	1.01 | 1.05	0.99 | 1.03	1.02 | 1.03	1.02 | 1.02	1.02 | 1.03
44	Wahpeton 115	0.99 | 1.09	0.98 | 1.08	1.05 | 1.05	1.04 | 1.05	1.05 | 1.05
45	Watertown 345	1.00 | 1.06	1.00 | 1.05	1.03 | 1.03	1.03 | 1.03	1.03 | 1.03
46	**Dynamic Voltage Warnings**					
47		63061 [MIDCOMP] 1.22		none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 30.07%	MNTCE3 / 69.70%	KING 3 / 25.28%	SHERC3 / 81.10%	KING 3 / 20.46%
55	Dorsey SUVP / UdHold			/ 0.133	/ 0.133	
56	Forbes DC Red (DCAR)	492%	453%	490%	498%	482%
57	K22W (max +dP @ t, d-ang)	42.0@(2.33332,-16.6)	10.8@(2.43332,-0.5)	28.9@(0.12500,0.4)	21.3@(0.12500,-0.4)	196.1@(0.35000,-11.9)
58	K22W (max -dP @ t, d-ang)	1.7@(0.29167,0.0)	11.3@(0.76666,2.6)	23.4@(0.99166,-4.5)	12.3@(0.24167,0.7)	0.0@(0.01667,0.0)
59	K22W (max d-ang @ t, dP)	-24.9@(10.00821,18.0)	4.2@(1.01666,-3.6)	-8.0@(10.00821,-14.4)	0.7@(0.25833,-11.7)	-43.0@(0.96666,196.1)
60	**OS Rel Trip / Marg**					
61	MH - OH					0.35000 sec
62	D602F at Forbes/Dorsey	257% / 431%	261% / 437%	274% / 460%	289% / 482%	283% / 474%
63	G82R at Rugby/L20D at Drayton	42% / 542%	999% / 583%	999% / 624%	999% / 661%	999% / 643%
64	R50M / F3M	911% / 258%	872% / 291%	979% / 209%	960% / 319%	612% / 324%
65	B10T	135%	191%	109%	103%	337%
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)

Case	mh3-so15aa-eq1	mh3-so15aa-fds	mh3-so15aa-mc3	mh3-so15aa-md3	mh3-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

1	**Case No.**	11	12	13	14	15
2	**Case Name**	mh3-so15aa-mjs	mh3-so15aa-mkd	mh3-so15aa-mks	mh3-so15aa-nad	mh3-so15aa-nmz
3	**Disturbance**	mjs	mkd	mks	nad	nmz
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 23 2009 20:52	APR 23 2009 20:54	APR 23 2009 20:57	APR 23 2009 21:00	APR 23 2009 21:03
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2329 / 130	2329 / 130	2329 / 130	2329 / 130	2329 / 130
10	MHEX / L20D	2052 / 293	2052 / 293	2052 / 293	2052 / 293	2052 / 293
11	ECL-ARP / PRI-BYN	726 / 119	726 / 119	726 / 119	726 / 119	726 / 119
12	MWEX / AHD-SLK	1669 / 647	1669 / 647	1669 / 647	1669 / 647	1669 / 647
13	D602F / F601C	0 / 1233	0 / 1233	0 / 1233	0 / 1233	0 / 1233
14	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
15	OH E-W / OH>MH	190 / -196	190 / -196	190 / -196	190 / -196	190 / -196
16	R50M / OH>MP	138 / 150	138 / 150	138 / 150	138 / 150	138 / 150
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	900 / -48	900 / -48	900 / -48	900 / -48	900 / -48
20	Forbes SVC / MSC	-7 / 600	-7 / 600	-7 / 600	-7 / 600	-7 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 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 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009
26	Int Falls 115/Badoura 115	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044
27	Drayton 230/Groton 345	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	295% / 494%	295% / 494%	295% / 494%	295% / 494%	295% / 494%
30	G82R at Rugby/L20D at Drayton	999% / 673%	999% / 673%	999% / 673%	999% / 673%	999% / 673%
31	R50M/F3M	979% / 324%	979% / 324%	979% / 324%	979% / 324%	979% / 324%
32	B10T	343%	343%	343%	343%	343%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.98 | 1.01	0.94 | 1.01	0.97 | 1.02	1.01 | 1.06	0.97 | 1.06
35	Boise 115	1.02 | 1.03	1.02 | 1.03	1.02 | 1.03	0.97 | 1.02	0.98 | 1.02
36	Dorsey 230	1.03 | 1.06	1.03 | 1.05	1.03 | 1.07	1.04 | 1.08	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 | 1.03	1.00 | 1.04	1.01 | 1.05	0.98 | 1.06
39	Coal Creek 230	0.98 | 1.07	0.98 | 1.07	0.97 | 1.08	1.00 | 1.07	0.97 | 1.07
40	Jamestown 345	0.92 | 1.00	0.91 | 1.00	0.91 | 1.00	0.94 | 0.99	0.88 | 1.02
41	Drayton 230	1.01 | 1.04	1.00 | 1.03	1.01 | 1.04	0.99 | 1.05	0.99 | 1.07
42	Groton 345	0.97 | 1.02	0.97 | 1.02	0.96 | 1.03	0.99 | 1.03	0.95 | 1.06
43	Minong 161	0.99 | 1.01	0.95 | 1.03	0.98 | 1.04	1.02 | 1.08	1.00 | 1.08
44	Wahpeton 115	1.01 | 1.05	1.00 | 1.05	1.00 | 1.06	1.02 | 1.05	0.98 | 1.08
45	Watertown 345	1.00 | 1.03	1.00 | 1.03	1.00 | 1.03	1.01 | 1.04	0.99 | 1.06
46	**Dynamic Voltage Warnings**					
47		none	none	none	63061 [MIDCOMP] 1.23	63061 [MIDCOMP] 1.23
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	SHERC3 / 83.30%	KING 3 / 76.72%	KING 3 / 76.81%	KING 3 / 39.83%	KING 3 / 39.57%
55	Dorsey SUVP / UdHold		/ 0.133	/ 0.150	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	455%	339%	398%	507%	507%
57	K22W (max +dP @ t, d-ang)	3.6@(0.11667,0.3)	12.6@(0.10833,1.6)	7.8@(2.29999,0.1)	85.2@(2.00000,-39.7)	104.1@(2.02500,-46.1)
58	K22W (max -dP @ t, d-ang)	20.7@(0.35000,3.1)	31.4@(0.22500,4.1)	30.5@(0.36667,5.5)	68.5@(0.25833,7.7)	53.1@(0.23333,5.2)
59	K22W (max d-ang @ t, dP)	5.3@(0.99166,-14.5)	11.9@(0.77500,-10.0)	8.6@(0.69166,-5.3)	-65.8@(10.00821,39.8)	-70.4@(10.00821,58.4)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	275% / 476%	293% / 488%	255% / 452%	0.16667 sec / 0.16667 sec	0.18333 sec / 0.18333 sec
63	G82R at Rugby/L20D at Drayton	999% / 595%	999% / 548%	999% / 585%	999% / 417%	999% / 540%
64	R50M / F3M	883% / 324%	848% / 324%	850% / 315%	480% / 173%	687% / 196%
65	B10T	235%	189%	205%	184%	148%
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 | 3) / (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 | 3 | 3)	(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 | 1 | 1)	(1 | 3 | 1) / (1 | 2 | 2)

Case	mh3-so15aa-mjs	mh3-so15aa-mkd	mh3-so15aa-mks	mh3-so15aa-nad	mh3-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**	mh3-so15aa-pas	mh3-so15aa-pc0	mh3-so15aa-pcs	mh3-so15aa-pct	mh3-so15aa-pzs
3	**Disturbance**	pas	pc0	pcs	pct	pzs
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 23 2009 21:06	APR 23 2009 21:09	APR 23 2009 21:12	APR 23 2009 21:15	APR 23 2009 21:17
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2329 / 130	2329 / 130	2329 / 130	2329 / 130	2329 / 130
10	MHEX / L20D	2052 / 293	2052 / 293	2052 / 293	2052 / 293	2052 / 293
11	ECL-ARP / PRI-BYN	726 / 119	726 / 119	726 / 119	726 / 119	726 / 119
12	MWEX / AHD-SLK	1669 / 647	1669 / 647	1669 / 647	1669 / 647	1669 / 647
13	D602F / F601C	0 / 1233	0 / 1233	0 / 1233	0 / 1233	0 / 1233
14	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
15	OH E-W / OH>MH	190 / -196	190 / -196	190 / -196	190 / -196	190 / -196
16	R50M / OH>MP	138 / 150	138 / 150	138 / 150	138 / 150	138 / 150
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	900 / -48	900 / -48	900 / -48	900 / -48	900 / -48
20	Forbes SVC / MSC	-7 / 600	-7 / 600	-7 / 600	-7 / 600	-7 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 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 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009
26	Int Falls 115/Badoura 115	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044
27	Drayton 230/Groton 345	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	295% / 494%	295% / 494%	295% / 494%	295% / 494%	295% / 494%
30	G82R at Rugby/L20D at Drayton	999% / 673%	999% / 673%	999% / 673%	999% / 673%	999% / 673%
31	R50M/F3M	979% / 324%	979% / 324%	979% / 324%	979% / 324%	979% / 324%
32	B10T	343%	343%	343%	343%	343%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.06	0.88 | 0.99	0.87 | 0.98	0.93 | 0.96	0.98 | 1.03
35	Boise 115	0.98 | 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 | 1.08	1.03 | 1.08	1.04 | 1.05	1.03 | 1.07
37	Forbes 230	0.99 | 1.04	1.02 | 1.03	1.02 | 1.04	1.02 | 1.03	1.03 | 1.06
38	Riverton 230	1.01 | 1.05	1.00 | 1.04	1.00 | 1.04	1.02 | 1.03	1.02 | 1.05
39	Coal Creek 230	1.00 | 1.06	0.96 | 1.08	0.96 | 1.08	1.02 | 1.04	0.98 | 1.08
40	Jamestown 345	0.95 | 0.99	0.92 | 1.01	0.92 | 1.01	0.98 | 1.00	0.94 | 1.01
41	Drayton 230	1.00 | 1.05	1.02 | 1.07	1.01 | 1.05	1.02 | 1.03	1.02 | 1.04
42	Groton 345	0.99 | 1.03	0.97 | 1.03	0.97 | 1.03	1.00 | 1.02	0.98 | 1.03
43	Minong 161	1.02 | 1.08	0.85 | 1.01	0.85 | 0.99	0.92 | 0.97	0.99 | 1.05
44	Wahpeton 115	1.02 | 1.05	1.01 | 1.07	1.01 | 1.06	1.04 | 1.05	1.02 | 1.06
45	Watertown 345	1.01 | 1.04	1.00 | 1.04	1.00 | 1.04	1.02 | 1.03	1.01 | 1.04
46	**Dynamic Voltage Warnings**					
47		63061 [MIDCOMP] 1.23	63061 [MIDCOMP] 1.22	63061 [MIDCOMP] 1.23	63061 [MIDCOMP] 1.21	63061 [MIDCOMP] 1.21
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 42.06%	SHERC3 / 70.07%	SHERC3 / 68.81%	SHERC3 / 52.31%	KING 3 / 69.58%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.141	/ 0.141		
56	Forbes DC Red (DCAR)	503%	313%	291%	348%	373%
57	K22W (max +dP @ t, d-ang)	86.1@(2.00833,-39.2)	8.1@(3.30831,-0.4)	3.3@(0.11667,0.7)	0.0@(0.10000,0.0)	18.3@(2.35832,-2.4)
58	K22W (max -dP @ t, d-ang)	47.9@(0.25833,4.2)	51.0@(0.37500,8.4)	51.1@(0.37500,8.3)	37.4@(1.96666,15.5)	28.1@(0.38333,4.5)
59	K22W (max d-ang @ t, dP)	-64.1@(10.00821,45.3)	20.7@(1.00833,-36.9)	21.4@(1.05000,-41.7)	15.5@(1.96666,-37.4)	12.7@(0.90000,-13.4)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.38333 sec / 0.18333 sec	230% / 383%	234% / 390%	278% / 466%	240% / 401%
63	G82R at Rugby/L20D at Drayton	999% / 474%	999% / 524%	999% / 533%	999% / 600%	999% / 565%
64	R50M / F3M	548% / 199%	732% / 311%	737% / 324%	854% / 324%	797% / 296%
65	B10T	210%	166%	176%	269%	174%
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 | 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 | 3 | 2) / (0 | 1 | 1)	(1 | 1 | 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)

Case	mh3-so15aa-pas	mh3-so15aa-pc0	mh3-so15aa-pcs	mh3-so15aa-pct	mh3-so15aa-pzs
Disturbance	pas	pc0	pcs	pct	pzs
System Response	OK	OK	OK	OK	OK
70% or 120% Violations	M	M	M	M	M
ORWG Criteria Violations					
Line Tripping	(5T)(6T)				

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

1	**Case No.**	21	22	23	24	25
2	**Case Name**	mh3-so15aa-pzt	mh3-so15aa-ya3	mh3-so15aa-yas	mh3-so15aa-yb3	mh3-so15aa-h13
3	**Disturbance**	pzt	ya3	yas	yb3	h13
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 23 2009 21:20	APR 23 2009 22:02	APR 23 2009 22:05	APR 23 2009 22:07	APR 23 2009 21:38
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2329 / 130	2329 / 130	2329 / 130	2329 / 130	2329 / 130
10	MHEX / L20D	2052 / 293	2052 / 293	2052 / 293	2052 / 293	2052 / 293
11	ECL-ARP / PRI-BYN	726 / 119	726 / 119	726 / 119	726 / 119	726 / 119
12	MWEX / AHD-SLK	1669 / 647	1669 / 647	1669 / 647	1669 / 647	1669 / 647
13	D602F / F601C	0 / 1233	0 / 1233	0 / 1233	0 / 1233	0 / 1233
14	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
15	OH E-W / OH>MH	190 / -196	190 / -196	190 / -196	190 / -196	190 / -196
16	R50M / OH>MP	138 / 150	138 / 150	138 / 150	138 / 150	138 / 150
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	900 / -48	900 / -48	900 / -48	900 / -48	900 / -48
20	Forbes SVC / MSC	-7 / 600	-7 / 600	-7 / 600	-7 / 600	-7 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 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 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009
26	Int Falls 115/Badoura 115	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044
27	Drayton 230/Groton 345	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	295% / 494%	295% / 494%	295% / 494%	295% / 494%	295% / 494%
30	G82R at Rugby/L20D at Drayton	999% / 673%	999% / 673%	999% / 673%	999% / 673%	999% / 673%
31	R50M/F3M	979% / 324%	979% / 324%	979% / 324%	979% / 324%	979% / 324%
32	B10T	343%	343%	343%	343%	343%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.00 | 1.01	1.01 | 1.02	0.96 | 0.99	1.03 | 1.05	1.00 | 1.03
35	Boise 115	1.02 | 1.03	1.03 | 1.04	1.02 | 1.04	1.03 | 1.04	1.01 | 1.03
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.07	1.04 | 1.05	0.99 | 1.05
37	Forbes 230	1.03 | 1.04	1.03 | 1.04	1.02 | 1.04	1.03 | 1.04	1.02 | 1.04
38	Riverton 230	1.03 | 1.04	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 | 1.05
40	Jamestown 345	0.99 | 0.99	0.98 | 1.00	0.97 | 1.00	0.98 | 1.00	0.97 | 1.00
41	Drayton 230	1.03 | 1.03	1.02 | 1.04	1.02 | 1.04	1.02 | 1.04	1.01 | 1.04
42	Groton 345	1.01 | 1.02	1.00 | 1.01	1.00 | 1.01	1.00 | 1.01	1.00 | 1.03
43	Minong 161	1.01 | 1.01	0.97 | 0.99	0.96 | 1.03	0.97 | 1.00	1.01 | 1.04
44	Wahpeton 115	1.05 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05
45	Watertown 345	1.02 | 1.03	1.02 | 1.02	1.02 | 1.02	1.02 | 1.02	1.02 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	none		none	
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	SHERC3 / 53.57%	SHERC3 / 49.74%	ANTEL3 / 67.32%	KING 3 / 52.84%	SHERC3 / 70.41%
55	Dorsey SUVP / UdHold					/ 0.133
56	Forbes DC Red (DCAR)	463%	379%	427%	410%	465%
57	K22W (max +dP @ t, d-ang)	0.0@(0.10000,0.0)	4.9@(0.11667,0.7)	3.0@(0.11667,0.4)	3.3@(0.11667,0.6)	103.7@(0.15000,-2.3)
58	K22W (max -dP @ t, d-ang)	9.3@(1.74166,3.7)	27.0@(1.65833,12.5)	22.1@(1.64166,9.6)	19.6@(1.61666,8.8)	22.5@(2.95832,4.5)
59	K22W (max d-ang @ t, dP)	3.8@(2.06666,-9.0)	12.7@(1.90000,-24.5)	10.2@(1.06666,-15.7)	8.9@(1.87500,-17.4)	-9.8@(0.64166,3.7)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	292% / 489%	295% / 494%	290% / 485%	295% / 494%	277% / 462%
63	G82R at Rugby/L20D at Drayton	999% / 655%	999% / 610%	999% / 622%	999% / 627%	999% / 608%
64	R50M / F3M	954% / 324%	979% / 324%	973% / 324%	979% / 324%	876% / 261%
65	B10T	319%	267%	274%	284%	274%
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)

Case	mh3-so15aa-pzt	mh3-so15aa-ya3	mh3-so15aa-yas	mh3-so15aa-yb3	mh3-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**	mh3-so15aa-h23	mh3-so15aa-h33	mh3-so15aa-h43	mh3-so15aa-hc3	mh3-so15aa-hd3
3	**Disturbance**	h23	h33	h43	hc3	hd3
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 23 2009 21:41	APR 23 2009 21:44	APR 23 2009 21:47	APR 23 2009 21:50	APR 23 2009 21:53
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2329 / 130	2329 / 130	2329 / 130	2329 / 130	2329 / 130
10	MHEX / L20D	2052 / 293	2052 / 293	2052 / 293	2052 / 293	2052 / 293
11	ECL-ARP / PRI-BYN	726 / 119	726 / 119	726 / 119	726 / 119	726 / 119
12	MWEX / AHD-SLK	1669 / 647	1669 / 647	1669 / 647	1669 / 647	1669 / 647
13	D602F / F601C	0 / 1233	0 / 1233	0 / 1233	0 / 1233	0 / 1233
14	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
15	OH E-W / OH>MH	190 / -196	190 / -196	190 / -196	190 / -196	190 / -196
16	R50M / OH>MP	138 / 150	138 / 150	138 / 150	138 / 150	138 / 150
17	G82R	N/A	N/A	N/A	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	900 / -48	900 / -48	900 / -48	900 / -48	900 / -48
20	Forbes SVC / MSC	-7 / 600	-7 / 600	-7 / 600	-7 / 600	-7 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 1.045	1.046 / 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 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009	1.031 / 1.009
26	Int Falls 115/Badoura 115	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044	1.023 / 1.044
27	Drayton 230/Groton 345	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015	1.029 / 1.015
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	295% / 494%	295% / 494%	295% / 494%	295% / 494%	295% / 494%
30	G82R at Rugby/L20D at Drayton	999% / 673%	999% / 673%	999% / 673%	999% / 673%	999% / 673%
31	R50M/F3M	979% / 324%	979% / 324%	979% / 324%	979% / 324%	979% / 324%
32	B10T	343%	343%	343%	343%	343%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.02 | 1.06	1.03 | 1.08	1.00 | 1.03	1.01 | 1.04	0.97 | 1.05
35	Boise 115	1.01 | 1.03	0.97 | 1.01	1.00 | 1.02	1.00 | 1.02	1.00 | 1.02
36	Dorsey 230	1.02 | 1.07	1.04 | 1.07	0.99 | 1.04	1.03 | 1.06	1.03 | 1.06
37	Forbes 230	1.04 | 1.05	1.05 | 1.07	1.02 | 1.04	1.01 | 1.04	1.02 | 1.04
38	Riverton 230	1.04 | 1.05	1.04 | 1.06	1.03 | 1.04	1.02 | 1.04	1.00 | 1.04
39	Coal Creek 230	1.03 | 1.06	1.03 | 1.07	1.02 | 1.05	1.02 | 1.06	1.01 | 1.06
40	Jamestown 345	0.97 | 1.00	0.94 | 1.00	0.97 | 1.00	0.95 | 0.99	0.96 | 0.99
41	Drayton 230	1.03 | 1.06	1.01 | 1.05	1.01 | 1.03	1.01 | 1.04	1.01 | 1.04
42	Groton 345	1.00 | 1.04	0.99 | 1.04	1.00 | 1.03	0.99 | 1.03	0.99 | 1.03
43	Minong 161	1.02 | 1.07	1.04 | 1.08	1.01 | 1.04	1.03 | 1.06	1.00 | 1.08
44	Wahpeton 115	1.04 | 1.06	1.02 | 1.06	1.04 | 1.05	1.02 | 1.05	1.02 | 1.05
45	Watertown 345	1.03 | 1.04	1.02 | 1.04	1.02 | 1.03	1.02 | 1.03	1.02 | 1.04
46	**Dynamic Voltage Warnings**					
47		63061 [MIDCOMP] 1.26	63061 [MIDCOMP] 1.24	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping	KING 3 / 3.51%	KING 3 / 32.95%	SHERC3 / 70.12%	KING 3 / 29.92%	KING 3 / 50.09%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	446%	507%	477%	507%	507%
57	K22W (max +dP @ t, d-ang)	103.7@(0.15000,-2.3)	98.0@(0.15000,-1.9)	98.0@(0.15000,-1.9)	103.7@(0.15000,-2.3)	74.8@(2.05000,-28.4)
58	K22W (max -dP @ t, d-ang)	0.0@(0.01667,0.0)	18.2@(0.24167,0.5)	33.8@(2.95832,7.3)	4.0@(0.25000,0.3)	60.2@(0.26667,7.0)
59	K22W (max d-ang @ t, dP)	-39.7@(10.00821,48.8)	-67.5@(10.00821,44.3)	8.3@(2.61665,-21.0)	-47.6@(10.00821,36.8)	-47.1@(10.00821,37.8)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	295% / 494%	0.18333 sec / 0.18333 sec	285% / 473%	224% / 377%	190% / 323%
63	G82R at Rugby/L20D at Drayton	999% / 673%	999% / 629%	999% / 535%	999% / 671%	999% / 483%
64	R50M / F3M	979% / 250%	581% / 171%	732% / 259%	903% / 232%	714% / 227%
65	B10T	328%	255%	259%	267%	196%
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 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 3) / (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)

Case	mh3-so15aa-h23	mh3-so15aa-h33	mh3-so15aa-h43	mh3-so15aa-hc3	mh3-so15aa-hd3
Disturbance	h23	h33	h43	hc3	hd3
System Response	OK	OK	OK	OK	OK
70% or 120% Violations	M	M			
ORWG Criteria Violations					
Line Tripping		(5T)(6T)			

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

1	**Case No.**	31	32
2	**Case Name**	mh3-so15aa-hf0	mh3-so15aa-his
3	**Disturbance**	hfs	his
4	**Prior Outage**	None	None
5	**Date/Time**	APR 24 2009 9:20	APR 23 2009 21:59
6	**Comments**		
7			
8	**Steady State Flows**		
9	NDEX / EAST BIAS	2329 / 130	2329 / 130
10	MHEX / L20D	2052 / 293	2052 / 293
11	ECL-ARP / PRI-BYN	726 / 119	726 / 119
12	MWEX / AHD-SLK	1669 / 647	1669 / 647
13	D602F / F601C	0 / 1233	0 / 1233
14	B10T / MH>SPC	165 / 60	165 / 60
15	OH E-W / OH>MH	190 / -196	190 / -196
16	R50M / OH>MP	138 / 150	138 / 150
17	G82R	N/A	N/A
18	Dorsey bipole / CU bipole	3245 / 1103	3245 / 1103
19	Dorsey Reserve / Wtrtn SVC	900 / -48	900 / -48
20	Forbes SVC / MSC	-7 / 600	-7 / 600
21	RCDC	0	0
22	**Steady State Vltgs**		
23	Dorsey 500/Dorsey 230	1.046 / 1.045	1.046 / 1.045
24	Roseau 500/Forbes 500	1.043 / 1.035	1.043 / 1.035
25	Chisago 500/EauClaire 345	1.031 / 1.009	1.031 / 1.009
26	Int Falls 115/Badoura 115	1.023 / 1.044	1.023 / 1.044
27	Drayton 230/Groton 345	1.029 / 1.015	1.029 / 1.015
28	**SS OS Relay Margins**		
29	D602F at Forbes/Dorsey	295% / 494%	295% / 494%
30	G82R at Rugby/L20D at Drayton	999% / 673%	999% / 673%
31	R50M/F3M	979% / 324%	979% / 324%
32	B10T	343%	343%
33	**Min/MaxTransientVltg**		
34	Arrowhd 230	1.01 | 1.06	0.87 | 1.03
35	Boise 115	1.00 | 1.04	0.99 | 1.03
36	Dorsey 230	1.04 | 1.16	1.04 | 1.07
37	Forbes 230	1.04 | 1.07	1.00 | 1.04
38	Riverton 230	1.03 | 1.05	0.98 | 1.05
39	Coal Creek 230	1.01 | 1.06	0.99 | 1.06
40	Jamestown 345	0.96 | 1.00	0.96 | 1.01
41	Drayton 230	1.05 | 1.11	1.02 | 1.06
42	Groton 345	0.99 | 1.04	0.98 | 1.03
43	Minong 161	1.02 | 1.08	0.87 | 1.06
44	Wahpeton 115	1.03 | 1.06	1.02 | 1.07
45	Watertown 345	1.02 | 1.04	1.00 | 1.04
46	**Dynamic Voltage Warnings**		
47		none	none
48			
49			
50			
51			
52			
53			
54	Worst Case Angle Damping	KING 3 / 32.93%	SHERC3 / 67.81%
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	413%	467%
57	K22W (max +dP @ t, d-ang)	146.1@(1.52500,-43.3)	76.0@(2.24166,-28.9)
58	K22W (max -dP @ t, d-ang)	52.5@(0.39166,6.4)	55.0@(0.30000,8.0)
59	K22W (max d-ang @ t, dP)	-78.3@(10.00821,82.1)	-42.5@(10.00821,24.5)
60	**OS Rel Trip / Marg**		
61	MH - OH		
62	D602F at Forbes/Dorsey	59% / 84%	169% / 283%
63	G82R at Rugby/L20D at Drayton	999% / 334%	999% / 515%
64	R50M / F3M	489% / 196%	679% / 234%
65	B10T	227%	118%
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 | 4 | 1) / (0 | 1 | 1)	(1 | 2 | 1) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 1 | 0) / (1 | 2 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 3 | 2) / (1 | 2 | 2)

Case	mh3-so15aa-hf0	mh3-so15aa-his
Disturbance	hfs	his
System Response	OK	OK
70% or 120% Violations		
ORWG Criteria Violations		
Line Tripping		