Report R30-10 DRAFT

MHEB Group TSR System Impact Study Transmission Option 1

Prepared for

Midwest ISO

Submitted by:
Douglas R. Brown
Patrick Jehring

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Siemens Energy, Inc.
Siemens Power Technologies International
10900 Wayzata Boulevard
Minnetonka, MN 55305
Tel: 518-395-5000 • Fax: 518-346-2777
www.usa.siemens.com/PTI

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Executive Summary

A System Impact Study (SIS) for several requests for long term firm transmission service was posted on the Midwest ISO OASIS Studies Page in July of 2009[1]. Through the course of the SIS, the Study Group identified a need for studying additional scenarios. The results of the additional impact analysis of the Option 1 network upgrades is summarized in this report.

The active requests are shown in Table E-1 and Table E-2. The South bound requests seek to reserve 1100 MW of transmission service from Manitoba Hydro to various sinks in the United States. The North bound requests seek to reserve 1100 MW of transmission service from various sources in the United State to Manitoba Hydro.

Table E-1: MH-US South bound Requests

Oasis Ref No	Service Type	Start Time	Stop Time	POR	POD	Requested Capacity	Queue Date	Study Number
76703536	Network	Nov-2014	Nov-2024	MHEB-MISO	GRE	200	12/7/2006	A388
76703671	Network	Jun-2017	Jun-2027	MHEB-MISO	WPS	500	6/12/2007	A380
76703672	Network	Jun-2017	Jun-2037	MHEB-MISO	MP	250	7/6/2007	A383
76703686	Network	Jun-2017	Jun-2027	MHEB-MISO	NSP	50	4/17/2008	A416
76703687	Network	Jun-2017	Jun-2027	MHEB-MISO	WEC	100	4/17/2008	A417
					Total MW	1100		

Table E-2: US-MH North bound Requests

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

[1] *MHEB Group TSR System Impact Study*; Siemens PTI Report R164-08, (July 17, 2009)

Option 1 Transmission Facilities

Two updates have been made to the Option 1 transmission facilities since the July SIS was completed. The proposed 500 kV substation near Fargo was modeled at Maple River in the SIS; the Facilities Study assumes the new 500 kV substation is located at the Bison substation proposed by CapX. The second update is a revision to the 500 kV line impedance based on mileage and line construction assumptions developed in the Facilities Study. The Option 1 transmission facilities are as follows:

- Dorsey-Bison 500 kV line (230 miles); 50% series compensation
- Bison-Helena 500 kV line (286 miles); 50% series compensation
- One 500-345 kV, 1200 MVA transformer at Bison (1500 MVA emergency rating)
- Two 500-345 kV, 1200 MVA transformers at Helena (1500 MVA emergency rating)

Existing 500 kV and 230 kV triggers to the Manitoba Hydro HVDC power order reduction scheme are modeled using current MW reduction values. All analyses assume that outage of the Dorsey-Bison 500 kV line associated with upgrade Option 1 is accompanied by HVDC reduction if Manitoba is exporting.

Shunt Reactors

A steady-state analysis has been performed to size shunt reactors for the Option 1 500 kV transmission facilities to limit voltage rise when one of the 500 kV lines is open ended and to limit voltage when the system is lightly loaded. After sizing the reactors, a stability analysis was performed to identify any transient-period criteria violations.

The shunt reactors listed in Table E-3 will be connected to the line terminals to limit voltage during open circuit conditions. Steady-state analysis of a low transfer case indicates that an additional 100 MVAr reactor is required at Bison to limit voltage during light load conditions. Steady-state post-contingent voltage at Bison remains below 1.07 per unit and there is no indication that fast switching is required.

Table E-3: Proposed Line Connected Shunt Reactors

Line	End	Proposed
Dorsey-Bison	Dorsey	150 MVAR
	Bison	150 MVAR
Bison-Helena	Bison	225 MVAR
	Helena	225 MVAR

The Forbes SVS exceeds the 110 MVAr continuous rating at the end of simulations where the Bison-Helena 500 kV line is opened for fault clearing (*h53, o53,o6s*). Disturbances were simulated assuming that outage of the Bison-Helena 500 kV line is not accompanied by HVDC reduction; HVDC reduction can be used to reduce SVS loading.

Synchronous Condensers

Synchronous condensers at Dorsey and Riel were checked to determine the impact of the Option 1 transmission facilities on reactive power production. The system is planned so that at maximum HVDC loading levels with one synchronous condenser out of service, the system can withstand the loss of a second condenser and still remain at maximum power levels. At low HVDC loading levels, the steady-state output of the synchronous condensers at Dorsey should be close to zero (±100 MVAr).

Analysis of a case with the Manitoba DC bipoles near maximum loading with maximum Manitoba to US exports (2175 MW + 1100 MW) shows that condenser output exceeds the maximum allowable production by approximately 62 MVAr. Two additional 36.7 MVAr tertiary capacitors mitigate the TSR impact on condenser loading and restore the Dorsey 460 MVAr reserve and Riel 500 MVAr reserve in the case with the DC bipoles at maximum loading.

Analysis of a low transfer case with the Option 1 transmission facilities indicates that shunt reactors are required in Manitoba to increase condenser output so that the Dorsey and Riel condensers are not absorbing a significant amount of reactive power; a total of 125 MVAr will increase condenser output back to benchmark case levels.

A stability simulation was performed to confirm that the Dorsey System Undervoltage Controller (SUVC) does not operate for loss of a synchronous condenser. One 160 MVAr condenser was modeled out of service in the off-peak stability case and a Dorsey 230 kV bus fault was cleared by tripping one 300 MVAr condenser. The 230 kV voltage drops below 0.99 per unit during the fault, which is long enough that the Dorsey Stability Control (UDhold) operates. However, voltage recovers when the fault is cleared and does not drop back below 0.99 per unit so the SUVC does not operate.

Prior Outage

Analyses have been performed with the Option 1 network upgrades to determine transfer capability on the MHEX_S interface with the Riel-Forbes-Chisago 500 kV line out of service. The existing Manitoba-US transfer limit (SOL, system intact) is 2175 MW, and there is a 1420 MW (2175-755) difference between the system intact and prior outage transfer limit. A linear analysis was performed to screen for thermal constraints at two transfer levels - 2175 MW and 1855 MW. The 2175 MW transfer level would maintain the existing transfer capability with one 500 kV line in service; the 1855 MW transfer level would maintain the existing 1420 MW difference between the system intact and prior outage transfer capability. A stability analysis was performed at the 2175 MW transfer level.

Thermal and stability power flow models were created with the Riel-Forbes-Chisago 500 kV line out of service. The Forbes SVS is assumed to be in service. A 300 MVAr shunt capacitor was modeled at the Bison 500 kV bus with the Riel-Forbes-Chisago 500 kV line out of service. There were no voltage violations in the July SIS or in the stability analysis described in Section 2.2 to indicate that dynamic voltage control is required at Bison.

The only thermal constraint identified in the linear screening analysis for the 1855 MW transfer level is the Alexandria 115 kV line; the rating of this facility is limited by terminal equipment. The 2175 MW transfer level is limited by the Blue Lake-Helena 345 kV line in addition to the Alexandria 115 kV line.

A stability analysis was performed at the 2175 MW transfer level. The disturbances listed in Table 4-5 were simulated in the prior outage stability analysis. The list includes faults on the Leland Olds-Ft Thompson 345 kV line (*ag1 and ag3*), faults at Monticello and Sherburne Co (*mcs*, *mes*, *mfs* and *mts*), and block of the Manitoba Hydro HVDC bipole 2 (*mis* and *miz*).

The only transient period criteria violation occurs for a fault on the Helena-Bison 500 kV line (*h53*), which causes the DPDARE relay on the MH-OH ties to operate. Disturbances were simulated assuming that outage of the Bison-Helena 500 kV line is not accompanied by HVDC reduction; the post-contingent surge of power on the Manitoba to Ontario tie lines can be minimized using HVDC reduction.

The post-disturbance voltage at the Bison 500 kV bus is 1.16 per unit following a breaker failure at the Bison 500 kV bus cleared by tripping the 500-345 kV transformer and Bison-Dorsey line (*ho0*), which leaves the Bison-Helena line open circuited at Bison with the 300 MVAr capacitor connected. A similar situation will occur for failure of any circuit breaker in the 500 kV ring at Bison so the capacitor should be disconnected when this condition occurs. The post-disturbance voltage at Bison is less than 1.10 per unit for the other disturbances simulated.

Conclusions

System impact study results demonstrate a need for the system upgrades listed in Table E-4.

All analyses assume that outage of the Dorsey-Bison 500 kV line associated with upgrade Option 1 is accompanied by HVDC reduction if Manitoba is exporting. Study results show that HVDC reduction should also be initiated for outage of the Bison-Helena 500 kV line.

Study results do not show a need for dynamic voltage control (SVS or fast-switching) at Bison.

Table E-4: Option 1 System Upgrades

Item	Driver/Need	Cost Estimate ($1,000)
Facilities required to enable transmission service		
Transmission Facilities - Dorsey-Bison 500 kV line (230 miles); 50% series compensation - Bison-Helena 500 kV line (286 miles); 50% series compensation - One 500-345 kV, 1200 MVA transformer at Bison (1500 MVA emergency rating) - Two 500-345 kV, 1200 MVA transformers at Helena (1500 MVA emergency rating)	Enable new transmission service	$1,242,400
Constraint Mitigation - Reconductor 22.7 mi of the Saratoga - Petenwell 138 kV line - Replace substation equipment at East Krok on East Krok - Kewaunee 138 kV line - Replace terminal equipment on Stanton-Coal Creek 230 kV line	 Enable new transmission service Enable new transmission service Enable new transmission service	 $2,927 $1,000 $500
Facilities identified through evaluation of open circuit conditions		
Shunt reactors connected to line terminals - 150 MVAr at Dorsey on Dorsey-Bison 500 kV line - 150 MVAr at Bison on Dorsey-Bison 500 kV line - 225 MVAr at Bison on Bison-Helena 500 kV line - 225 MVAr at Helena on Bison-Helena 500 kV line	Limit voltage rise on 500 kV line during open circuit conditions.	TBD
Facilities identified through evaluation of operating scenarios		
Bison 500 kV shunt capacitors and reactors - 300 MVAr of shunt capacitors - 125 MVAr of shunt reactors (bus connected)	Voltage control at Bison. Capacitors are needed for prior outage of Riel-Forbes. Reactors are needed for light load conditions.	TBD
Dorsey shunt capacitors and reactors - Two 36.7 MVAr shunt capacitors (transformer tertiary) - 125 MVAr of shunt reactors (at bus or transformer tertiary)	Maintain reserves on synchronous condensers in Manitoba. Capacitors are needed for maximum export at peak load. Reactors are needed for low transfer conditions at light load.	TBD
Constraint Mitigation - Replace terminal equipment on the Alexandria-Alexandria SS 115 kV line - Mitigate constraint on Helena-Blue Lake 345 kV line	 Achieve 1855 MW transfer level with Riel-Forbes-Chisago out of service Achieve 2175 MW transfer level with Riel-Forbes-Chisago out of service	 TBD TBD

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Section
1

Cases and Option 1 Transmission

1.1 Benchmark Power Flow Cases

The benchmark power flow cases are used to benchmark system performance and do not include the study TSRs or Option 1 transmission facilities. Development of the original benchmark cases is described in the July SIS report.

The benchmark power flow cases from the July SIS have been updated based on feedback provided by the study group. The most significant changes are the addition of the proposed Bison substation west of Fargo and adjustment of HVDC loading at Dorsey and Riel.

The Bison substation is a CapX Group 1 project, and is the western terminal of the proposed Fargo-St Cloud 345 kV line. The Bison substation includes 345 kV and 230 kV buses and two new 345-230 kV transformers. The Bison substation will be connected to Maple River at 345 kV and at 230 kV as shown in Figure 1-1.

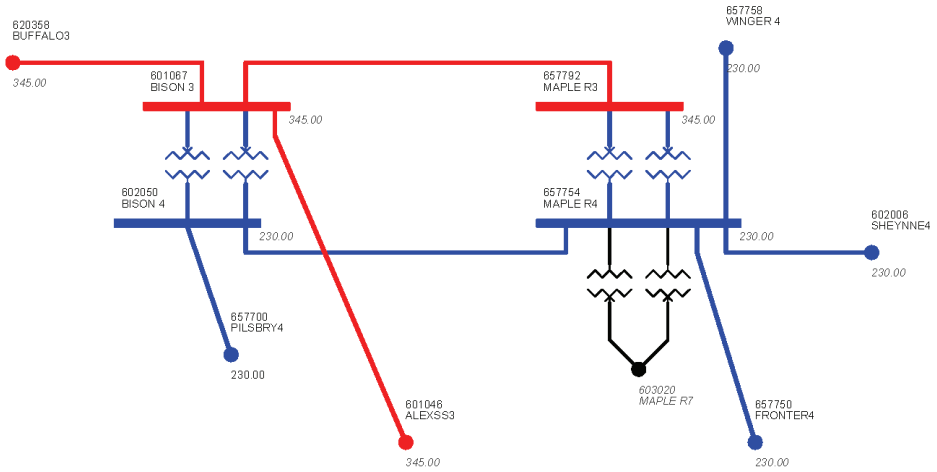

Figure 1-1: Bison Substation

HVDC loading at Dorsey and Riel was adjusted in the power flow cases so that only the loading at Dorsey is changed when the TSRs are added to the case. HVDC loading is described in more detail in Section 3.

A case representing off-peak conditions with low transfer levels (low transfer case) was created from the off-peak stability case. The low transfer case has a MHEX_S flow of

approximately 0 MW and a NDEX flow of approximately 948 MW. Development of the low transfer case is described in Appendix A.

MHEX flow for each benchmark case is summarized in Table 1-1; diagrams are in Appendix A.

Table 1-1: Case Summary

Case	MHEX
Summer Peak Thermal Cases	South Flow
Benchmark case	1848 MW
Benchmark case with Option 1 Transmission	1845 MW
Study case (Option 1 Transmission and TSRs)	2941 MW
Winter Peak Thermal Cases	North Flow
Benchmark case	695 MW
Benchmark case with Option 1 Transmission	699 MW
Study case (Option 1 Transmission and TSRs)	1799 MW
Off Peak Stability Cases	South Flow
Benchmark case	2178 MW
Benchmark case with Option 1 Transmission	2189 MW
Study case (Option 1 Transmission and TSRs)	3277 MW
Low Transfer Cases	
Benchmark case	2 MW
Benchmark case with Option 1 Transmission	2 MW

1.2 Option 1 Study Cases

TSR study cases were created by taking the benchmark case and modeling the requested transmission service along with the Option 1 transmission facilities. TSRs were modeled using the same sources and sinks as the July SIS. MHEX flow for each study case is summarized in Table 1-1; diagrams are in Appendix A.

1.3 Option 1 Transmission Facilities

Two updates have been made to the Option 1 transmission facilities since the July SIS was completed. The 500 kV substation near Fargo was modeled at Maple River in the SIS; the Facilities Study assumes the location will be the proposed Bison substation. The Option 1 transmission facilities are listed below; system topology assumptions are documented in Appendix A.2.

- Dorsey-Bison 500 kV line (230 miles); 50% series compensation
- Bison-Helena 500 kV line (286 miles); 50% series compensation
- One 500-345 kV, 1200 MVA transformer at Bison (1500 MVA emergency rating)
- Two 500-345 kV, 1200 MVA transformers at Helena (1500 MVA emergency rating)

The second update is a revision to the 500 kV line impedance based on mileage and line construction assumptions developed in the Facilities Study. Updated impedance values are

provided in Table 1-2. During the January 27 Facilities Study scoping call, the CapX group indicated that series compensation should remain at 50%.

Table 1-2: Option 1 Model Parameters [1]

Facility	R (pu)	X (pu)	B (pu)
Dorsey – Bison 500 kV line with 50% series compensation	0.00256	0.05119 -0.02560	4.42790
Bison – Helena 500 kV line with 50% series compensation	0.00316	0.06364 -0.03182	5.50596
500/345 kV, 1200 MVA Transformer One at Bison Two at Helena	0.000050	0.004700	

Note 1: Model parameters are expressed in per unit on a 100 MVA base

All analyses assume that outage of the Dorsey-Bison 500 kV line associated with upgrade Option 1 is accompanied by HVDC reduction if Manitoba is exporting. Existing 500 kV and 230 kV triggers to the Manitoba Hydro HVDC power order reduction scheme are modeled using current MW reduction values.

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Section
2

Shunt Reactors

2.1 Line Connected Reactors

Shunt reactors are used to limit voltage rise when an end of one of the 500 kV lines is open and to limit voltage when the system is lightly loaded. Reactor sizes were determined based on the following assumptions:

1) The series capacitor in the open line is completely bypassed.
2) All 500-345 kV transformers are in service.
3) Voltage at the sending end of line is 1.05 per unit.
4) Steady-state voltage at the open end of line should not exceed 1.10 per unit.

Table 2-1 shows the proposed line-connected shunt reactors.

Table 2-1: Proposed Shunt Reactors

Line	End	Proposed
Dorsey-Bison	Dorsey	150 MVAR
	Bison	150 MVAR
Bison-Helena	Bison	225 MVAR
	Helena	225 MVAR

The Option 1 transmission facilities were modeled in the benchmark power flow cases (without the TSRs) along with the line-connected reactors listed in Table 2-1; diagrams are in Appendix A.

2.1.1 Low Transfer Case

As shown in Appendix A, the Bison 500 kV voltage is 1.048 per unit in the low transfer case. Buses near Bison with pre-contingent voltages above 1.05 per unit are listed in Table 2-2; the voltage change caused by the Option 1 transmission facilities is less than 0.01 per unit and the impact is not considered significant.

Table 2-2: Pre Contingent Voltages Exceeding 1.05 Per Unit in Low Transfer Case

Bus	Benchmark Case	Benchmark Case with Option 1 Transmission	Change
Barnes 230 kV	1.061 pu	1.068 pu	0.007 pu
Pillsbury 230 kV	1.060 pu	1.066 pu	0.006 pu
Ashtabula 230 kV	1.062 pu	1.068 pu	0.006 pu
Jamestown 115 kV	1.051 pu	1.053 pu	0.002 pu

A steady-state non-linear contingency analysis was performed on the low transfer case to identify voltage violations; no voltage violations (voltages above 1.10 per unit) were identified. The steady-state voltage at Bison is 1.057 per unit when the Bison 500-345 kV transformer is outaged. Table 2-4 shows voltage at the Bison 500 kV bus for different sizes of shunt reactors connected to the 500 kV bus and the corresponding voltage with the Bison 500-345 kV transformer out of service.

Table 2-3: Voltage at Bison 500 kV Bus in Low Transfer Case

Reactor Size	System Intact Voltage	Voltage with Bison Xfmr Outaged
0 MVAr	1.048 pu	1.057 pu
70 MVAr	1.040 pu	1.044 pu

2.1.2 Open Circuit Conditions

The Option 1 transmission facilities were modeled in the benchmark power flow cases (without the TSRs); each end of the Dorsey-Bison north line and the Bison-Helena south line was opened and voltage was recorded at the open end. Table 2-4 shows voltage without any shunt reactors.

Table 2-5 shows voltage with the line-connected reactors from Table 2-1. These calculations assume that the series capacitor in the open line is completely bypassed. The steady-state voltage at Bison exceeds 1.05 per unit when the 500 kV line is open at Dorsey or at Helena. An additional 100 MVAr capacitor at the Bison 500 kV bus will keep the steady-state voltage at or below 1.05 per unit; results are included in the Table 2-5 column labeled "Low Transfer with Bison 100 MVAr Reactor".

The angle across the open circuit breaker (Dorsey, Bison or Helena) is approximately 35 degrees at the 2175 MW transfer level in the off-peak stability case and approximately 45 degrees at the 3275 MW transfer level.

Table 2-4: Voltages for Open Circuit Conditions without Shunt Reactors

Line	Open End	Summer Peak Thermal MHEX = 1850 MW (South)			Winter Peak Thermal MHEX = 700 MW (North)			Off-Peak Stability MHEX = 2175 MW (South)			Low Transfer MHEX = 0 MW		
		Dorsey 500 kV	Bison 500 kV	Helena 500 kV	Dorsey 500 kV	Bison 500 kV	Dorsey 500 kV	Dorsey 500 kV	Bison 500 kV	Helena 500 kV	Dorsey 500 kV	Bison 500 kV	Helena 500 kV
Dorsey - Bison	Dorsey [2]	1.289 [1]	1.145	1.066	1.283 [1]	1.139	1.056	1.287 [1]	1.143	1.062	1.331 [1]	1.182	1.079
	Bison	1.044	1.175 [1]		1.047	1.178 [1]		1.044	1.175 [1]		1.045	1.177 [1]	
Bison - Helena	Bison		1.298 [1]	1.075		1.285 [1]	1.065		1.295 [1]	1.073		1.306 [1]	1.082
	Helena [3]	1.045	1.137	1.372 [1]	1.045	1.134	1.368 [1]	1.045	1.141	1.376 [1]	1.046	1.169	1.411 [1]

Notes
1. Voltage at open end of line, not at substation
2. Values assume south line (Bison-Helena) is in service
3. Values assume north line (Dorsey-Bison) is in service

Table 2-5: Voltages for Open Circuit Conditions with Shunt Reactors

Line	Open End	Summer Peak Thermal MHEX = 1850 MW (South)			Winter Peak Thermal MHEX = 700 MW (North)			Off-Peak Stability MHEX = 2175 MW (South)			Low Transfer MHEX = 0 MW			Low Transfer with Bison 100 MVAr Reactor		
		Dorsey 500 kV	Bison 500 kV	Helena 500 kV	Dorsey 500 kV	Bison 500 kV	Helena 500 kV	Dorsey 500 kV	Bison 500 kV	Helena 500 kV	Dorsey 500 kV	Bison 500 kV	Helena 500 kV	Dorsey 500 kV	Bison 500 kV	Helena 500 kV
Dorsey - Bison	Dorsey [2]	1.084 [1]	1.044	1.021	1.091 [1]	1.051	1.034	1.086 [1]	1.046	1.024	1.108 [1]	1.067	1.037	1.090 [1]	1.050	1.033
	Bison	1.047	1.087 [1]		1.047	1.088 [1]		1.044	1.084 [1]		1.038	1.078 [1]		1.038	1.078 [1]	
Bison - Helena	Bison		1.056 [1]	1.020		1.072 [1]	1.035		1.062 [1]	1.025		1.071 [1]	1.035		1.071 [1]	1.034
	Helena [3]	1.046	1.048	1.085 [1]	1.045	1.051	1.089 [1]	1.045	1.053	1.091 [1]	1.039	1.064	1.102 [1]	1.037	1.049	1.087 [1]

Notes
1. Voltage at open end of line, not at substation
2. Values assume south line (Bison-Helena) is in service
3. Values assume north line (Dorsey-Bison) is in service

2.2 Stability Analysis

A stability analysis was performed with the off-peak power flow case to identify any transient-period criteria violations. The Option 1 transmission facilities were modeled in the off-peak stability case with the TSRs using the line-connected reactors from Table 2-1. The disturbances listed in Table 2-6 were simulated in the analysis.

Table 2-6: Stability Disturbances for Off-Peak Study Case

	Description
mis	Bipole 2 block in the Manitoba Hydro System, Cross trip Manitoba Ontario Ties @ t=0.35s; trigger HVDC reduction
nad	4 cycle 3PH fault at Forbes 500 kV on M602F; trigger HVDC reduction
nmz	4 cycle 3PH fault at Chisago 500 kV on F601C, xtrip M602F, 100% reduction, leave SVC on MP system
pas	5 cycle SLG fault at Forbes 500 kV on M602F, Forbes breaker fails, Forbes breakers operate at 16 cycles, clear at 17 cycles; trigger HVDC reduction
h13	5 cycle 3PH fault at Dorsey, trip Dorsey-Riel 500 kV line #1
h23	5 cycle 3PH fault at Dorsey, trip Dorsey 500/230 kV transformer #1; trigger HVDC reduction
h7d	5 cycle 3PH fault at Dorsey 500 kV, trip the Dorsey-Bison 500 kV line; trigger HVDC reduction
he0	5 cycle SLG fault at Dorsey 500 kV on Dorsey-Bison line, Dorsey breaker fails, clear at 16 cycles by tripping Dorsey 500-230 kV xfmr, line outage triggers HVDC reduction; block SUVC
hl0	5 cycle SLG fault at Dorsey 500 kV on Dorsey-Bison line, Dorsey breaker fails, clear at 16 cycles by tripping Dorsey-Riel 500 kV line #2; line outage triggers HVDC reduction; block SUVC
h33	5 cycle 3PH fault at Riel, trip Riel-Forbes 500 kV line; trigger HVDC reduction
h43	5 cycle 3PH fault at Riel, trip Riel 500/230 kV transformer
h83	5 cycle 3PH fault at Bison 500 kV, trip the Bison 500/345 kV transformer
hmd	5 cycle 3PH fault at Bison 500 kV, trip the Dorsey-Bison line; trigger HVDC reduction
o53	5 cycle 3PH fault at Bison 500 kV, trip the Bison-Helena line
ho0	5 cycle SLG fault at Bison 500 kV on 500-345 kV xfmr, 500 kV breaker fails, clear at 16 cycles by tripping Dorsey-Bison; line outage triggers HVDC reduction
h93	5 cycle 3PH fault at Bison 345 kV, trip Bison-Alexandria SS 345 kV line
hks	5 cycle SLG fault at Bison 345 on Alexandria SS line, Bison breaker fails, clear at 16 cycles by tripping Bison 345-230 kV xfmr
o3s	5 cycle SLG fault at Bison 345 kV on Alexandria line, Bison breaker fails, clear at 16 cycles by tripping Bison-Jamestown

	Description
o4s	5 cycle SLG fault at Bison 345 kV on Maple River line, Bison breaker fails, clear at 16 cycles by tripping Bison 345-230 kV xfmr
h53	5 cycle 3PH fault at Helena 500 kV, trip the Helena-Bison 500 kV line
o13	5 cycle 3PH fault at Helena 500 kV, trip Helena 500-345 kV xfmr
o6s	5 cycle SLG fault at Helena 500 kV on 500-345 kV xfmr, 500 kV breaker fails, clear at 16 cycles by tripping Helena-Bison
h63	5 cycle 3PH fault at Helena 345 kV, trip the Helena-Blue Lake 345 kV line
he3	5 cycle 3PH fault at Helena 345 kV, trip the Helena-Lake Marion 345 kV line
hgs	5 cycle SLG fault at Helena 345 kV on 500-345 kV xfmr, 345 kV breaker fails, clear at 16 cycles by tripping Helena-Blue Lake
hjs	5 cycle SLG fault at Helena 345 kV on Helena-Blue Lake line, Helena breaker fails, clear at 16 cycles by tripping Helena-Wilmarth
o2s	5 cycle SLG fault at Helena 345 kV on Lake Marion line, Helena breaker fails, clear at 16 cycles by tripping Helena-Franklin

Transient stability simulation results for the Option 1 study case are summarized in Appendix B; no transient-period criteria violations were noted. The Forbes SVS exceeds the 110 MVAr continuous rating at the end of simulations where the Bison-Helena 500 kV line is opened for fault clearing (*h53, o53,o6s*). Potential solutions include HVDC reduction or the addition of a fast-switched capacitor bank at Forbes.

Table 2-7: Option 1 Stability Violations

ID	Description	Forbes SVS Output at 10 sec
h53	3PH fault at Helena 500 on Bison line	290 MVAr
o53	3PH fault at Bison 500 on Helena line	290 MVAr
o6s	SLG fault at Helena 500 on 500-345 kV xfmr with breaker failure; trip Helena-Bison	290 MVAr

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Section
3

Condenser Reactive Power Production

Synchronous condensers at Dorsey and Riel were checked to determine the impact of the Option 1 transmission facilities on reactive power production. The system is planned so that at maximum HVDC loading levels with one synchronous condenser out of service, the system can withstand the loss of a second condenser and still remain at maximum power levels[2]. The maximum allowable production of the synchronous condensers is 1410 MVAr at Dorsey and 500 MVAr at Riel. At low HVDC loading levels, the MAPP Study Procedures Manual indicates that the steady-state output of the synchronous condensers at Dorsey should be close to zero (±100 MVAr).

All cases analyzed in Section 3 include the line-connected reactors shown in Table 2-1.

3.1 Steady State

Table 3-1 shows synchronous condenser output in the summer peak thermal and off-peak stability cases, which have high MHEX flow. Scenario 1 is the benchmark case without Option 1 or the TSRs; scenario 3 is the study case with Option 1 and the TSRs. A second benchmark scenario (scenario 2) shows Dorsey synchronous condenser output in the benchmark case with high loading on bipole 1 and bipole 2 for comparison with scenario 3. Synchronous condenser output does not exceed the allowable maximum in any of the scenarios; note that there is additional reserve at Riel since the HVDC filter will be larger than the 200 MVAr filter modeled in these cases.

Changes in synchronous condenser output between the benchmark and study cases in Table 3-1 are due to changes in HVDC loading and filters, the addition of Option 1 transmission facilities and losses associated with the TSRs. Table 3-2 compares reactive power flow on the 500 kV facilities at Riel and Dorsey. The net reactive flow into the 500 kV network from the 500-230 kV transformers is equal to the sum of the reactive flows on the US ties plus losses on the Dorsey-Riel lines, and increases by 68 MVAr in the summer peak case and by 29 MVAr in the off-peak case.

[2] B. Bagen and D. Diakiw, “Study on Manitoba Hydro System Reactive Power Reserve Associated with the 500 kV Tie Line”, 2009.

Table 3-1: Synchronous Condenser Output for High Transfer Levels

	Summer Peak Thermal Case			Off-Peak Stability Case		
	Scenario 1 Benchmark	Scenario 2 Benchmark	Scenario 3 Study Case with Option 1	Scenario 1 Benchmark	Scenario 2 Benchmark	Scenario 3 Study Case with Option 1
Interface Loading (MW)						
MHEX	1848.4	1837.2	1817.0	2178.0	2139.4	1956.4
New 500 kV line			1124.6			1320.2
Total Loading	1848.4	1837.2	2941.6	2178.0	2139.4	3276.6
HVDC Loading (MW)						
BP1	1006.0	1522.0	1522.0	992.0	1508.0	1508.0
BP2	1138.0	1722.0	1722.0	1122.0	1706.0	1706.0
BP3	1258.0	158.0	1258.0	1130.0	0.0	1130.0
Total HVDC	3402.0	3402.0	4502.0	3244.0	3214.0	4344.0
Synchronous Condenser Loading (MVAr)						
SCE-1-3G	23.4	350.9	393.3	52.3	296.9	303.7
SCA-4-6G	15.6	233.9	262.2	52.3	296.9	303.7
DRSC7-9G	29.2	438.0	491.0	64.2	364.0	372.3
Dorsey Total	68.2	1022.7	1146.5	168.9	957.8	979.7
RIELSC1G	67.8	0.0	86.7	92.5	0.0	104.8
RIELSC2G	67.8	0.0	86.7	92.5	0.0	104.8
RIELSC3G	67.8	0.0	86.7	92.5	0.0	104.8
RIELSC4G	67.8	0.0	86.7	92.5	0.0	104.8
Riel Total	271.1	0.0	346.8	370.2	0.0	419.2
Tertiary Capacitors (MVAr)						
DORSEYT9	73.4	73.4	73.4	0.0	73.4	73.4
DORSY2T9	146.8	146.8	146.8	0.0	146.8	146.8
RIELTER9	220.2	220.2	220.2	0.0	0.0	0.0
HVDC Filters (MVAr)						
DORSEY 230 kV	755.6	755.6	755.6	755.6	755.6	755.6
RIEL 230 kV	200.0	0.0	200.0	200.0	0.0	200.0
Bus Voltage (per unit)						
DORSEY 500 kV	1.037	1.036	1.031	1.043	1.039	1.036
RIEL 500 kV	1.035	1.034	1.030	1.040	1.035	1.037
Xfmr Taps						
Dorsey 500-230 kV	0.99375	0.99375	0.99375	1.00000	1.00000	1.00000
Riel 500-230 kV	0.99375	0.99375	0.99375	1.01250	1.01250	1.01250

Table 3-2: Reactive Power Flow on 500 kV Lines in Manitoba [1]

	Summer Peak Thermal Case		Off-Peak Stability Case	
	Scenario 1 Benchmark	Scenario 3 Study Case with Option 1	Scenario 1 Benchmark	Scenario 3 Study Case with Option 1
Flow on Riel-Roseau @ Riel	25.2 MVAr	26.6 MVAr	163.5 MVAr	35.9 MVAr
Riel-Dorsey (net)	-104.4 MVAr	-113.2 MVAr	-94.4 MVAr	-112.4 MVAr
Flow on Dorsey-Bison @ Dorsey		75.6 MVAr		171.4 MVAr
Total	-79.2 MVAr	-11.0 MVAr	69.1 MVAr	94.9 MVAr
Change		68.2 MVAr		25.8 MVAr

Note 1: A positive flow indicates reactive flow leaving the bus and corresponds to an increase in condenser output

Table 3-3 shows synchronous condenser output in the winter peak thermal and the low transfer cases. Scenario 1 is the benchmark case without Option 1 or the TSRs and scenario 2 shows condenser output after adding Option 1 transmission into the benchmark case without the TSRs.

During conditions with low MHEX flow, condenser output needs to remain close to 0. The impact of the Option 1 transmission can be determined by directly comparing scenarios 1 and 2 since HVDC loading is the same in both scenarios. The net change in condenser output in the winter peak case is -38 MVAr at Dorsey and -26 MVAr at Riel, which is -63 MVAr total. The synchronous condensers are not absorbing more than 100 MVAr at Dorsey or at Riel in the winter peak case.

The net change in condenser output in the low transfer case is -90 MVAr at Dorsey and -34 MVAr at Riel, which is -124 MVAr total. The synchronous condensers at Riel do not absorb more than 100 MVAr at Riel, but are absorbing 146 MVAr at Dorsey. The total condenser output at Dorsey increases to -118 MVAr if a 100 MVAr shunt reactor is added at the Bison 500 kV bus as discussed in Section 2.1.2.

Shunt reactors are required in Manitoba to increase condenser output so that the Dorsey and Riel condensers are not absorbing a significant amount of reactive power; a total of 125 MVAr will increase condenser output back to benchmark case levels.

Table 3-3: Synchronous Condenser Output for Low Transfer Levels

	Winter Peak Thermal Case			Low Xfer Case	
	Scenario 1 Benchmark	Scenario 2 Benchmark with Option 1	Scenario 3 Study Case with Option 1	Scenario 1 Benchmark	Scenario 2 Benchmark with Option 1
Interface Loading (MW)					
MHEX	-695.3	-346.8	-992.3	-1.8	-10.7
New 500 kV line		-351.9	-807.0	0.0	8.6
Total Loading	-695.3	-698.8	-1799.3	-1.8	-2.1
HVDC Loading (MW)					
BP1	914.0	914.0	398.0	376.0	376.0
BP2	1036.0	1036.0	452.0	424.0	424.0
BP3	400.0	400.0	400.0	425.0	425.0
Total HVDC	2350.0	2350.0	1250.0	1225.0	1225.0
Synchronous Condenser Loading (MVAr)					
SCE-1-3G	34.4	23.8	55.7	-17.1	-45.1
SCA-4-6G	22.9	15.8	37.1	-17.1	-45.1
DRSC7-9G	64.4	44.5	104.3	-21.0	-55.3
Dorsey Total	121.7	84.1	197.1	-55.3	-145.5
RIELSC1G	-6.6	-13.0	12.2	-13.8	-22.3
RIELSC2G	-6.6	-13.0	12.2	-13.8	-22.3
RIELSC3G	-6.6	-13.0	12.2	-13.8	-22.3
RIELSC4G	-6.6	-13.0	12.2	-13.8	-22.3
Riel Total	-26.3	-52.1	48.6	-55.1	-89.3
Tertiary Capacitors (MVAr)					
DORSEYT9	0.0	0.0	0.0	0.0	0.0
DORSY2T9	0.0	0.0	0.0	0.0	0.0
RIELTER9	0.0	0.0	0.0	0.0	0.0
HVDC Filters (MVAr)					
DORSEY 230 kV	755.6	755.6	275.0	194.3	194.3
RIEL 230 kV	100.0	100.0	100.0	100.0	100.0
Bus Voltage (per unit)					
DORSEY 500 kV	1.047	1.043	1.039	1.039	1.037
RIEL 500 kV	1.047	1.043	1.039	1.041	1.038
Xfmr Taps					
Dorsey 500-230 kV	0.99979	0.99375	0.99979	0.98750	0.98125
Riel 500-230 kV	0.98750	0.98125	0.98750	0.98750	0.98125

The study group requested analysis of an additional scenario with the DC bipoles near maximum loading and maximum exports. Noting that the winter peak load in Manitoba is approximately 1100 MW higher than the summer peak, the study group suggested scaling load in zones 1646, 1647 and 1649 until the DC bipoles are at maximum loading.

Based on the comparison shown below of load in the SUPK and WIPK cases, load in zones 1647 and 1649 was scaled to get the DC bipoles at maximum loading; the reactive power component of the load was not scaled since the reactive power load in the SUPK and WIPK cases is approximately equal.

```
WORKING CASE MH_SUPK_Study_Option 1_100218.sav:
SAVED CASE MH_WIPK_Study_Option 1_100218.sav:
ZONE LOAD TOTALS:
                     IN WORKING CASE   IN SAVED CASE
ZONE  X-- NAME --X      MW      MVAR       MW      MVAR  DELTA MW  DELTA MVAR
1646  MHSUBWPG        888.9    154.9     806.1     98.5    -82.8       -56.4
1647  MHRURALS       1337.2    305.6    2388.1    303.3   1050.9        -2.2
1649  MHRURALN         72.7     21.0     251.0     45.1    178.4        24.1
```

Two sets of scenarios were created from the summer peak thermal case. MH load was scaled by 662 MW in scenarios 4 and 5 to increase the DC bipoles to maximum loading; scenarios 4 and 5 have a MHEX_S base flow of 1848 MW. In scenarios 6 and 7, the MHEX_S base flow was increased to 2175 MW and MH load was scaled by 335 MW.

Table 3-4 shows that synchronous condenser output does not exceed 1410 MVAr at Dorsey or 500 MVAr at Riel in scenario 5 (1848 MW base flow), but does exceed limits in scenario 6 (2175 MW base flow). Table 3-5 shows that the net reactive flow into the 500 kV network from the 500-230 kV transformers increases by approximately 63 MVAr going from scenario 6 to scenario 7.

A total of four cases have been analyzed with high south flow and the results in Table 3-2 and Table 3-5 show that the impact of the Option 1 transmission and TSRs on total condenser output is between 25 and 80 MVAr. Two additional 36.7 MVAr tertiary capacitors mitigate the TSR impact on condenser loading and restore the Dorsey 460 MVAr reserve and Riel 500 MVAr reserve in the case with the DC bipoles at maximum loading.

Table 3-4: Synchronous Condenser Output with HVDC Near Maximum Output

	HVDC Max Case MH-US = 1848+1100 MW		HVDC Max Case MH-US = 2175+1100 MW	
	Scenario 4 Benchmark	Scenario 5 Study Case with Option 1	Scenario 6 Benchmark	Scenario 7 Study Case with Option 1
Interface Loading (MW)				
MHEX	1847.8	1801.1	2173.4	1998.7
New 500 kV line		1145.9		1274.3
Total Loading	1847.8	2946.9	2173.4	3272.9
HVDC Loading (MW)				
BP1	1254.0	1572.0	1254.0	1572.0
BP2	1420.0	1778.0	1420.0	1778.0
BP3	1388.0	1764.0	1388.0	1764.0
Total HVDC	4062.0	5114.0	4062.0	5114.0
Synchronous Condenser Loading (MVAr)				
SCE-1-3G	181.7	406.9	186.9	450.6
SCA-4-6G	121.1	406.9	124.6	450.6
DRSC7-9G	226.8	507.3	233.3	561.8
Dorsey Total	529.5	1321.1	544.9	1463.1
RIELSC1G	39.1	121.6	75.7	127.4
RIELSC2G	39.1	121.6	75.7	127.4
RIELSC3G	39.1	121.6	75.7	127.4
RIELSC4G	39.1	121.6	75.7	127.4
Riel Total	156.6	486.3	302.8	509.5
Tertiary Capacitors (MVAr)				
DORSEYT9	73.4	73.4	73.4	73.4
DORSY2T9	146.8	146.8	146.8	146.8
RIELTER9	220.2	220.2	220.2	220.2
HVDC Filters (MVAr)				
DORSEY 230 kV	755.6	755.6	755.6	755.6
RIEL 230 kV	400.0	400.0	400.0	400.0
Bus Voltage (per unit)				
DORSEY 500 kV	1.037	1.037	1.035	1.036
RIEL 500 kV	1.034	1.036	1.032	1.033
Xfmr Taps				
Dorsey 500-230 kV	0.99375	1.00000	0.99375	1.00625
Riel 500-230 kV	0.99375	1.00000	1.00625	1.00000

Table 3-5: Reactive Power Flow on 500 kV Lines in Manitoba with HVDC Near Maximum Output [1]

	HVDC Max Case MH-US = 1848+1100 MW		HVDC Max Case MH-US = 2175+1100 MW	
	Scenario 4 Benchmark	Scenario 5 Study Case with Option 1	Scenario 6 Benchmark	Scenario 7 Study Case with Option 1
Flow on Riel-Roseau @ Riel	40.1 MVAr	44.8 MVAr	179.1 MVAr	112.8 MVAr
Riel-Dorsey (net)	-102 MVAr	-118.6 MVAr	-93.4 MVAr	-116.4 MVAr
Flow on Dorsey-Bison @ Dorsey		92 MVAr		152.2 MVAr
Total	-61.9 MVAr	18.2 MVAr	85.7 MVAr	148.6 MVAr
Change		80.1 MVAr		62.9 MVAr

Note 1: A positive flow indicates reactive flow leaving the bus and corresponds to an increase in condenser output

3.2 Stability

A stability simulation was performed to confirm that the Dorsey System Undervoltage Controller (SUVC) does not operate for loss of a synchronous condenser. One 160 MVAr condenser was modeled out of service in the off-peak stability case. A 5-cycle 3-phase fault was simulated on the Dorsey 230 kV bus and the fault was cleared by tripping one 300 MVAr condenser. The MVAr reserve at Dorsey is 1700-995=705 MVAr in the study off peak stability case.

The summary table for disturbance *bjz* is in Appendix B. Figure 3-1 shows the voltage at Dorsey. The 230 kV voltage drops below 0.99 per unit during the fault, which is long enough that the Dorsey Stability Control (UDhold) operates. However, voltage recovers when the fault is cleared and does not drop back below 0.99 per unit so the SUVC does not operate.

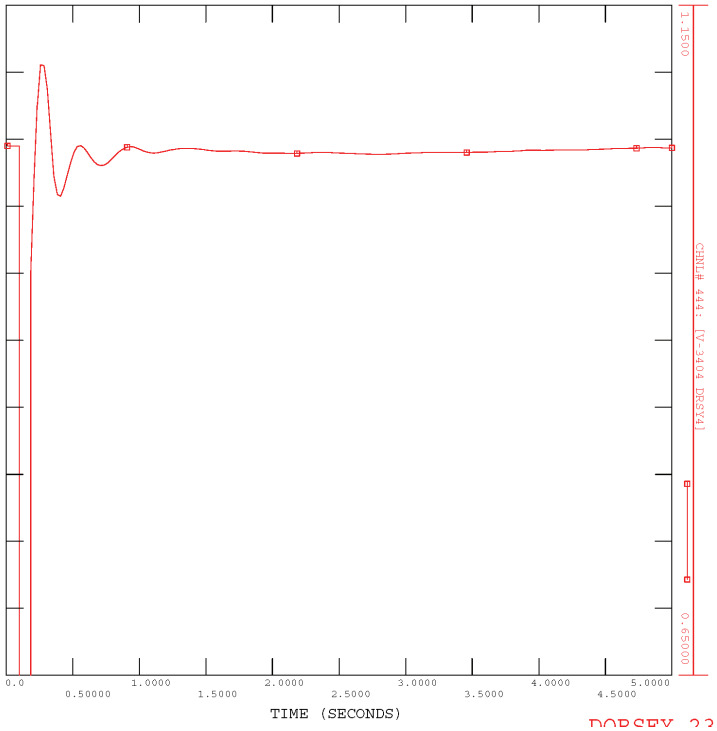

Figure 3-1: Dorsey 230 kV Voltage; 3PH Fault Cleared by Tripping Condenser (*bjz*)

Section
4

Prior Outage Analysis

The analyses summarized in Section 4 have been performed with the Option 1 network upgrades to determine transfer capability on the MHEX_S interface with the Riel-Forbes-Chisago 500 kV line out of service. the line-connected reactors from Table 2-1

4.1 Methodology

Thermal and stability power flow models were created with the Riel-Forbes-Chisago 500 kV line out of service. The Forbes SVS is assumed to be in service.

The existing Manitoba-US transfer limit (SOL, system intact) is 2175 MW, and there is a 1420 MW (2175-755) difference between the system intact and prior outage transfer limit. A linear analysis was performed to screen for thermal constraints at two transfer levels - 2175 MW and 1855 MW. The 2175 MW transfer level would maintain the existing transfer capability with one 500 kV line in service; the 1855 MW transfer level would maintain the existing 1420 MW difference between the system intact and prior outage transfer capability. A stability analysis was performed at the 2175 MW transfer level.

4.2 Power Flow Cases

MH to US transfers were adjusted using a pro rata reduction of benchmark case flow and study TSRs. Benchmark case flow in the thermal case was adjusted based on confirmed firm transmission service using generation in the POD control area; benchmark case flow in the stability case was adjusted using the methodology employed in the IPLAN program setexports.ipl. Each study TSR was reduced to 74% (2175 MW case) or 63% (1855 MW case) of the requested service.

Table 4-1: MHEX Transfers in Prior Outage Cases

	SUPK Thermal Case			SUOP Stability Case	
	System Intact	Prior Outage 2175 MW	Prior Outage 1855 MW	System Intact	Prior Outage 2175 MW
Benchmark Case Flow	1848 MW	1363 MW	1163 MW	2175 MW	1444 MW
TSRs	1100 MW	812 MW	692 MW	1100 MW	731 MW
Total	2948 MW	2175 MW	1855 MW	3275 MW	2175 MW

Table 4-2 shows bus voltages in the power flow cases for different amounts of shunt capacitance at the Bison 500 kV bus. The power flow cases include the line-connected reactors on the Bison-Dorsey (150 MVAr) and Bison-Helena (225 MVAr) lines. A 300 MVAr capacitor was modeled at the Bison 500 kV bus in the cases used for thermal and stability analyses. Switching a single 300 MVAr capacitor causes a 0.033 per unit change in steady state voltage at the Bison 500 kV bus and a 0.025 per unit change at the Bison 345 kV bus. Diagrams of the thermal and stability cases with Riel-Forbes-Chisago out of service are included in Appendix D.

Table 4-2: Impact of Bison 500 kV Capacitor on Bus Voltages; 2175 MW Prior Outage Cases

	SUPK Thermal Case			SUOP Stability Case		
	0 MVAr	300 MVAr	600 MVAr	0 MVAr	300 MVAr	600 MVAr
Bison 500 kV	0.976	1.007	1.042	0.961	0.994	1.032
Bison 345 kV	0.984	1.007	1.036	0.974	0.999	1.031
Helena 500 kV	0.991	0.997	1.005	0.978	0.986	0.995
Helena 345 kV	0.997	1.001	1.007	0.988	0.994	1.000
Jamestown 345 kV	0.979	0.991	1.006	0.972	0.988	1.009

4.3 Thermal Screening

A linear analysis was performed to screen the summer peak thermal case for thermal constraints at the 2175 MW and 1855 MW transfer levels. A thermal impact is considered significant if the post-contingent loading exceeds the thermal rating and the impact of at least one TSR exceeds the applicable PTDF or OTDF threshold.

Significantly affected facilities are listed in Table 4-3; details are provided in Table D-1 and Table D-2.

Table 4-3: Significantly Affected Facilities

Monitored Element	Owner	Rating [1]		Loading	
		N/E	MVA	1855 MW Xfer	2175 MW Xfer
Alexandria-Alexandria SS 115 kV	OTP	E	160	105%	108%
Blue Lake-Helena 345 kV	Xcel	E	1511		106%
Blackberry-Nashwauk 115 kV	MP	E	158		100.6%
Broadland 345-230 kV xfmr	BEPC	N (E)	400 (480)	100.1% (83%)	103% (86%)
Center-Heskett 230 kV	MDU	N (E)	428 (471)	103% (94%)	106% (96%)
Saratoga-Petenwell 115 kV	ATC	E	72.2	127%	130%

Note 1: Loading is compared against Normal (N) and/or Emergency (E) rating

Saratoga-Petenwell was identified as a TSR constraint in the July SIS; after mitigation, the line will accommodate the loading identified in the prior outage screening.

The only thermal constraint for the 1855 MW transfer is the Alexandria 115 kV line; the rating of this facility is limited by terminal equipment. The 2175 MW transfer is limited by the Blue Lake-Helena 345 kV line in addition to the Alexandria 115 kV line.

The Broadland transformer and Center-Heskett 230 kV line are not constraints since loading does not exceed emergency ratings.

4.4 Stability Analysis

A stability analysis was performed to identify stability issues at the 2175 MW transfer level.

Table 4-4 summarizes differences between the benchmark off-peak case and the study off-peak case with Riel-Forbes-Chisago out of service. Both cases have approximately 2175 MW of flow on the MH-US ties. Flow on the Richer-Moranville 230 kV tie increases by 50 MW and one capacitor switches on at Running to support voltage. Appendix D.3 includes power flow summaries for the benchmark and study cases.

Table 4-4: Comparison of Benchmark and Study Case with One 500 kV Line in Service

	Benchmark Off Peak Stability Case	Study Off Peak Stability Case with Riel-Forbes-Chisago Out
MH-US Tie Line Flow		
M602F (Riel-Forbes 500 kV)	1777	0
L20D (Letellier-Drayton 230 kV)	287	293
R50M (Richer-Moranville 230 kV)	138	185
G82R (Glenboro-Rugby 230 kV)	-27	-25
Dorsey-Bison 500 kV	0	1730
Total MH-US Flow	2175 MW	2183 MW
Fast Switched Capacitors / Regulated Bus Voltage		
Balta / Balta 230 kV	0 MVAr / 1.025 pu	0 MVAr / 1.028 pu
Parkers Lk / Parkers Lk 115 kV	0 MVAr / 1.022 pu	0 MVAr / 1.016 pu
Prairie / Prairie 230 kV	40 MVAr / 1.027 pu	40 MVAr / 1.015 pu
Ramsey / Ramsey 230 kV	0 MVAr / 1.004 pu	30 MVAr / 1.021 pu
Roseau / Roseau 115 kV	0 MVAr / 1.026 pu	30 MVAr / 1.035 pu
Running / Running 230 kV	30 MVAr / 1.028 pu	30 MVAr / 1.025 pu
Split Rock / Split Rock 115 kV	80 MVAr / 1.025 pu	80 MVAr / 1.025 pu
Sheyenne / Sheyenne 230 kV	40 MVAr / 1.030 pu	40 MVAr / 1.016 pu

The disturbances listed in Table 4-5 were simulated in the prior outage stability analysis. The list includes faults on the Leland Olds-Ft Thompson 345 kV line (*ag1 and ag3*), faults at Monticello and Sherburne Co (*mcs*, *mes*, *mfs* and *mts*), and block of the Manitoba Hydro HVDC bipole 2 (*mis* and *miz*).

Table 4-5: Stability Disturbances for Prior Outage Case

	Description
ag1	4 cycle SLG fault at Leland Olds 345 kV on Leland Olds-Ft Thompson line; breaker 2692 fails; clear at 11 cycles by tripping faulted line
ag3	4 cycle 3PH fault at Leland Olds 345 kV, trip Leland Olds-Ft Thompson line
ei2	CU DC permanent bipole fault with tripping of both Coal Creek units
em3	5 cycle 3PH fault at Letellier 230, clear by tripping Letellier-Drayton line; trigger HVDC reduction
eq1	SLG fault with breaker failure at Coal Creek on CU DC pole 1 with cross-trip of Coal Creek unit #2
fds	5 cycle 3PH fault at Square Butte 230 kV, clear by tripping Square Butte-Stanton line
mc3	5 cycle 3PH fault at Richer 230 kV, clear by tripping Richer-Roseau line; trigger HVDC reduction
md3	5 cycle 3PH fault at Glenboro 230 kV, clear by tripping Glenboro-Rugby line
mis	Bipole 2 block in the Manitoba Hydro System, Cross trip Manitoba Ontario Ties @ t=0.35s; trigger HVDC reduction
miz	Bipole 2 block in the Manitoba Hydro System.
mkd	4 cycle 3 phase fault at Chisago 345 kV, clear the Chisago-King line
pc0	4.5 cycle SLG fault at King 345 kV on King-Eau Claire line, King breaker fails, clear at 16 cycles by tripping King-Chisago
pcs	4.5 cycle SLG fault at King 345 kV on King-Eau Claire line, King breaker fails, clear at 16 cycles by tripping King-Chisago, cross trip Eau Claire-Arpin
pct	Trip of King-Eau Claire-Arpin without a fault
pzs	4.5 cycle SLG fault Prairie Island 345 kV on Prairie Island-N Rochester, 8H9 fails, clear at 16 cycles by tripping Prairie Island xfmr #10
pzt	Trip of Prairie Island-N Rochester without a fault
ya3	4 cycle 3 phase fault at Arrowhead 230 kV, clear the Arrowhead-Gardner park 345 kV line
yas	4 cycle SLG fault at Arrowhead 345 on AHD-GDP ckt #1, AHD brkr stk, clear at 17 cycles by tripping AHD-GDP bus section
yb3	4 cycle 3PH fault at Arrowhead 345 kV, trip the Arrowhead-Stone Lake line
h13	5 cycle 3PH fault at Dorsey, trip Dorsey-Riel 500 kV line #1
h23	5 cycle 3PH fault at Dorsey, trip Dorsey 500/230 kV transformer #1; trigger HVDC reduction

	Description
h7d	5 cycle 3PH fault at Dorsey 500 kV, trip the Dorsey-Bison 500 kV line; trigger HVDC reduction
he0	5 cycle SLG fault at Dorsey 500 kV on Dorsey-Bison line, Dorsey breaker fails, clear at 16 cycles by tripping Dorsey 500-230 kV xfmr, line outage triggers HVDC reduction; block SUVC
hl0	5 cycle SLG fault at Dorsey 500 kV on Dorsey-Bison line, Dorsey breaker fails, clear at 16 cycles by tripping Dorsey-Riel 500 kV line #2; line outage triggers HVDC reduction; block SUVC
h43	5 cycle 3PH fault at Riel, trip Riel 500/230 kV transformer
h83	5 cycle 3PH fault at Bison 500 kV, trip the Bison 500/345 kV transformer
hmd	5 cycle 3PH fault at Bison 500 kV, trip the Dorsey-Bison line; trigger HVDC reduction
o53	5 cycle 3PH fault at Bison 500 kV, trip the Bison-Helena line
ho0	5 cycle SLG fault at Bison 500 kV on 500-345 kV xfmr, 500 kV breaker fails, clear at 16 cycles by tripping Dorsey-Bison; line outage triggers HVDC reduction
h93	5 cycle 3PH fault at Bison 345 kV, trip Bison-Alexandria SS 345 kV line
hks	5 cycle SLG fault at Bison 345 on Alexandria SS line, Bison breaker fails, clear at 16 cycles by tripping Bison 345-230 kV xfmr
o3s	5 cycle SLG fault at Bison 345 kV on Alexandria line, Bison breaker fails, clear at 16 cycles by tripping Bison-Jamestown
o4s	5 cycle SLG fault at Bison 345 kV on Maple River line, Bison breaker fails, clear at 16 cycles by tripping Bison 345-230 kV xfmr
h53	5 cycle 3PH fault at Helena 500 kV, trip the Helena-Bison 500 kV line
o13	5 cycle 3PH fault at Helena 500 kV, trip Helena 500-345 kV xfmr
o6s	5 cycle SLG fault at Helena 500 kV on 500-345 kV xfmr, 500 kV breaker fails, clear at 16 cycles by tripping Helena-Bison
h63	5 cycle 3PH fault at Helena 345 kV, trip the Helena-Blue Lake 345 kV line
he3	5 cycle 3PH fault at Helena 345 kV, trip the Helena-Lake Marion 345 kV line
hgs	5 cycle SLG fault at Helena 345 kV on 500-345 kV xfmr, 345 kV breaker fails, clear at 16 cycles by tripping Helena-Blue Lake
hjs	5 cycle SLG fault at Helena 345 kV on Helena-Blue Lake line, Helena breaker fails, clear at 16 cycles by tripping Helena-Wilmarth
o2s	5 cycle SLG fault at Helena 345 kV on Lake Marion line, Helena breaker fails, clear at 16 cycles by tripping Helena-Franklin
mcs	4.5 cycle SLG fault at Sherburne Co. 345 kV on Coon Creek line with 8M40 stuck, clear at 12 cycles by tripping Bunker Lake and Bunker Lake TR1
mes	4 cycle SLG fault at Monticello 345 kV on Waite Park line with 8N8 stuck, clear at 14 cycles by tripping Elm Creek line

	Description
mfs	4 cycle SLG fault at Monticello 345 kV on Sherburne Co. line with 8N8 stuck; clear at 14 cycles by tripping Monticello Generator
mts [1]	4 cycle SLG fault at Monticello 345 kV on Elm Creek line, breaker 8N6 fails, clear by tripping Monticello 345-115 kV xfmr, Monticello 345-230 kV xfmr, Monticello-Benton Co 230 kV line and Monticello-Elk River 230 kV line

Note 1: Disturbance mts is not valid with CapX line but results are reported for comparison with previous studies

The only transient period criteria violation occurs for disturbance *h53*, which is a 5 cycle 3-phase fault at Helena on the Helena-Bison 500 kV line. This disturbance causes the DPDARE relay on the MH-OH ties to operate. Disturbances were simulated assuming that outage of the Bison-Helena 500 kV line is not accompanied by HVDC reduction; the post-contingent surge of power on the Manitoba to Ontario tie lines can be minimized using HVDC reduction.

The post-disturbance voltage at the Bison 500 kV bus is 1.16 per unit following a breaker failure at the Bison 500 kV bus cleared by tripping the 500-345 kV transformer and Bison-Dorsey line (*ho0*), which leaves the Bison-Helena line open circuited at Bison with the 300 MVAr capacitor connected. A similar situation will occur for failure of any circuit breaker in the 500 kV ring at Bison so the capacitor should be disconnected when this condition occurs. The post-disturbance voltage at Bison is less than 1.10 per unit for the other disturbances simulated.

No other criteria violations were noted for the disturbances simulated. All of the voltage channels in the snapshot were scanned in the study case simulations and the CU bipole fault (*ei2*) is the only disturbance that causes a bus voltage to dip below 0.85 per unit after fault clearing. Voltage at the Jamestown 345 kV bus dips to 0.847 during simulation *ei2* in the study case as shown in Figure 4-1; however, the difference between minimum voltage in the benchmark and study cases is not significant.

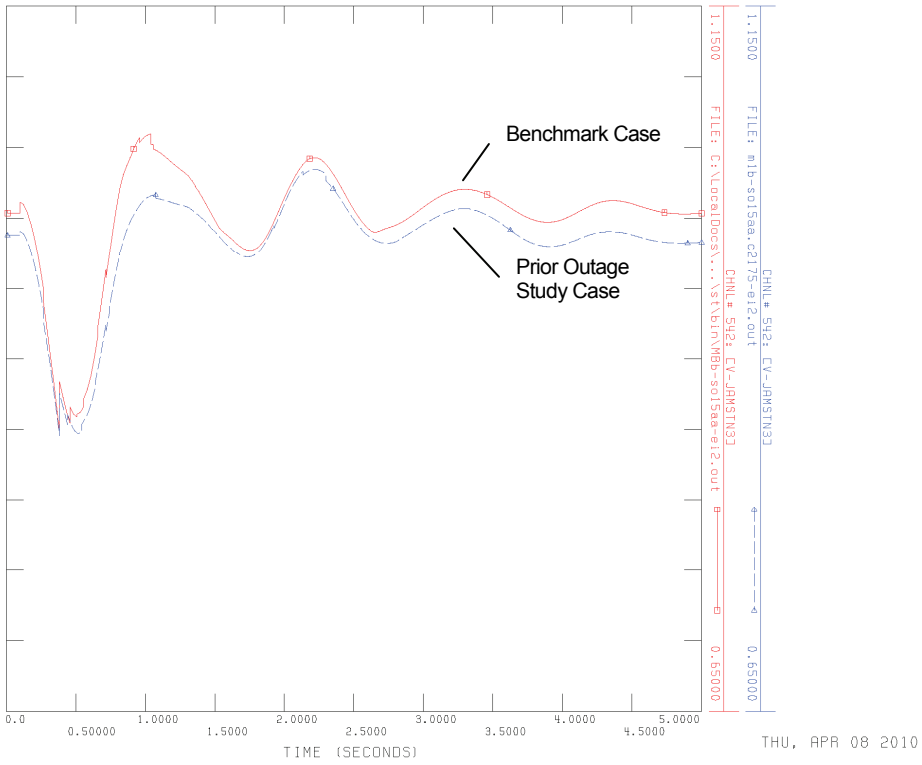

Figure 4-1: Jamestown 345 kV Voltage for CU Bipole Fault (*ei2*)

There are several sources of dynamic reactive power along the path of the Option 1 transmission facilities, including the fast switched capacitors listed in Table 4-4 and SVCs at Fargo and Watertown. Table D-3 in Appendix D shows the number of fast-switched capacitors utilized at each bank during the simulations. In general, the difference between the number of fast-switched capacitors utilized in the benchmark and prior outage study case for the same disturbance is less than one. There are three exceptions:

1) 3 additional capacitors are used at Sheyenne (4 capacitors total) during simulation of a 3PH fault at the Bison 345 kV on the Alexandria SS line (*h93*)
2) 2 additional capacitors are used at Sheyenne (3 capacitors total) during simulation of a SLG fault at the Helena 345 kV on the Lake Marion line (*o2s*)
3) 2 additional capacitors are used at Prairie (3 capacitors total) during simulation of a SLG fault at the Helena 345 kV on the Blue Lake line (*hjs*)

Figure 4-1 compares voltage at the Maple River 345 kV bus and the Prairie 230 kV bus for a SLG fault at the Helena 345 kV bus on the Blue Lake line (*hjs*). The results shown in Figure 4-1 and Figure 4-2 are typical of the prior outage stability analysis; transient-period system performance in the prior outage study case with the Option 1 transmission and MH-OH flow at 2175 MW is consistent with system performance in the benchmark case.

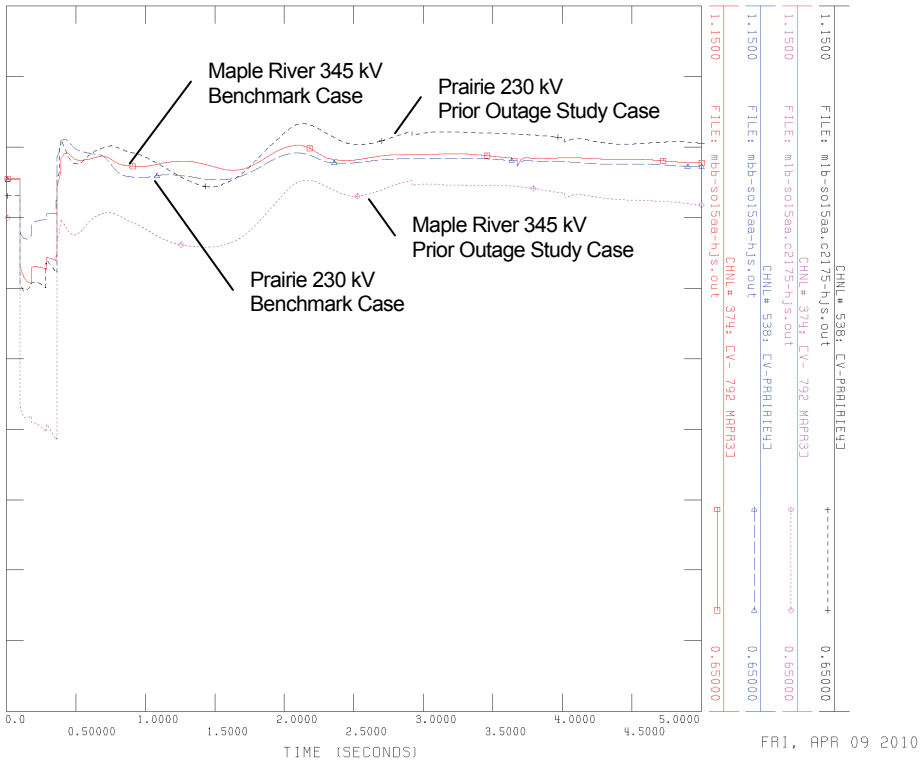

Figure 4-2: Maple River and Prairie Bus Voltage for SLG fault at Helena 345 kV on Blue Lake line (*hjs*)

4.5 Summary

Analyses have been performed with the Option 1 network upgrades to determine transfer capability on the MHEX_S interface with the Riel-Forbes-Chisago 500 kV line out of service. A 300 MVAr shunt capacitor was modeled at the Bison 500 kV bus with the Riel-Forbes-Chisago 500 kV line out of service. There were no voltage violations in the July SIS or in the stability analysis described in Section 2.2 to indicate that the 300 MVAr capacitor needs to be capable of fast switching.

A linear analysis was performed to screen for thermal constraints at two transfer levels - 2175 MW and 1855 MW. The only thermal constraint for the 1855 MW transfer level is the Alexandria 115 kV line; the rating of this facility is limited by terminal equipment. The 2175 MW transfer level is limited by the Blue Lake-Helena 345 kV line in addition to the Alexandria 115 kV line.

A stability analysis was performed at the 2175 MW transfer level. The only transient period criteria violation occurs for a fault on the Helena-Bison 500 kV line (*h53*), which causes the DPDARE relay on the MH-OH ties to operate. Disturbances were simulated assuming that outage of the Bison-Helena 500 kV line is not accompanied by HVDC reduction; the post-contingent surge of power on the Manitoba to Ontario tie lines can be minimized using HVDC reduction.

The post-disturbance voltage at the Bison 500 kV bus is 1.16 per unit following a breaker failure at the Bison 500 kV bus cleared by tripping the 500-345 kV transformer and Bison-

Dorsey line (*ho0*), which leaves the Bison-Helena line open circuited at Bison with the 300 MVAr capacitor connected. A similar situation will occur for failure of any circuit breaker in the 500 kV ring at Bison so the capacitor should be disconnected when this condition occurs. The post-disturbance voltage at Bison is less than 1.10 per unit for the other disturbances simulated.

Study results have not shown a need for dynamic voltage control (SVS or fast-switching) at Bison.

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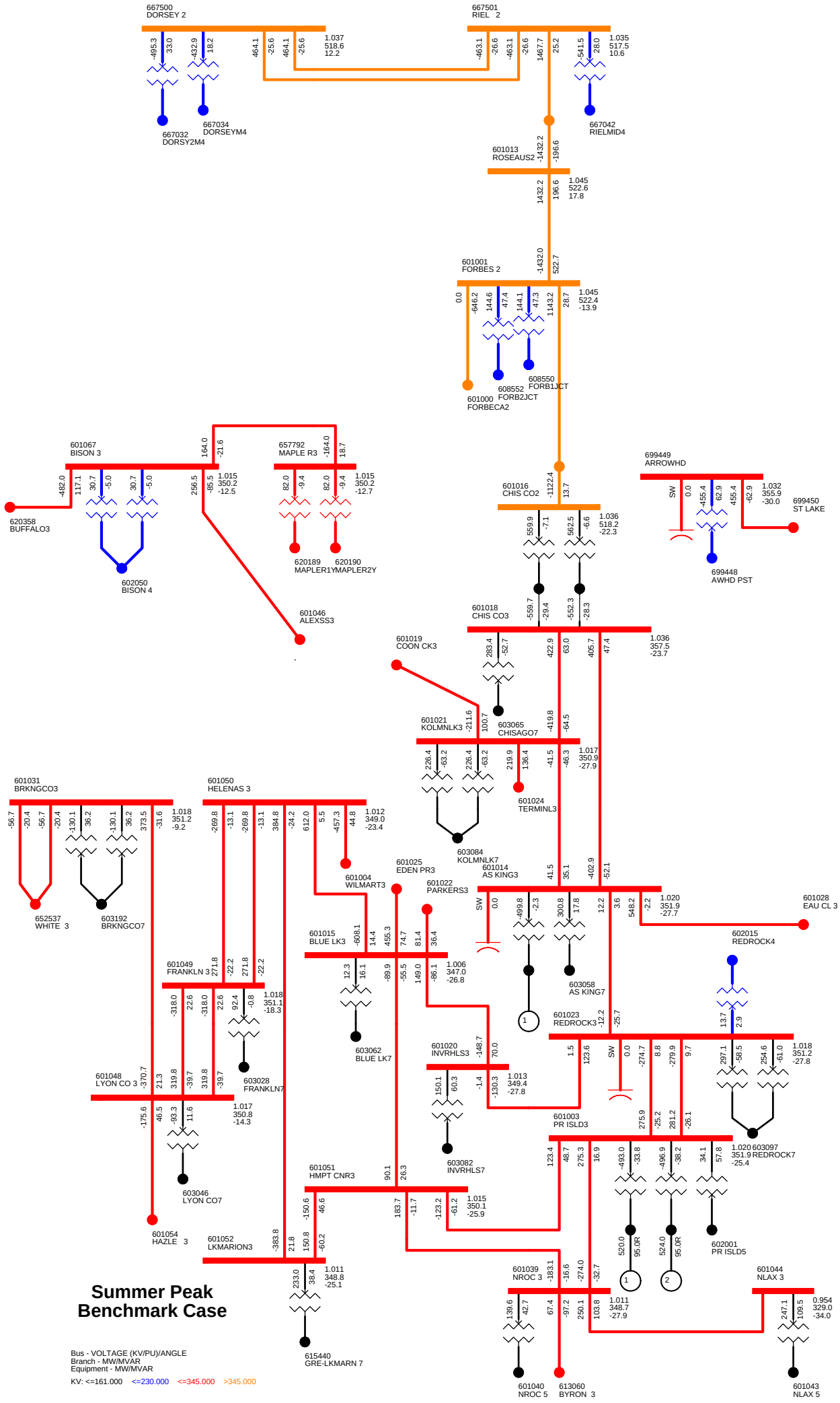
Appendix

A

Power Flow Cases

A.1 Power Flow Diagrams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Summer Peak
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Branch - MW/MVAR
Equipment - MW/MVAR
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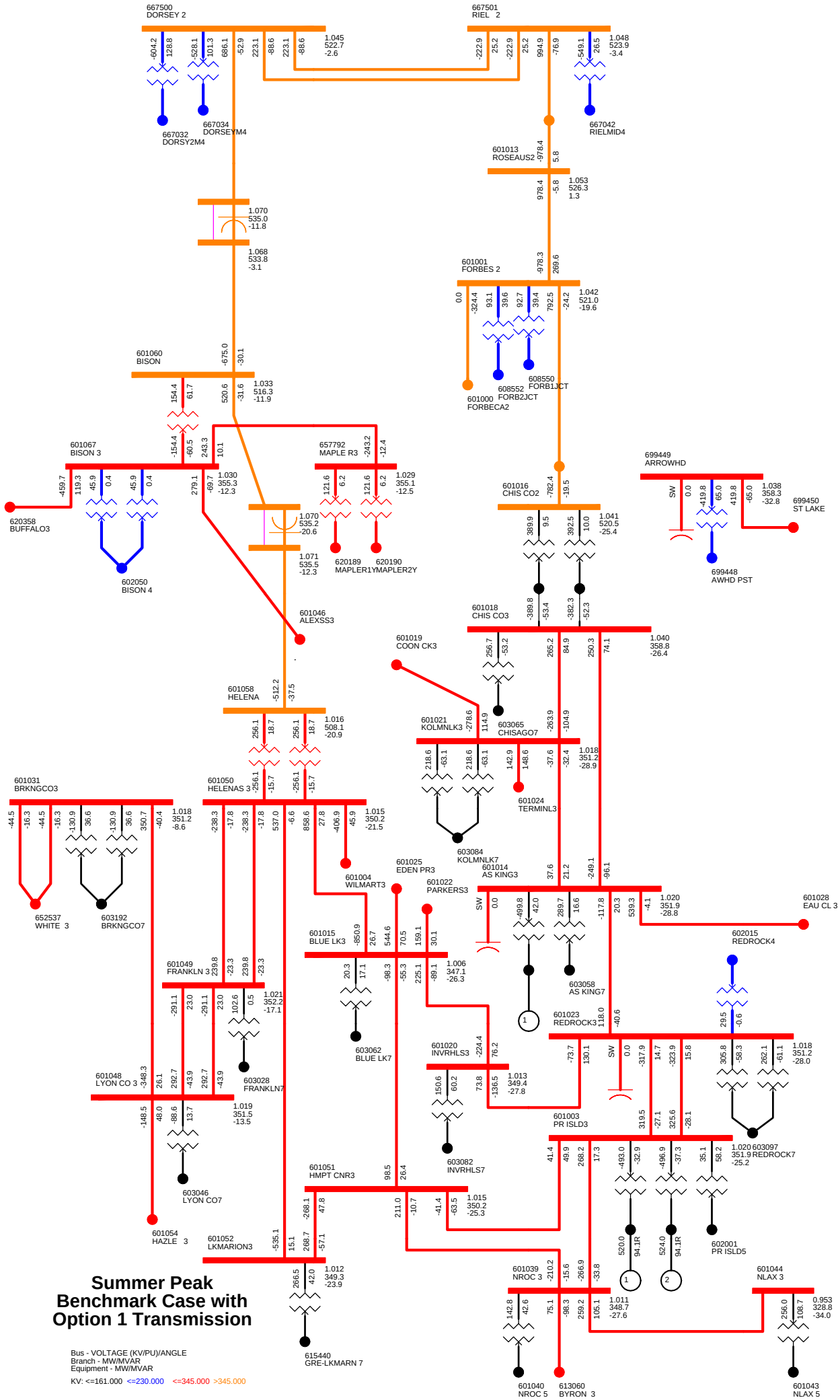
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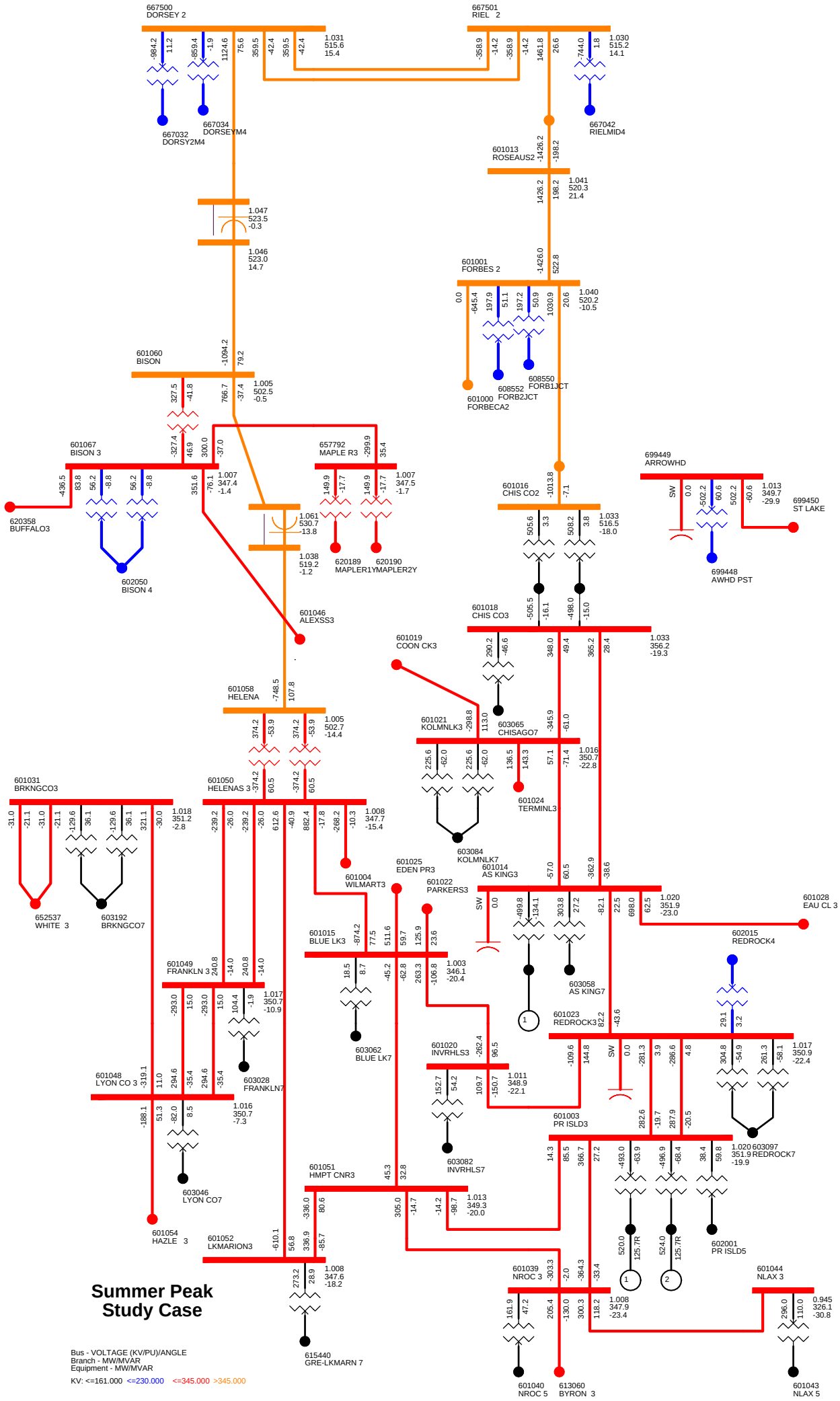
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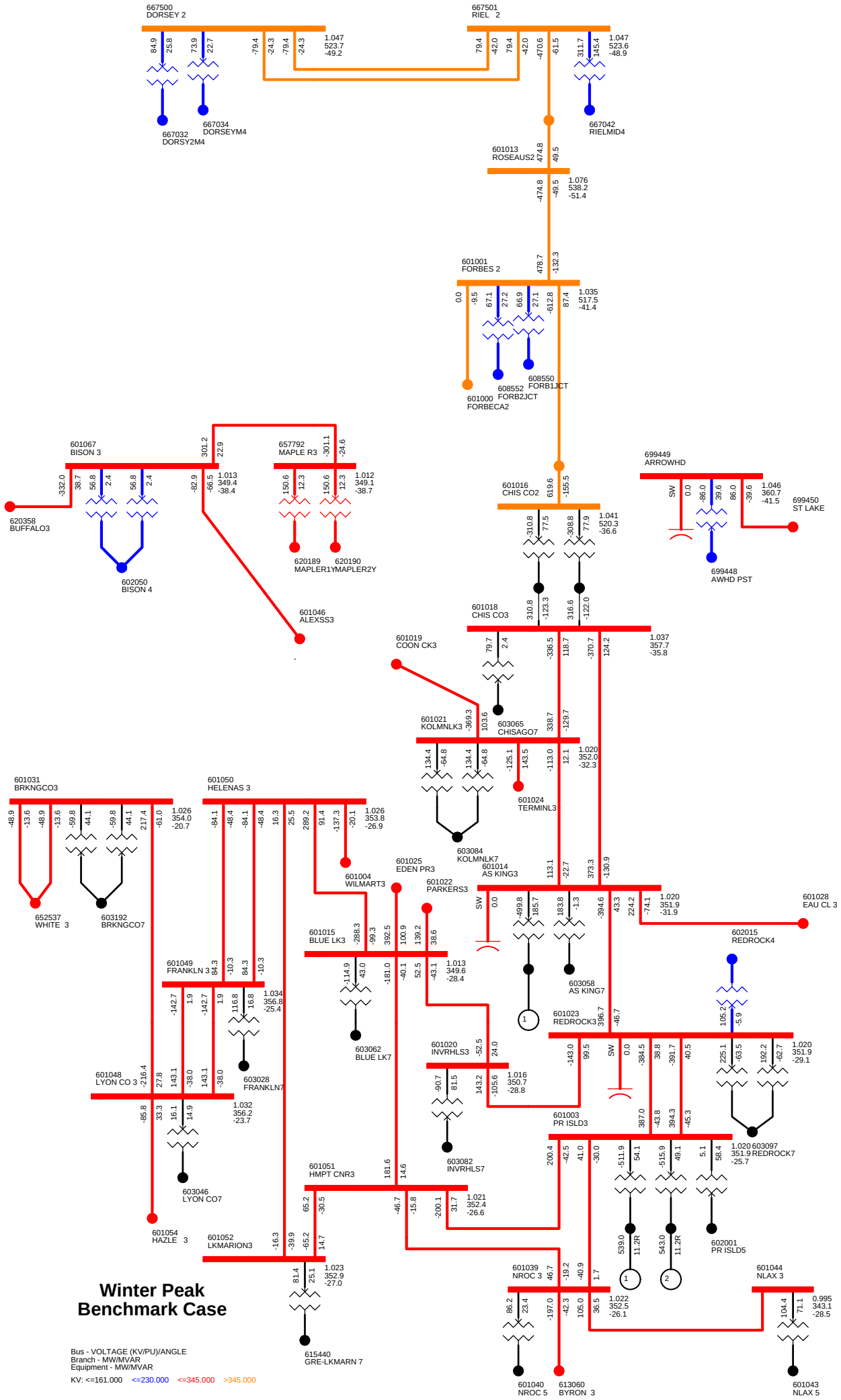
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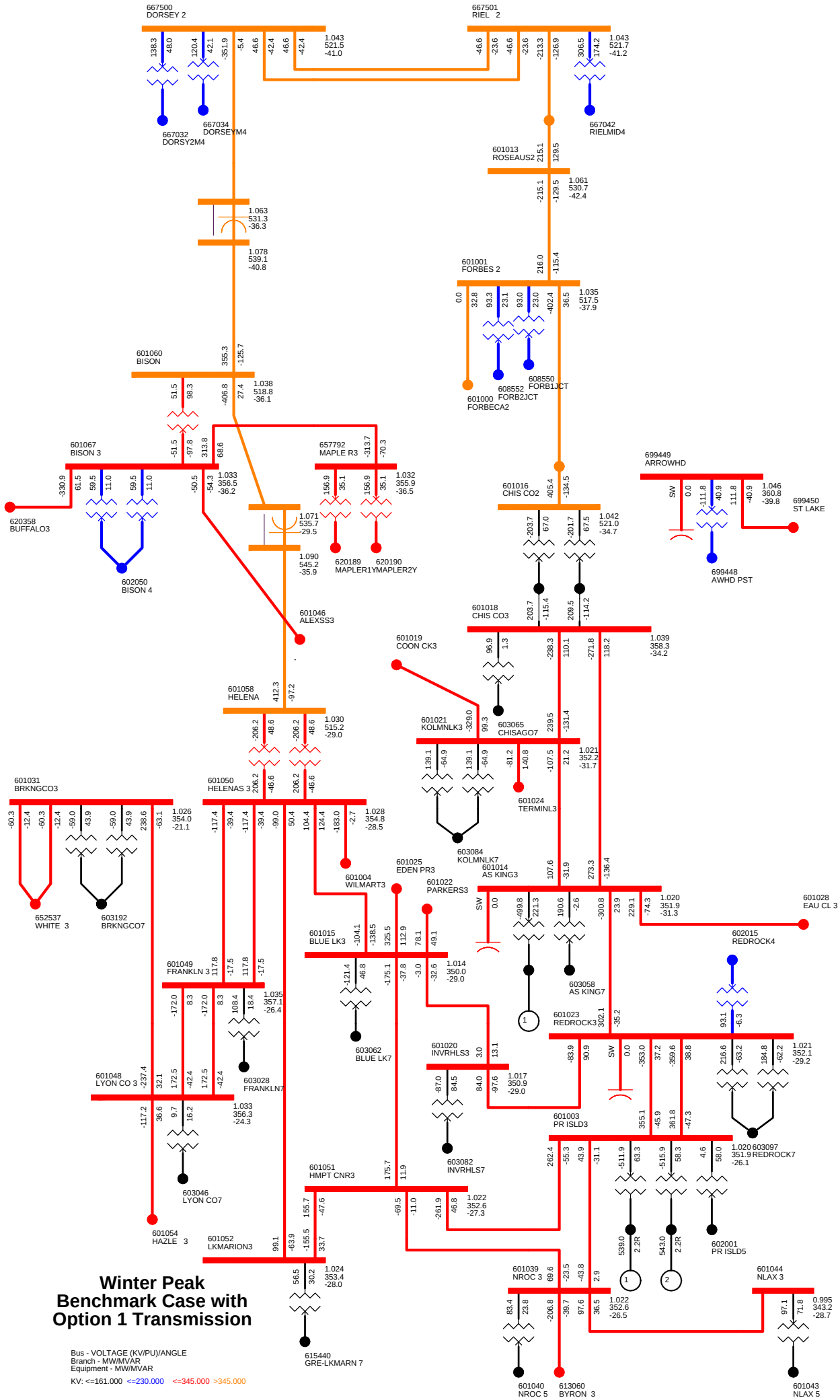
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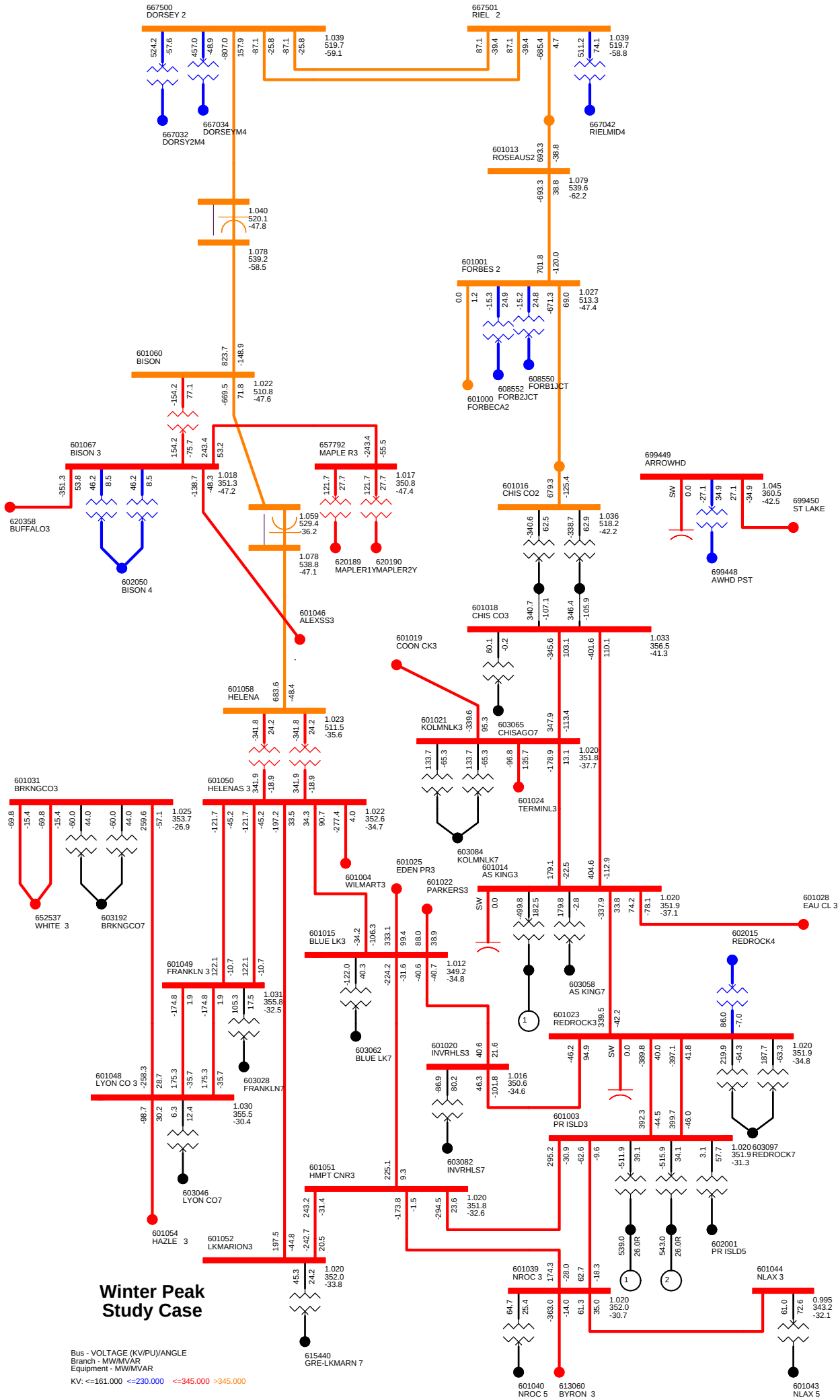
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Winter Peak
Study Case
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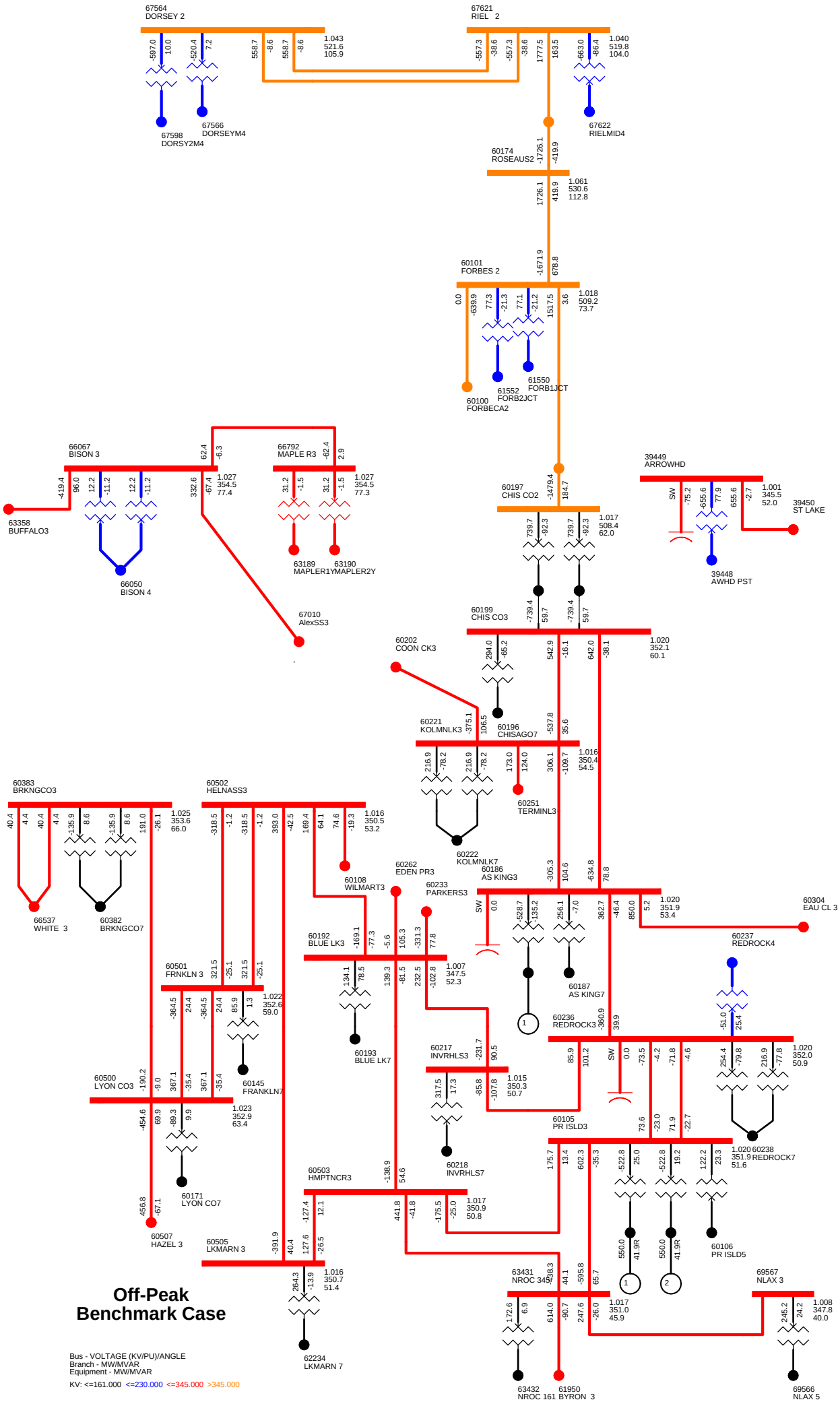
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BLUE LK7
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FRNKLN 3
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FRANKLN7
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LYON CO3
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LYON CO7
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HAZEL 3
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INVRHLS7
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HMPTNCR3
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LKMARN 7
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NROC 345
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NROC 161
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BYRON 3
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NLAX 3
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Off-Peak
Benchmark Case
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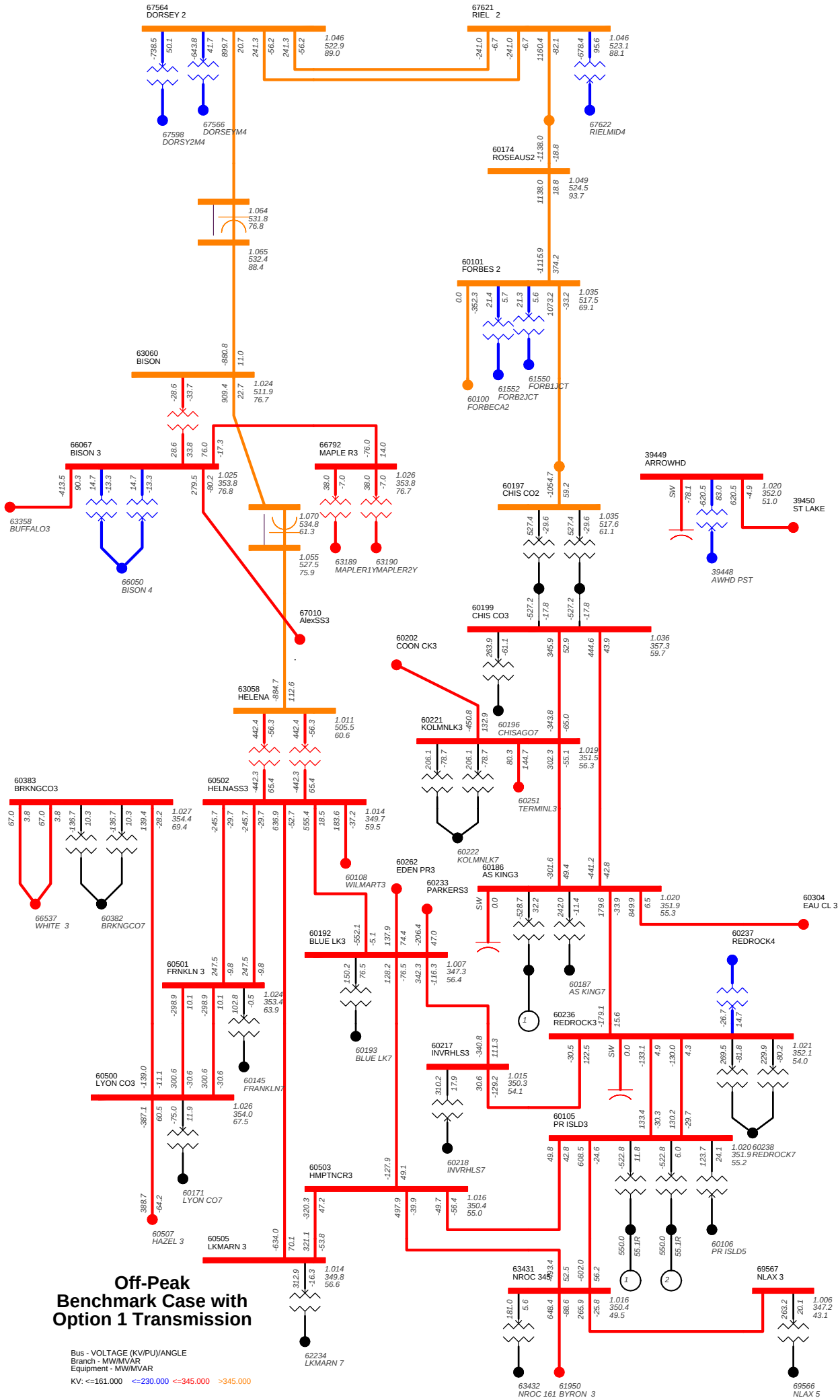
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000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NROC 345
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NROC 161
61950
BYRON 3
69567
NLAX 3
69566
NLAX 5
Off-Peak
Benchmark Case with
Option 1 Transmission
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Branch - MW/MVAR
Equipment - MW/MVAR
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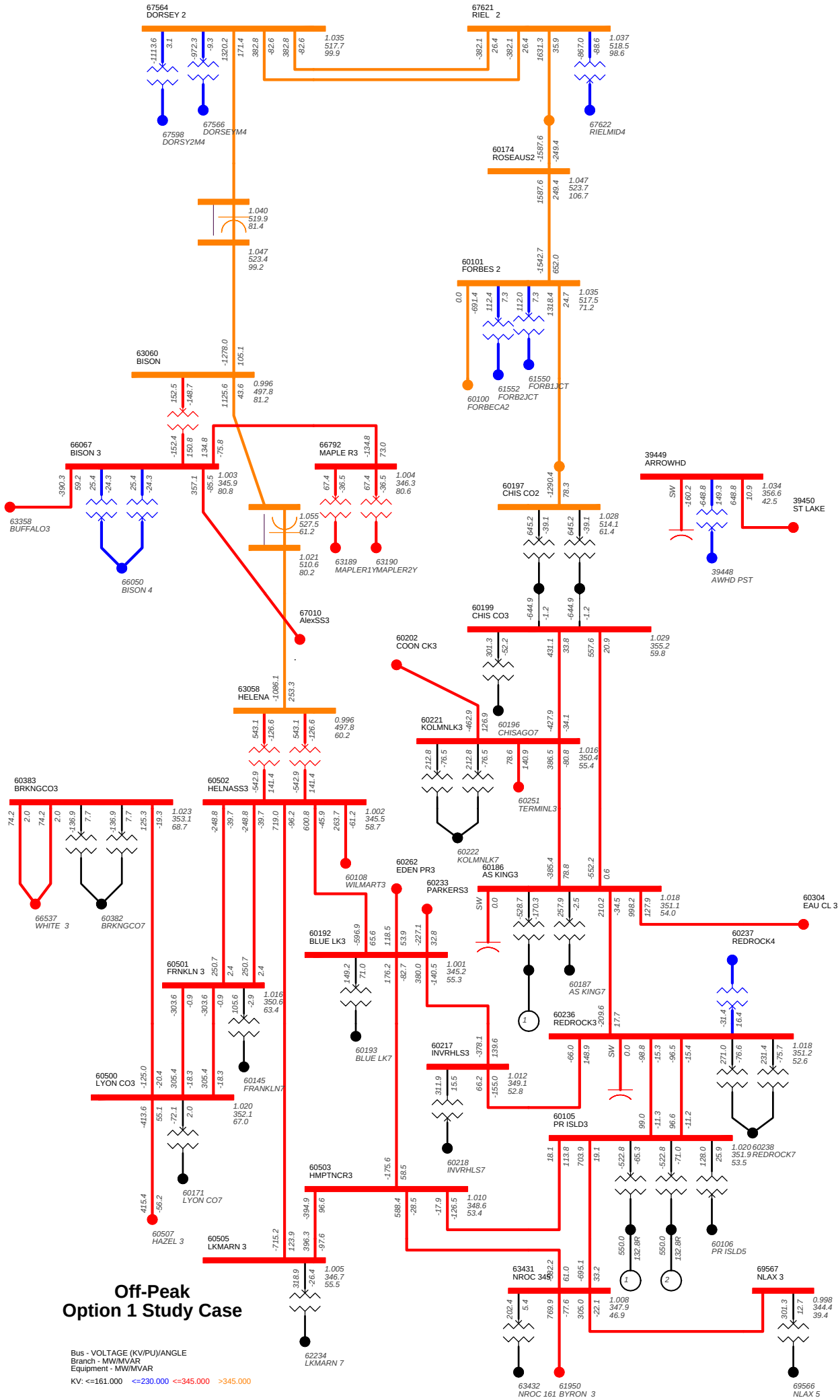
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Off-Peak
Option 1 Study Case
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Branch - MW/MVAR
Equipment - MW/MVAR
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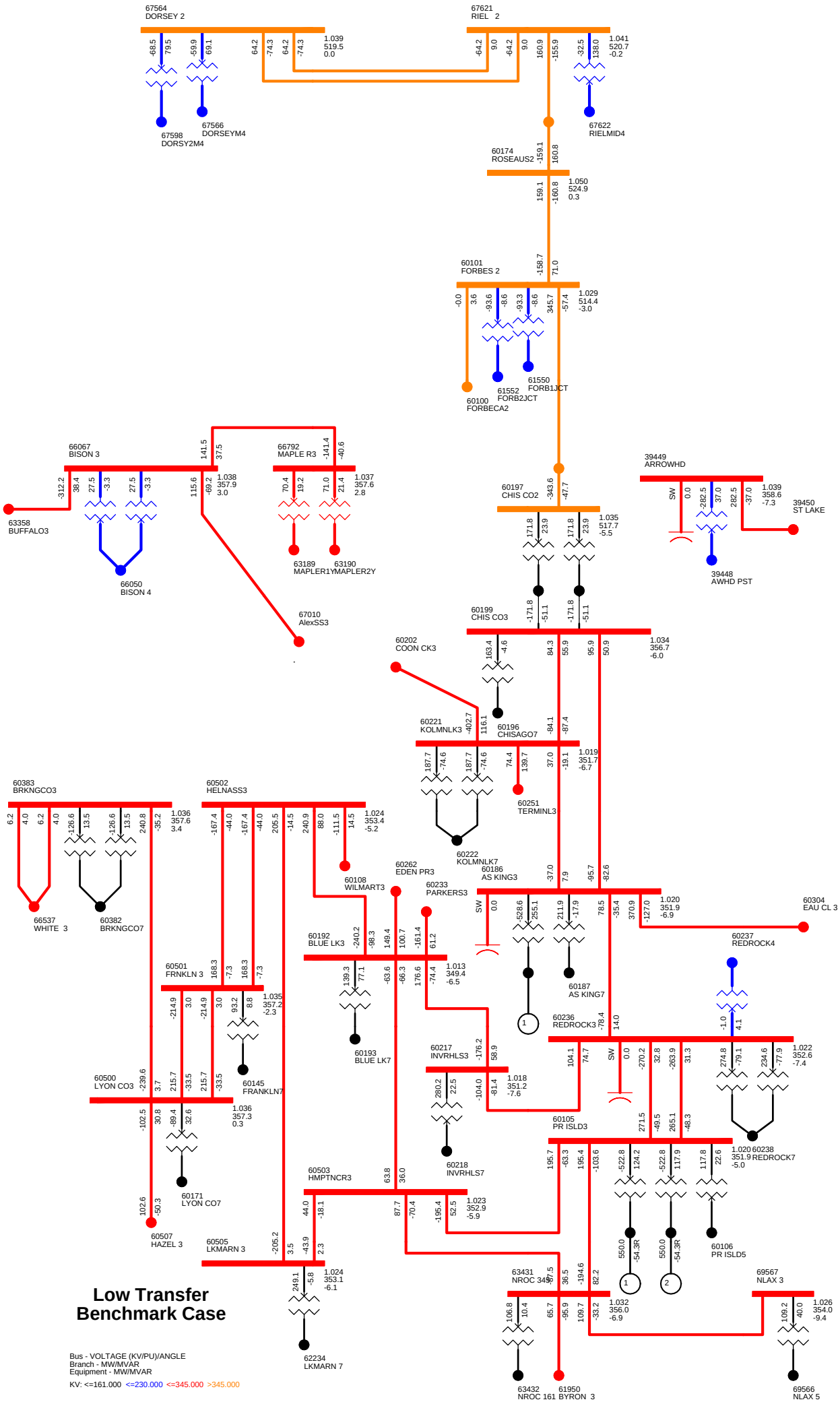
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NROC 161
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BYRON 3
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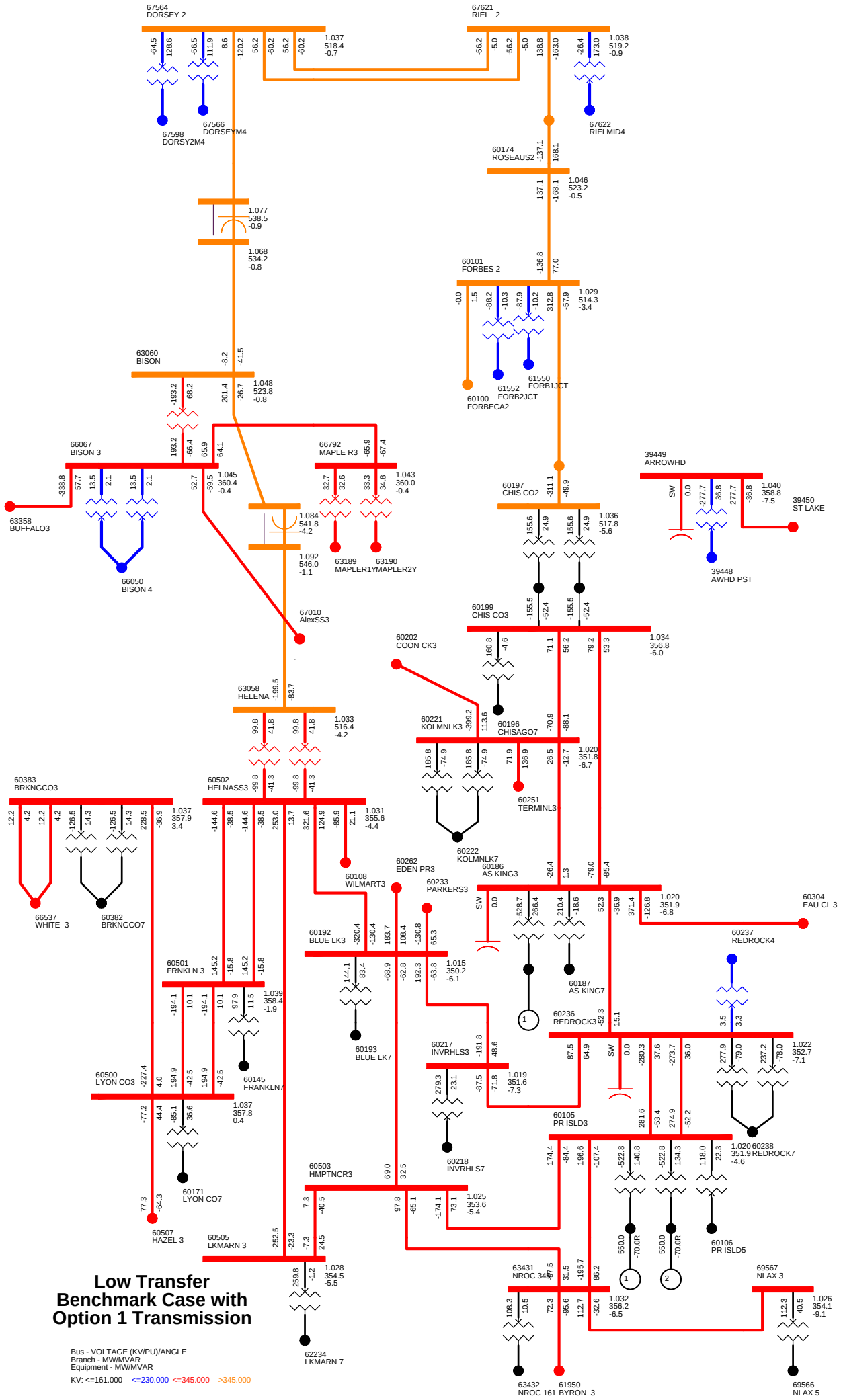
NLAX 5
Low Transfer
Benchmark Case
Bus - VOLTAGE (KV/PU)/ANGLE
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000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BYRON 3
69566
NLAX 5
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PR ISLD5
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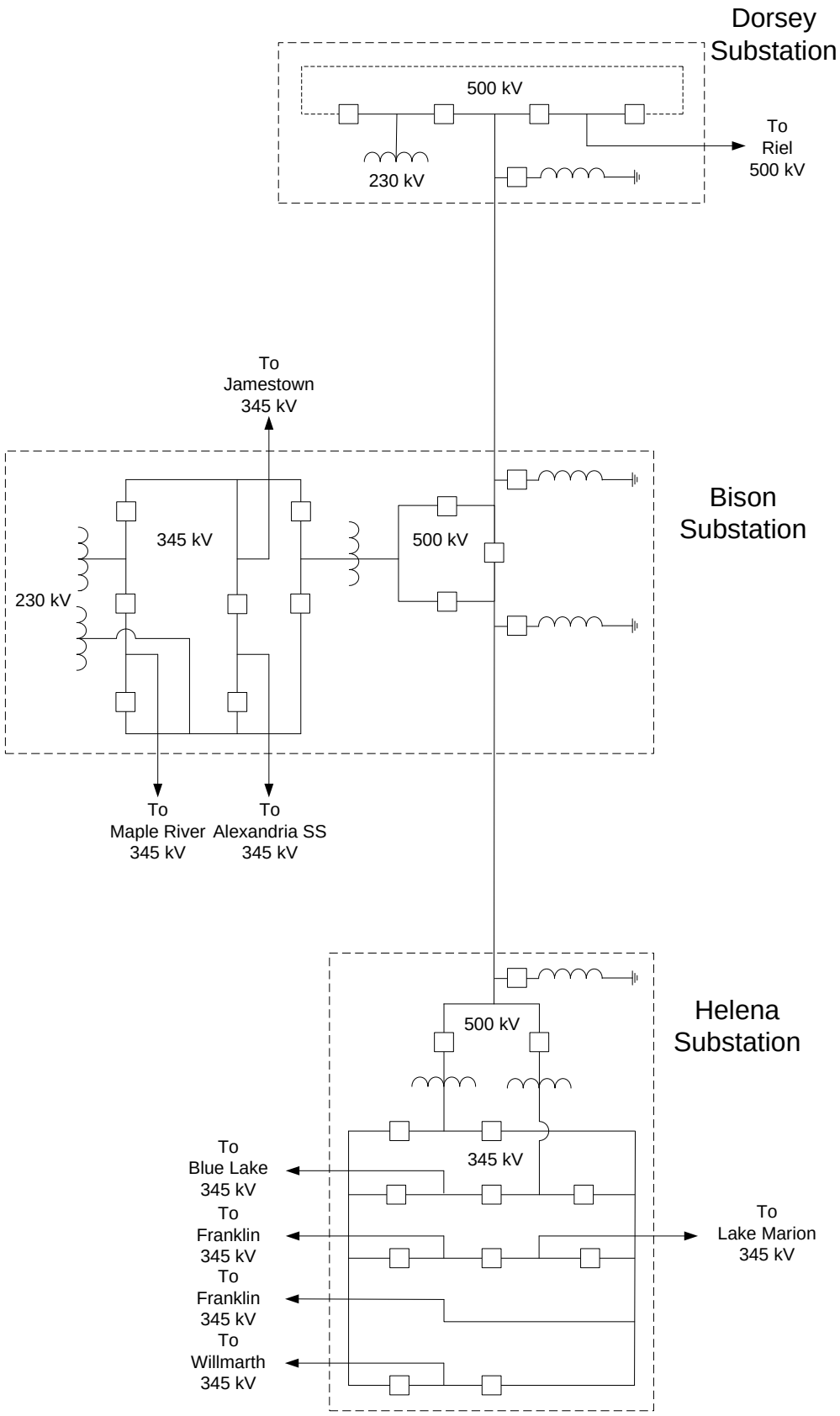
Low Transfer
Benchmark Case with
Option 1 Transmission
Bus - VOLTAGE (KV/PU)/ANGLE
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000
<=230.000
<=345.000
>345.000

A.2 System Topology Assumptions

Option 1
System Topology Assumptions



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

A.3 Low Transfer Case

The low transfer case was developed from the off-peak stability case as described below.

1) Adjust HVDC loading so that BP3 loading is 425 MW; make corresponding generation changes on the northern collector system.
2) Reduce flow on MHEX_S to approximately 0 MW using the IPLAN program setexports.ipl.
3) Increase HVDC loading on BP1 and BP2 to 800 MW using the IPLAN program mhdc-acc-01.ipl; reduce generation at Grand Rapids by a corresponding amount.
4) Change HVDC filters at Dorsey (194.28 MVAr) and Riel (100 MVAr).
5) Switch off capacitors at Rosser, St Vital, and LaVerendrye
6) Reduce generation west of NDEX by approximately 1527 MW as shown in Table A-1; MAIN and ATC load is scaled by a corresponding amount.

Table A-1: ND Generation Reduction

Bus	Off-Peak Stability	Low-Xfer Stability	Change
66459 Garrison 3	96 MW	0 MW	-96 MW
66460 Garrison 4	99 MW	0 MW	-99 MW
66461 Garrison 5	99 MW	0 MW	-99 MW
66666 Big Stone 2	600 MW (net)	0 MW	-600 MW (net)
67103 Antelope Valley 1	480 MW	400 MW	-80 MW
67107 Antelope Valley 2	480 MW	400 MW	-80 MW
67110 Leland Olds 1	230 MW	130 MW	-100 MW
67111 Lelend Olds 2	475 MW	210 MW	-265 MW
67344 Heskett 1	23 MW	0 MW	-23 MW
67345 Heskett 2	75 MW	45.5 MW	-29.5 MW

7) Reduce generation in South Dakota by approximately 528 MW as shown in Table A-2; MAIN and ATC load is scaled by a corresponding amount.

Table A-2: SD Generation Reduction

Bus	Off-Peak Stability	Low-Xfer Stability	Change
66545 Big Bend 7, 8	117 MW	0 MW	-117 MW
66549 Ft Randall 7,8	88 MW	0 MW	-88 MW
66557 Oahe 4, 5	196 MW	0 MW	-196 MW
66558 Oahe 6, 7	97 MW	0 MW	-97 MW
66577 Gavins Point 3	30 MW	0 MW	-30 MW

A.3.1 Power flow summary for benchmark low transfer case

```
                    P O W E R   F L O W   S U M M A R Y
--------------------------------------------------------------------------------
               NDEX:      1069 MW[3]       ECL-ARP:  164 MW
               MHEX:        -1 MW          PRI-BYN:   65 MW
               MWEX:       653 MW          AHD-SLK:  282 MW
               KING-ECL:   370 MW          SLK-GPK:   86 MW
               COOPER S:   469 MW          WNE-WKS:  385 MW
               FTCAL S:    236 MW          GGS:     1498 MW
               GRIS-LNC:   423 MW          QC WEST:  425 MW
               BISON-ALEX: 115 MW          WIL-BOWS:-150 MW
               NROC-NLAX:  109 MW

          LOAD LEVELS AS PERCENT OF 2015 SUMMER PEAK:
          NORTH DAKOTA (ZONE 90,990) 2904.1 MW,  78.3% OF  3710.2 MW
          NSP             (AREA 600) 8324.2 MW,  70.0% OF  11889.2 MW
          MAN HYDRO       (AREA 667) 2348.2 MW,  76.3% OF  3076.0 MW

Load/Losses   MW  / MW       Generation        MW       Export            MW
----------- ------ -----     --------------- ------     --------------- ------
Manitoba      2348/  75      MH total gross    2614     ATC West Import    305
Ont. total   22150/ 478         Wpg River       568     ATC SW Import      756
     NW        915/  36         7 Sisters       170     ATC SE Import    -1160
Sask.         2150/  82      OH total gross   21884     East Bias           73
MP            2341/ 102         northwest       717     SPC>WAPA (B10T)    164
NSP           8324/ 209      SPC total gross   2406     MH>SPC  (3-230)     60
N. Dakota     2904/ 189      MP total gross    2859     MH>SPC  (FALLS)      0
Manitoba       481 MVARS     ND Cfd AC gross   2277     OH>MH  @Kenora    -196
Ont. total   13082 MVARS              net      2106     OH>MP  @Ft Fran    150
     NW        489 MVARS     NSP East gross    2427     OH E>W @Wawa       188
Sask.          502 MVARS              net      2295     OH>East USA          0
MP             669 MVARS          West gross    3057     F601C  @Forbes     345
NSP           1764 MVARS              net      2895     D602F  @Riel       160
N. Dakota      756 MVARS          Total net     6652     L20D   @Letell      10
ATC          10457/ 230       WAPA SD Hydro      969     R50M   @Richer      -2
ATC           3055 MVARS      Pleasant Valley    110     G82R   @Glenboro  -170
                              LGS/Trimont        109
                              SW MN Wind        1008
                              N DAK WIND         252
                              Swing Bus          791


Tfmrs          MVA/ Load     Ph Shifters  Deg/  MW      DC Lines          MW
-------------- ---- -----     ------------ --- -----     --------------- ------
Wshell #1 7-7  106/  73%     Stinson       10/   30     CU (1,2)          1104
Wshell #2 7-7  106/  73%     Boundary Dam  32/  165     SQ BU (3,4)        455
Drayton#1 4-7   27/  19%     Whiteshell    -9/  200     MH Bipole 1        376
Drayton#2 4-7   28/  15%     Int Falls     31/  149     MH Bipole 2        424
Dorsey #1 2-4   90/   7%     St. Lawrence  16/    0     MH (BP1+BP2)       800
Dorsey #2 2-4  104/   8%     Arrowhead      0/  282     Miles City E>W    -150
Forbes    2-4   93/  13%                               RCDC (15)            0
Stone Lk  3-5  193/  57%                               Stegall (10)         0

Dorsey SC's       I/S  MVAR  Qmax/ Qmin    SVC's              MVAR  Qmax/ Qmin
----------------- --- -----  ---- -----    ----------------- -----  ---- -----
MIL 7-9G     17.0  2    -21   600/ -330    Forbes        500    -3   400/ -450
SCE 1-3G     18.2  3    -17   480/ -240    Fargo        13.2   -15    20/ -135
SCA 4-6G     18.2  3    -17   480/ -240    Watertown    20.0   -35   125/  -86
                         -----  ---- -----
       Total              -55  1560/ -810    Series Caps       Num In Serv
       Margin            1615                ----------------- -----------
                                             Roseau        500   2 of 2
                                             Chisago       500   1 of 1
```

[3] Value does not include flow on CapX transmission facilities; flow is approximately 948 MW considering flow on CapX facilities

Caps/Reactors	MVAR	Caps/Reactors	MVAR	Caps/Reactors	MVAR
Balta (FS) 230	0	Arrowhead 230	120	Chisago T 9 34.5	30
Drayton 115	0	Blackberry 230	47	Chisago T 10 34.5	30
Drayton 13.8	-20	Minntac 115	45	Forbes 230	70
Eau Claire(FS) 161	178	Riverton 230	47	Forbes 500	0
Kohlman Lake 115	240	Roseau Co.(FS) 230	0		0
Parkers Lk(FS) 115	0	Running (FS) 230	0	Fargo 115	27
Prairie (FS) 115	0	Running react 230	0	Watertown 20	0
Ramsey (FS) 230	0	Shannon 230	72	Watertown 230	0
Red Rock 115	240		0		0
Rugby 13.8	0	Glenboro 230	0	Arrowhead 345	0
Split Rock(FS) 115	80	Laverendrye 110	0	Stone Lake 345	0
Sheyenne (FS) 115	0	Richer react 230	0	Stone Lk Reac 345	-75
Wilton/Bemidji 115	20	St Vital 110	0	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	1.034	Arrowhead 230	1.032	Whiteshell 110	118.9
Alexandria 115	1.035	Badoura 115	1.029	Kenora 220	247.7
Audubon 115	1.051	Blackberry 230	1.035	Dryden 220	251.9
Bemidji 115	1.028	Boise Cascade 13.8	1.057	Fort Frances 220	247.0
Byron 345	1.036	Boise Cascade 115	1.025	Mackenzie 220	254.6
Chisago Co. 345	1.034	ETCO 115	1.015	Lakehead 220	246.3
Chisago Co. 500	1.035	Forbes 230	1.031	Marathon 220	252.7
Drayton 230	1.023	Forbes 500	1.029	Wawa 220	254.7
Eau Claire 345	1.053	Hubbard 115	1.027	Mississagi 220	250.6
WEST FARIBAULT 115	1.037	Intl Falls 115	1.025	Fort Frances 118	120.4
LaPorte 115	1.021	Minntac 115	1.021	Lakehead 118	122.8
Maple River 230	1.033	Moranville 230	1.047	Birch 118	120.2
Marshall Tap 115	1.028	Riverton 230	1.033	Marathon 118	126.4
Owatonna 161	1.007	Running 230	1.039		0.000
Prairie 115	1.019	Shannon 230	1.036	Arrowhead 345	1.039
Prairie 230	1.020	Stinson MN 115	1.037	Stone Lake 345	1.036
Ramsey 230	1.004	Jamestown 345	1.028	Stone Lake 161	1.038
Roseau County 230	1.047	Groton 345	1.025	Gardner Park 345	1.035
Roseau County 500	1.050	Watertown 230	1.030	Weston 115	1.035
Sheyenne 230	1.034	Watertown 345	1.034	Arpin 345	1.050
Thief R Falls 115	1.021		0.000	Eau Claire 161	1.030
Tioga 230	1.032	Dorsey 230	1.045	Council Creek 161	0.988
Wahpeton 230	1.029	Dorsey 500	1.039	Hydro Lane 161	1.009
Winger 115	1.040		0.000	Wien 115	1.035
	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-RIEL	ATP ???	SLINOS	4281%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	4235%	N/A	N/A
6) -Forbes (Em Nrth)	APT S-PRO	SLINOS		N/A	N/A
8) F3M-Intl Falls	APT S-PRO	SLINOS	336%	N/A	N/A
9) G82R-Rugby	APT	SLINOS	N/A	405%	
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	660%	N/A	N/A
11) -Drayton (Em Nrth)	ASEA RXZF2	SLINOS		N/A	N/A
12) R50M-Moranville (Norm)	APT, West	SLINOS	N/A	999999%	
13) -Moranville (Em N)	ASEA RXZF2	SLINOS	N/A		999999%

A.3.2 Power flow summary for low transfer case with Option 1 transmission

```
                    P O W E R   F L O W   S U M M A R Y
-------------------------------------------------------------------------------
               NDEX:       953 MW[4]        ECL-ARP:  166 MW
               MHEX:       -10 MW           PRI-BYN:   72 MW
               MWEX:       649 MW           AHD-SLK:  277 MW
               KING-ECL:   371 MW           SLK-GPK:   82 MW
               COOPER S:   469 MW           WNE-WKS:  384 MW
               FTCAL S:    238 MW           GGS:     1496 MW
               GRIS-LNC:   418 MW           QC WEST:  425 MW
               BISON-ALEX:  52 MW           WIL-BOWS:-163 MW
               NROC-NLAX:  112 MW           DRSY-BISN:   8 MW
               BISN-BRCO:  201 MW           New MHEX:  -2 MW

          LOAD LEVELS AS PERCENT OF 2015 SUMMER PEAK:
          NORTH DAKOTA (ZONE 90,990) 2904.1 MW,  78.3% OF  3710.2 MW
          NSP             (AREA 600) 8324.2 MW,  70.0% OF  11889.2 MW
          MAN HYDRO       (AREA 667) 2348.2 MW,  76.3% OF  3076.0 MW

Load/Losses   MW  / MW       Generation        MW       Export            MW
----------- ------ -----     --------------- ------     --------------- ------
Manitoba      2348/  76      MH total gross    2614     ATC West Import    305
Ont. total   22150/ 478         Wpg River       568     ATC SW Import      756
     NW        915/  36         7 Sisters       170     ATC SE Import    -1160
Sask.         2150/  82      OH total gross   21884     East Bias            50
MP            2341/ 102         northwest        717     SPC>WAPA (B10T)    166
NSP           8324/ 207      SPC total gross   2406     MH>SPC  (3-230)     62
N. Dakota     2904/ 191      MP total gross    2859     MH>SPC  (FALLS)      0
Manitoba       481 MVARS     ND Cfd AC gross   2277     OH>MH  @Kenora    -194
Ont. total   13082 MVARS              net      2106     OH>MP  @Ft Fran    150
     NW        489 MVARS     NSP East gross    2427     OH E>W @Wawa       191
Sask.          502 MVARS              net      2295     OH>East USA          0
MP             669 MVARS          West gross    3057     F601C  @Forbes     312
NSP           1764 MVARS              net      2895     D602F  @Riel       138
N. Dakota      756 MVARS          Total net     6652     L20D   @Letell      20
ATC           10457/ 230      WAPA SD Hydro      969     R50M   @Richer      -3
ATC            3055 MVARS     Pleasant Valley    110     G82R   @Glenboro  -166
                              LGS/Trimont        109
                              SW MN Wind        1008
                              N DAK WIND         252
                              Swing Bus          790


Tfmrs          MVA/ Load      Ph Shifters  Deg/  MW      DC Lines          MW
------------- ---- -----     ------------ --- -----     --------------- ------
Wshell #1 7-7  105/  73%     Stinson       10/   28     CU (1,2)          1104
Wshell #2 7-7  105/  73%     Boundary Dam  32/  166     SQ BU (3,4)        455
Drayton#1 4-7   27/  19%     Whiteshell    -9/  198     MH Bipole 1        376
Drayton#2 4-7   29/  15%     Int Falls     31/  149     MH Bipole 2        424
Dorsey #1 2-4  123/  10%     St. Lawrence  16/    0     MH (BP1+BP2)       800
Dorsey #2 2-4  142/  11%     Arrowhead      0/  277     Miles City E>W    -150
Forbes    2-4   88/  13%                               RCDC (15)            0
Stone Lk  3-5  192/  57%                               Stegall (10)         0

Dorsey SC's       I/S  MVAR  Qmax/ Qmin    SVC's              MVAR  Qmax/ Qmin
---------------- --- -----  ---- -----    ---------------- -----  ---- -----
MIL 7-9G     17.0  2    -55   600/ -330    Forbes         500    -1   400/ -450
SCE 1-3G     18.2  3    -45   480/ -240    Fargo         13.2   -24    20/ -135
SCA 4-6G     18.2  3    -45   480/ -240    Watertown     20.0   -35   125/  -86
                         -----  ---- -----
       Total            -145  1560/ -810    Series Caps       Num In Serv
       Margin           1705                ---------------- -----------
                                            Roseau         500   2 of 2
                                            Chisago        500   1 of 1
```

[4] Value does not include flow on CapX or Option 1 transmission facilities; flow is approximately 948 MW considering flow on CapX and Option 1 facilities

Caps/Reactors	MVAR	Caps/Reactors	MVAR	Caps/Reactors	MVAR
Balta (FS) 230	0	Arrowhead 230	120	Chisago T 9 34.5	30
Drayton 115	0	Blackberry 230	47	Chisago T 10 34.5	30
Drayton 13.8	-20	Minntac 115	45	Forbes 230	70
Eau Claire(FS) 161	178	Riverton 230	47	Forbes 500	0
Kohlman Lake 115	240	Roseau Co.(FS) 230	0		0
Parkers Lk(FS) 115	0	Running (FS) 230	0	Fargo 115	27
Prairie (FS) 115	0	Running react 230	0	Watertown 20	0
Ramsey (FS) 230	0	Shannon 230	72	Watertown 230	0
Red Rock 115	240		0		0
Rugby 13.8	0	Glenboro 230	0	Arrowhead 345	0
Split Rock(FS) 115	80	Laverendrye 110	0	Stone Lake 345	0
Sheyenne (FS) 115	0	Richer react 230	0	Stone Lk Reac 345	-75
Wilton/Bemidji 115	20	St Vital 110	0	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	1.034	Arrowhead 230	1.033	Whiteshell 110	118.9
Alexandria 115	1.037	Badoura 115	1.030	Kenora 220	247.8
Audubon 115	1.052	Blackberry 230	1.035	Dryden 220	251.9
Bemidji 115	1.029	Boise Cascade 13.8	1.056	Fort Frances 220	247.0
Byron 345	1.036	Boise Cascade 115	1.025	Mackenzie 220	254.6
Chisago Co. 345	1.034	ETCO 115	1.015	Lakehead 220	246.3
Chisago Co. 500	1.036	Forbes 230	1.031	Marathon 220	252.6
Drayton 230	1.024	Forbes 500	1.029	Wawa 220	254.6
Eau Claire 345	1.053	Hubbard 115	1.028	Mississagi 220	250.6
WEST FARIBAULT 115	1.039	Intl Falls 115	1.025	Fort Frances 118	120.4
LaPorte 115	1.022	Minntac 115	1.021	Lakehead 118	122.8
Maple River 230	1.037	Moranville 230	1.047	Birch 118	120.2
Marshall Tap 115	1.029	Riverton 230	1.033	Marathon 118	126.4
Owatonna 161	1.009	Running 230	1.038		0.000
Prairie 115	1.020	Shannon 230	1.036	Arrowhead 345	1.040
Prairie 230	1.020	Stinson MN 115	1.038	Stone Lake 345	1.036
Ramsey 230	1.004	Jamestown 345	1.029	Stone Lake 161	1.038
Roseau County 230	1.047	Groton 345	1.026	Gardner Park 345	1.035
Roseau County 500	1.046	Watertown 230	1.030	Weston 115	1.035
Sheyenne 230	1.037	Watertown 345	1.035	Arpin 345	1.050
Thief R Falls 115	1.022		0.000	Eau Claire 161	1.030
Tioga 230	1.032	Dorsey 230	1.045	Council Creek 161	0.987
Wahpeton 230	1.030	Dorsey 500	1.037	Hydro Lane 161	1.009
Winger 115	1.041		0.000	Wien 115	1.035
	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	335%	N/A	N/A
2) -Tioga (North)	GE OST	SLLP	690%	N/A	N/A
3) -Tioga (Em North)	GE OST	SLLP		N/A	N/A
4) D602F-RIEL	ATP ???	SLINOS	4073%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	4531%	N/A	N/A
6) -Forbes (Em Nrth)	APT S-PRO	SLINOS		N/A	N/A
8) F3M-Intl Falls	APT S-PRO	SLINOS	335%	N/A	N/A
9) G82R-Rugby	APT	SLINOS	N/A	419%	
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	2394%	N/A	N/A
11) -Drayton (Em Nrth)	ASEA RXZF2	SLINOS		N/A	N/A
12) R50M-Moranville (Norm)	APT, West	SLINOS	N/A	32200%	
13) -Moranville (Em N)	ASEA RXZF2	SLINOS	N/A		29687%

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Appendix

B

Shunt Reactor Analysis

Table B-1: Option 1 Study Case

	Case No.	1	2	3	4	5
	Case Name	M1b-so15aa-ag1	M1b-so15aa-mis	M1b-so15aa-nad	M1b-so15aa-nmz	M1b-so15aa-pas
	Disturbance	ag1	mis	nad	nmz	pas
	Prior Outage	None	None	None	None	None
	Date/Time	FEB 24 2010 16:58	FEB 24 2010 17:01	FEB 24 2010 17:03	FEB 24 2010 17:05	FEB 24 2010 17:08
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2363 / 195	2363 / 195	2363 / 195	2363 / 195	2363 / 195
	MHEX / L20D	1956 / 243	1956 / 243	1956 / 243	1956 / 243	1956 / 243
	ECL-ARP / PRI-BYN	810 / 28	810 / 28	810 / 28	810 / 28	810 / 28
	MWEX / AHD-SLK	1648 / 648	1648 / 648	1648 / 648	1648 / 648	1648 / 648
	D602F / F601C	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318
	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	135 / 150	135 / 150	135 / 150	135 / 150	135 / 150
	G82R	-53	-53	-53	-53	-53
	Dorsey bipole / CU bipole	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104
	Dorsey Reserve / Wtrtn SVC	581 / 12	581 / 12	581 / 12	581 / 12	581 / 12
	Forbes SVC / MSC	48 / 600	48 / 600	48 / 600	48 / 600	48 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045
	Roseau 500/Forbes 500	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035
	Chisago 500/EauClaire 345	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992
	Int Falls 115/Badoura 115	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034
	Drayton 230/Groton 345	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	292% / 486%	292% / 486%	292% / 486%	292% / 486%	292% / 486%
	G82R at Rugby/L20D at Drayton	999% / 866%	999% / 866%	999% / 866%	999% / 866%	999% / 866%
	R50M/F3M	999% / 323%	999% / 323%	999% / 323%	999% / 323%	999% / 323%
	B10T	343%	343%	343%	343%	343%
	Min/MaxTransientVltg					
	Arrowhd 230	0.99 | 1.02	1.01 | 1.02	1.00 | 1.06	0.95 | 1.05	0.98 | 1.06
	Boise 115	1.01 | 1.03	1.05 | 1.06	0.97 | 1.02	0.98 | 1.02	0.99 | 1.02
	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.07	1.04 | 1.08	1.05 | 1.07
	Forbes 230	1.02 | 1.04	1.03 | 1.04	1.02 | 1.04	1.01 | 1.04	0.98 | 1.04
	Riverton 230	1.01 | 1.04	1.03 | 1.03	0.99 | 1.05	0.96 | 1.05	0.99 | 1.05
	Coal Creek 230	0.97 | 1.11	1.03 | 1.04	0.99 | 1.06	0.96 | 1.07	0.98 | 1.06
	Jamestown 345	0.93 | 1.02	0.99 | 0.99	0.94 | 1.01	0.88 | 1.03	0.94 | 1.01
	Drayton 230	1.01 | 1.05	1.03 | 1.04	1.00 | 1.06	0.98 | 1.08	1.00 | 1.06
	Groton 345	0.93 | 1.04	1.02 | 1.02	0.99 | 1.04	0.94 | 1.05	0.99 | 1.04
	Minong 161	1.00 | 1.04	1.03 | 1.04	1.02 | 1.09	0.99 | 1.09	1.02 | 1.09
	Wahpeton 115	1.00 | 1.04	1.03 | 1.03	0.99 | 1.04	0.95 | 1.06	0.99 | 1.04
	Watertown 345	0.99 | 1.04	1.03 | 1.03	1.01 | 1.04	0.97 | 1.05	1.01 | 1.04
	Dynamic Voltage Warnings					
		none	none	none	none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold			/ 0.133	/ 0.133	/ 0.150
	Forbes DC Red (DCAR)	471%	486%	507%	507%	374%
	K22W (max +dP @ t, d-ang)	10.8@(2.31666,2.1)	196.1@(0.35000,-11.9)	87.8@(2.05000,-42.3)	97.4@(2.20833,-43.0)	86.0@(2.07500,-40.5)
	K22W (max -dP @ t, d-ang)	20.0@(1.74166,0.6)	0.0@(0.35000,0.0)	62.3@(0.25000,7.0)	48.4@(0.23333,4.9)	43.1@(0.25833,3.9)
	K22W (max d-ang @ t, dP)	6.6@(1.00000,-5.9)	-43.3@(0.96666,196.1)	-49.1@(4.99995,36.0)	-45.2@(2.51666,84.2)	-45.3@(4.99995,40.4)
	OS Rel Trip / Marg					
	MH - OH		0.35000 sec			
	D602F at Forbes/Dorsey	254% / 424%	281% / 468%	0.16667 sec / 0.16667 sec	0.18333 sec / 0.18333 sec	0.38333 sec / 0.18333 sec
	G82R at Rugby/L20D at Drayton	999% / 776%	999% / 830%	999% / 595%	999% / 705%	999% / 654%
	R50M / F3M	895% / 284%	630% / 323%	521% / 164%	646% / 196%	585% / 193%
	B10T	215%	321%	178%	132%	202%
	FSCAPS (SS/Unav/Final)					
	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 1)	(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 | 2) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)
	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 3 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)
	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 3 | 3)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 2 | 2)
	Shey 115 / Split Rock 115	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 2 | 2)	(1 | 4 | 4) / (1 | 2 | 2)	(1 | 2 | 2) / (1 | 1 | 1)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	M1b-so15aa-ag1	M1b-so15aa-mis	M1b-so15aa-nad	M1b-so15aa-nmz	M1b-so15aa-pas
Disturbance	ag1	mis	nad	nmz	pas
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping		(1T)	(5T)(6T)	(5T)(6T)	(5T)(6T)

Table B-1: Option 1 Study Case

	Case No.	6	7	8	9	10
	Case Name	M1b-so15aa-h13	M1b-so15aa-h23	M1b-so15aa-h7d	M1b-so15aa-he0	M1b-so15aa-hl0
	Disturbance	h13	h23	h7d	he0	hl0
	Prior Outage	None	None	None	None	None
	Date/Time	FEB 24 2010 17:10	FEB 24 2010 17:12	FEB 24 2010 17:14	FEB 24 2010 17:16	FEB 24 2010 17:18
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2363 / 195	2363 / 195	2363 / 195	2363 / 195	2363 / 195
	MHEX / L20D	1956 / 243	1956 / 243	1956 / 243	1956 / 243	1956 / 243
	ECL-ARP / PRI-BYN	810 / 28	810 / 28	810 / 28	810 / 28	810 / 28
	MWEX / AHD-SLK	1648 / 648	1648 / 648	1648 / 648	1648 / 648	1648 / 648
	D602F / F601C	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318
	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	135 / 150	135 / 150	135 / 150	135 / 150	135 / 150
	G82R	-53	-53	-53	-53	-53
	Dorsey bipole / CU bipole	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104
	Dorsey Reserve / Wtrtn SVC	581 / 12	581 / 12	581 / 12	581 / 12	581 / 12
	Forbes SVC / MSC	48 / 600	48 / 600	48 / 600	48 / 600	48 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045
	Roseau 500/Forbes 500	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035
	Chisago 500/EauClaire 345	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992
	Int Falls 115/Badoura 115	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034
	Drayton 230/Groton 345	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	292% / 486%	292% / 486%	292% / 486%	292% / 486%	292% / 486%
	G82R at Rugby/L20D at Drayton	999% / 866%	999% / 866%	999% / 866%	999% / 866%	999% / 866%
	R50M/F3M	999% / 323%	999% / 323%	999% / 323%	999% / 323%	999% / 323%
	B10T	343%	343%	343%	343%	343%
	Min/MaxTransientVltg					
	Arrowhd 230	1.00 | 1.02	1.02 | 1.05	1.02 | 1.05	1.02 | 1.06	1.02 | 1.06
	Boise 115	1.01 | 1.03	1.01 | 1.03	1.00 | 1.02	1.00 | 1.04	1.00 | 1.04
	Dorsey 230	1.00 | 1.05	1.03 | 1.06	1.04 | 1.07	1.03 | 1.17	1.04 | 1.17
	Forbes 230	1.03 | 1.04	1.03 | 1.05	1.02 | 1.05	1.03 | 1.06	1.03 | 1.06
	Riverton 230	1.02 | 1.03	1.03 | 1.05	1.02 | 1.05	1.04 | 1.05	1.04 | 1.05
	Coal Creek 230	1.02 | 1.07	1.02 | 1.06	1.01 | 1.06	1.03 | 1.06	1.03 | 1.06
	Jamestown 345	0.96 | 1.00	0.97 | 1.02	0.93 | 1.01	0.96 | 1.01	0.96 | 1.01
	Drayton 230	1.01 | 1.04	1.02 | 1.06	1.01 | 1.05	1.04 | 1.11	1.04 | 1.11
	Groton 345	1.01 | 1.04	1.01 | 1.05	1.00 | 1.05	1.01 | 1.05	1.01 | 1.05
	Minong 161	1.02 | 1.05	1.04 | 1.08	1.05 | 1.08	1.04 | 1.09	1.04 | 1.09
	Wahpeton 115	1.02 | 1.04	1.03 | 1.05	1.01 | 1.05	1.04 | 1.05	1.04 | 1.05
	Watertown 345	1.02 | 1.04	1.02 | 1.04	1.02 | 1.05	1.03 | 1.05	1.03 | 1.05
	Dynamic Voltage Warnings					
		none	none	none	none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
	Forbes DC Red (DCAR)	464%	468%	507%	367%	367%
	K22W (max +dP @ t, d-ang)	102.4@(0.15000,-2.1)	102.4@(0.15000,-2.1)	102.4@(0.15000,-2.1)	99.7@(1.53333,-34.0)	100.6@(1.53333,-34.2)
	K22W (max -dP @ t, d-ang)	19.2@(2.94998,4.6)	0.0@(0.02500,0.0)	10.9@(0.25000,0.7)	65.3@(0.40000,7.4)	65.6@(0.40000,7.4)
	K22W (max d-ang @ t, dP)	-7.0@(0.65000,0.0)	-32.4@(4.99995,46.9)	-43.8@(4.99995,49.0)	-43.3@(4.99995,46.0)	-43.4@(4.99995,46.4)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	278% / 464%	292% / 486%	246% / 413%	69% / 102%	69% / 102%
	G82R at Rugby/L20D at Drayton	999% / 794%	999% / 866%	999% / 614%	999% / 347%	999% / 347%
	R50M / F3M	911% / 265%	999% / 247%	960% / 217%	513% / 204%	513% / 204%
	B10T	286%	288%	172%	126%	128%
	FSCAPS (SS/Unav/Final)					
	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 1)	(0 | 1 | 1)
	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 3) / (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 | 5 | 1) / (0 | 1 | 1)	(1 | 5 | 1) / (0 | 1 | 1)
	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 | 1)	(0 | 1 | 0) / (1 | 2 | 1)
	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	M1b-so15aa-h13	M1b-so15aa-h23	M1b-so15aa-h7d	M1b-so15aa-he0	M1b-so15aa-hl0
Disturbance	h13	h23	h7d	he0	hl0
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					

Table B-1: Option 1 Study Case

	Case No.	11	12	13	14	15
2	**Case Name**	M1b-so15aa-h33	M1b-so15aa-h43	M1b-so15aa-h83	M1b-so15aa-hmd	m1b-so15aa-o53
3	**Disturbance**	h33	h43	h83	hmd	o53
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	FEB 24 2010 17:20	FEB 24 2010 17:22	FEB 24 2010 17:31	FEB 24 2010 17:33	APR 07 2010 15:32
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2363 / 195	2363 / 195	2363 / 195	2363 / 195	2363 / 195
10	MHEX / L20D	1956 / 243	1956 / 243	1956 / 243	1956 / 243	1956 / 243
11	ECL-ARP / PRI-BYN	810 / 28	810 / 28	810 / 28	810 / 28	810 / 28
12	MWEX / AHD-SLK	1648 / 648	1648 / 648	1648 / 648	1648 / 648	1648 / 648
13	D602F / F601C	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318
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	135 / 150	135 / 150	135 / 150	135 / 150	135 / 150
17	G82R	-53	-53	-53	-53	-53
18	Dorsey bipole / CU bipole	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104
19	Dorsey Reserve / Wtrtn SVC	581 / 12	581 / 12	581 / 12	581 / 12	581 / 12
20	Forbes SVC / MSC	48 / 600	48 / 600	48 / 600	48 / 600	48 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045
24	Roseau 500/Forbes 500	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035
25	Chisago 500/EauClaire 345	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992
26	Int Falls 115/Badoura 115	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034
27	Drayton 230/Groton 345	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	292% / 486%	292% / 486%	292% / 486%	292% / 486%	292% / 486%
30	G82R at Rugby/L20D at Drayton	999% / 866%	999% / 866%	999% / 866%	999% / 866%	999% / 866%
31	R50M/F3M	999% / 323%	999% / 323%	999% / 323%	999% / 323%	999% / 323%
32	B10T	343%	343%	343%	343%	343%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.03 | 1.08	1.00 | 1.02	0.98 | 1.01	0.99 | 1.05	0.93 | 1.01
35	Boise 115	0.95 | 1.01	1.00 | 1.02	1.01 | 1.03	1.00 | 1.02	1.00 | 1.02
36	Dorsey 230	1.04 | 1.07	1.00 | 1.04	1.03 | 1.05	1.04 | 1.07	1.03 | 1.05
37	Forbes 230	1.05 | 1.07	1.02 | 1.04	1.03 | 1.04	1.03 | 1.05	1.00 | 1.02
38	Riverton 230	1.01 | 1.05	1.02 | 1.03	1.02 | 1.04	1.01 | 1.05	0.99 | 1.02
39	Coal Creek 230	1.01 | 1.07	1.02 | 1.06	1.00 | 1.08	0.99 | 1.08	0.99 | 1.05
40	Jamestown 345	0.94 | 1.00	0.96 | 1.00	0.98 | 1.03	0.92 | 1.01	0.98 | 1.02
41	Drayton 230	1.01 | 1.05	1.01 | 1.03	1.02 | 1.04	1.01 | 1.06	1.02 | 1.04
42	Groton 345	0.99 | 1.04	1.01 | 1.04	1.00 | 1.04	0.99 | 1.06	0.98 | 1.00
43	Minong 161	1.05 | 1.10	1.02 | 1.05	0.99 | 1.04	1.01 | 1.08	0.96 | 1.04
44	Wahpeton 115	1.00 | 1.04	1.01 | 1.03	1.03 | 1.06	1.01 | 1.06	1.00 | 1.02
45	Watertown 345	1.01 | 1.04	1.02 | 1.03	1.02 | 1.03	1.02 | 1.05	1.00 | 1.02
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping					
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	507%	479%	447%	507%	483%
57	K22W (max +dP @ t, d-ang)	95.7@(0.15000,-1.7)	95.7@(0.15000,-1.7)	27.4@(0.11667,0.6)	101.6@(2.05833,-38.4)	27.4@(0.11667,0.6)
58	K22W (max -dP @ t, d-ang)	20.3@(0.25000,0.9)	32.2@(2.94165,7.8)	39.8@(0.29167,5.8)	64.2@(0.27500,7.0)	50.8@(0.29167,6.9)
59	K22W (max d-ang @ t, dP)	-51.1@(4.99995,40.0)	7.9@(2.74998,-28.1)	8.9@(0.60833,-3.5)	-42.6@(4.99995,48.1)	16.4@(0.86666,-27.0)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.18333 sec / 0.18333 sec	281% / 466%	230% / 384%	187% / 319%	171% / 285%
63	G82R at Rugby/L20D at Drayton	999% / 731%	999% / 674%	999% / 678%	999% / 468%	999% / 730%
64	R50M / F3M	529% / 161%	745% / 263%	794% / 301%	699% / 216%	681% / 291%
65	B10T	220%	268%	219%	122%	201%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 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 | 2 | 2) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
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 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 2 | 2) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	M1b-so15aa-h33	M1b-so15aa-h43	M1b-so15aa-h83	M1b-so15aa-hmd	m1b-so15aa-o53
Disturbance	h33	h43	h83	hmd	o53
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(5T)(6T)				

Table B-1: Option 1 Study Case

	Case No.	16	17	18	19	20
	Case Name	M1b-so15aa-ho0	M1b-so15aa-h93	M1b-so15aa-hks	M1b-so15aa-o3s	M1b-so15aa-o4s
	Disturbance	ho0	h93	hks	o3s	o4s
	Prior Outage	None	None	None	None	None
	Date/Time	FEB 24 2010 17:35	FEB 24 2010 17:37	FEB 24 2010 17:39	FEB 24 2010 17:45	FEB 24 2010 17:46
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2363 / 195	2363 / 195	2363 / 195	2363 / 195	2363 / 195
	MHEX / L20D	1956 / 243	1956 / 243	1956 / 243	1956 / 243	1956 / 243
	ECL-ARP / PRI-BYN	810 / 28	810 / 28	810 / 28	810 / 28	810 / 28
	MWEX / AHD-SLK	1648 / 648	1648 / 648	1648 / 648	1648 / 648	1648 / 648
	D602F / F601C	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318
	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	135 / 150	135 / 150	135 / 150	135 / 150	135 / 150
	G82R	-53	-53	-53	-53	-53
	Dorsey bipole / CU bipole	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104
	Dorsey Reserve / Wtrtn SVC	581 / 12	581 / 12	581 / 12	581 / 12	581 / 12
	Forbes SVC / MSC	48 / 600	48 / 600	48 / 600	48 / 600	48 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045
	Roseau 500/Forbes 500	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035
	Chisago 500/EauClaire 345	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992
	Int Falls 115/Badoura 115	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034
	Drayton 230/Groton 345	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	292% / 486%	292% / 486%	292% / 486%	292% / 486%	292% / 486%
	G82R at Rugby/L20D at Drayton	999% / 866%	999% / 866%	999% / 866%	999% / 866%	999% / 866%
	R50M/F3M	999% / 323%	999% / 323%	999% / 323%	999% / 323%	999% / 323%
	B10T	343%	343%	343%	343%	343%
	Min/MaxTransientVltg					
	Arrowhd 230	1.00 | 1.05	0.97 | 1.01	1.00 | 1.02	1.00 | 1.01	1.00 | 1.02
	Boise 115	1.00 | 1.05	1.01 | 1.03	1.02 | 1.04	1.01 | 1.02	1.02 | 1.03
	Dorsey 230	1.04 | 1.18	1.03 | 1.05	1.03 | 1.10	1.03 | 1.06	1.03 | 1.07
	Forbes 230	1.02 | 1.07	1.02 | 1.04	1.03 | 1.07	1.03 | 1.04	1.03 | 1.05
	Riverton 230	1.03 | 1.05	1.00 | 1.03	1.03 | 1.05	1.02 | 1.03	1.03 | 1.04
	Coal Creek 230	1.01 | 1.06	1.00 | 1.07	1.00 | 1.08	1.01 | 1.04	1.01 | 1.06
	Jamestown 345	1.00 | 1.03	0.95 | 1.01	0.98 | 1.02	1.04 | 1.06	0.98 | 1.01
	Drayton 230	1.03 | 1.13	1.02 | 1.04	1.03 | 1.12	1.04 | 1.07	1.04 | 1.06
	Groton 345	1.01 | 1.04	1.00 | 1.03	1.01 | 1.04	1.00 | 1.01	1.02 | 1.03
	Minong 161	1.02 | 1.08	0.99 | 1.04	1.01 | 1.04	1.02 | 1.04	1.02 | 1.04
	Wahpeton 115	1.04 | 1.07	1.00 | 1.03	1.03 | 1.05	1.02 | 1.03	1.04 | 1.05
	Watertown 345	1.02 | 1.04	1.01 | 1.03	1.02 | 1.03	1.02 | 1.02	1.02 | 1.03
	Dynamic Voltage Warnings					
		none	none		none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.141	/ 0.141
	Forbes DC Red (DCAR)	506%	457%	432%	485%	460%
	K22W (max +dP @ t, d-ang)	89.4@(2.15833,-35.1)	23.3@(0.11667,0.6)	10.4@(2.15833,-1.5)	6.4@(0.11667,0.1)	7.7@(2.14166,-1.4)
	K22W (max -dP @ t, d-ang)	47.8@(0.40833,5.4)	36.8@(0.28333,5.1)	28.1@(0.38333,3.6)	21.8@(0.35000,2.6)	21.5@(0.35000,2.5)
	K22W (max d-ang @ t, dP)	-39.0@(4.99995,44.4)	8.9@(0.65000,-5.0)	3.9@(0.63333,1.2)	2.7@(0.33333,-17.1)	2.8@(0.60000,-0.2)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	211% / 357%	236% / 393%	242% / 401%	239% / 398%	252% / 419%
	G82R at Rugby/L20D at Drayton	999% / 655%	999% / 788%	999% / 672%	999% / 730%	999% / 731%
	R50M / F3M	788% / 219%	824% / 300%	870% / 308%	872% / 304%	900% / 310%
	B10T	170%	238%	252%	343%	274%
	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 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
	Prairie 115 / Ramsey 230	(1 | 3 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 5 | 1) / (0 | 1 | 1)	(1 | 4 | 3) / (0 | 1 | 1)	(1 | 8 | 2) / (0 | 1 | 1)
	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 | 3 | 2) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	M1b-so15aa-ho0	M1b-so15aa-h93	M1b-so15aa-hks	M1b-so15aa-o3s	M1b-so15aa-o4s
Disturbance	ho0	h93	hks	o3s	o4s
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					

Table B-1: Option 1 Study Case

	Case No.	21	22	23	24	25
	Case Name	M1b-so15aa-h53	M1b-so15aa-o13	m1b-so15aa-o6s	M1b-so15aa-h63	m1b-so15aa-he3
	Disturbance	h53	o13	o6s	h63	he3
	Prior Outage	None	None	None	None	None
	Date/Time	FEB 24 2010 17:24	FEB 24 2010 17:41	APR 07 2010 15:34	FEB 24 2010 17:26	APR 08 2010 11:37
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2363 / 195	2363 / 195	2363 / 195	2363 / 195	2363 / 195
	MHEX / L20D	1956 / 243	1956 / 243	1956 / 243	1956 / 243	1956 / 243
	ECL-ARP / PRI-BYN	810 / 28	810 / 28	810 / 28	810 / 28	810 / 28
	MWEX / AHD-SLK	1648 / 648	1648 / 648	1648 / 648	1648 / 648	1648 / 648
	D602F / F601C	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318
	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	135 / 150	135 / 150	135 / 150	135 / 150	135 / 150
	G82R	-53	-53	-53	-53	-53
	Dorsey bipole / CU bipole	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104
	Dorsey Reserve / Wtrtn SVC	581 / 12	581 / 12	581 / 12	581 / 12	581 / 12
	Forbes SVC / MSC	48 / 600	48 / 600	48 / 600	48 / 600	48 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045
	Roseau 500/Forbes 500	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035
	Chisago 500/EauClaire 345	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992
	Int Falls 115/Badoura 115	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034
	Drayton 230/Groton 345	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	292% / 486%	292% / 486%	292% / 486%	292% / 486%	292% / 486%
	G82R at Rugby/L20D at Drayton	999% / 866%	999% / 866%	999% / 866%	999% / 866%	999% / 866%
	R50M/F3M	999% / 323%	999% / 323%	999% / 323%	999% / 323%	999% / 323%
	B10T	343%	343%	343%	343%	343%
	Min/MaxTransientVltg					
	Arrowhd 230	0.93 | 1.01	0.96 | 1.03	0.97 | 1.01	0.95 | 1.03	0.95 | 1.03
	Boise 115	1.00 | 1.02	1.01 | 1.04	1.00 | 1.04	1.01 | 1.03	1.01 | 1.03
	Dorsey 230	1.03 | 1.05	1.03 | 1.05	1.03 | 1.09	1.03 | 1.05	1.03 | 1.05
	Forbes 230	0.99 | 1.03	1.03 | 1.04	1.01 | 1.05	1.02 | 1.04	1.02 | 1.04
	Riverton 230	0.98 | 1.02	1.01 | 1.04	1.00 | 1.03	1.00 | 1.04	1.00 | 1.04
	Coal Creek 230	1.00 | 1.06	1.01 | 1.07	1.00 | 1.05	1.00 | 1.06	1.00 | 1.06
	Jamestown 345	0.99 | 1.01	0.97 | 1.00	1.01 | 1.04	0.96 | 1.00	0.96 | 1.00
	Drayton 230	1.02 | 1.04	1.02 | 1.04	1.03 | 1.09	1.02 | 1.04	1.02 | 1.04
	Groton 345	0.97 | 1.01	1.01 | 1.03	0.99 | 1.01	1.00 | 1.04	1.00 | 1.03
	Minong 161	0.96 | 1.05	0.98 | 1.07	1.00 | 1.05	0.96 | 1.07	0.96 | 1.07
	Wahpeton 115	1.00 | 1.03	1.02 | 1.04	1.02 | 1.05	1.01 | 1.04	1.01 | 1.04
	Watertown 345	0.99 | 1.02	1.01 | 1.03	1.01 | 1.02	1.01 | 1.04	1.01 | 1.04
	Dynamic Voltage Warnings					
		none	none	none	none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold	/ 0.133	/ 0.133		/ 0.133	/ 0.133
	Forbes DC Red (DCAR)	376%	375%	491%	366%	365%
	K22W (max +dP @ t, d-ang)	6.4@(0.11667,1.2)	19.9@(3.20831,-4.3)	2.6@(0.10833,0.3)	25.2@(3.23331,-5.6)	23.5@(3.23331,-4.7)
	K22W (max -dP @ t, d-ang)	59.4@(1.32500,21.3)	35.7@(0.26667,5.0)	42.3@(1.50000,11.1)	39.6@(0.28333,6.0)	40.0@(0.28333,6.1)
	K22W (max d-ang @ t, dP)	24.3@(0.95000,-39.2)	14.3@(0.80833,-13.9)	16.4@(0.93333,-22.8)	18.0@(0.85000,-20.7)	18.6@(0.85833,-21.8)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	158% / 263%	239% / 397%	178% / 296%	220% / 366%	222% / 369%
	G82R at Rugby/L20D at Drayton	999% / 694%	999% / 762%	999% / 739%	999% / 749%	999% / 750%
	R50M / F3M	631% / 284%	818% / 290%	700% / 292%	769% / 280%	771% / 285%
	B10T	156%	206%	186%	187%	186%
	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 | 2 | 1) / (0 | 1 | 1)	(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	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	M1b-so15aa-h53	M1b-so15aa-o13	m1b-so15aa-o6s	M1b-so15aa-h63	
Disturbance	h53	o13	o6s	h63	
System Response	OK	OK	OK	OK	
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					

Table B-1: Option 1 Study Case

	Case No.	26	27	28	29	30
	Case Name	M1b-so15aa-hgs	M1b-so15aa-o2s	M1b-so15aa-mcs	m1b-so15aa-mes	m1b-so15aa-mfs
	Disturbance	hgs	o2s	mcs	mes	mfs
	Prior Outage	None	None	None	None	None
	Date/Time	FEB 24 2010 17:29	FEB 24 2010 17:43	MAR 17 2010 13:40	APR 08 2010 14:28	APR 08 2010 14:34
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2363 / 195	2363 / 195	2363 / 195	2363 / 195	2363 / 195
	MHEX / L20D	1956 / 243	1956 / 243	1956 / 243	1956 / 243	1956 / 243
	ECL-ARP / PRI-BYN	810 / 28	810 / 28	810 / 28	810 / 28	810 / 28
	MWEX / AHD-SLK	1648 / 648	1648 / 648	1648 / 648	1648 / 648	1648 / 648
	D602F / F601C	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318	1631 / 1318
	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	135 / 150	135 / 150	135 / 150	135 / 150	135 / 150
	G82R	-53	-53	-53	-53	-53
	Dorsey bipole / CU bipole	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104	3213 / 1104
	Dorsey Reserve / Wtrtn SVC	581 / 12	581 / 12	581 / 12	581 / 12	581 / 12
	Forbes SVC / MSC	48 / 600	48 / 600	48 / 600	48 / 600	48 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045	1.035 / 1.045
	Roseau 500/Forbes 500	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035	1.019 / 1.035
	Chisago 500/EauClaire 345	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992	1.028 / 0.992
	Int Falls 115/Badoura 115	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034	1.023 / 1.034
	Drayton 230/Groton 345	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023	1.033 / 1.023
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	292% / 486%	292% / 486%	292% / 486%	292% / 486%	292% / 486%
	G82R at Rugby/L20D at Drayton	999% / 866%	999% / 866%	999% / 866%	999% / 866%	999% / 866%
	R50M/F3M	999% / 323%	999% / 323%	999% / 323%	999% / 323%	999% / 323%
	B10T	343%	343%	343%	343%	343%
	Min/MaxTransientVltg					
	Arrowhd 230	0.97 | 1.03	0.99 | 1.02	0.94 | 1.03	0.95 | 1.03	0.97 | 1.05
	Boise 115	1.01 | 1.04	1.01 | 1.03	1.01 | 1.04	1.01 | 1.04	1.00 | 1.04
	Dorsey 230	1.03 | 1.08	1.04 | 1.06	1.03 | 1.05	1.03 | 1.07	1.03 | 1.06
	Forbes 230	1.02 | 1.05	1.03 | 1.05	1.02 | 1.04	1.02 | 1.05	1.02 | 1.04
	Riverton 230	1.02 | 1.04	1.03 | 1.04	0.99 | 1.05	1.00 | 1.05	1.00 | 1.04
	Coal Creek 230	1.01 | 1.07	1.00 | 1.06	0.95 | 1.08	1.00 | 1.08	1.00 | 1.07
	Jamestown 345	0.98 | 1.01	0.99 | 1.01	0.93 | 1.02	0.98 | 1.01	0.97 | 1.00
	Drayton 230	1.04 | 1.07	1.03 | 1.05	1.02 | 1.05	1.02 | 1.05	1.02 | 1.05
	Groton 345	1.01 | 1.04	1.02 | 1.03	0.98 | 1.04	1.01 | 1.03	1.00 | 1.03
	Minong 161	0.98 | 1.07	1.00 | 1.04	0.96 | 1.07	0.95 | 1.07	0.98 | 1.08
	Wahpeton 115	1.03 | 1.04	1.03 | 1.04	1.00 | 1.05	1.02 | 1.04	1.01 | 1.04
	Watertown 345	1.02 | 1.04	1.03 | 1.03	1.00 | 1.04	1.01 | 1.03	1.01 | 1.04
	Dynamic Voltage Warnings					
		none	none	none	none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold					
	Forbes DC Red (DCAR)	365%	419%	351%	305%	420%
	K22W (max +dP @ t, d-ang)	23.3@(3.26664,-6.0)	14.1@(2.25833,-2.5)	27.7@(3.28331,-6.7)	27.1@(3.31664,-6.3)	58.0@(2.31666,-20.1)
	K22W (max -dP @ t, d-ang)	40.3@(0.39166,6.7)	23.2@(0.35833,3.5)	34.5@(0.34167,5.6)	31.5@(0.37500,5.6)	29.7@(0.35833,4.9)
	K22W (max d-ang @ t, dP)	15.3@(0.85000,-14.3)	7.2@(0.77500,-4.7)	17.0@(0.88333,-17.9)	17.2@(0.90833,-16.6)	-23.0@(2.69165,42.8)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	223% / 371%	265% / 442%	226% / 375%	234% / 389%	229% / 380%
	G82R at Rugby/L20D at Drayton	999% / 764%	999% / 804%	999% / 748%	999% / 760%	999% / 743%
	R50M / F3M	782% / 278%	909% / 300%	798% / 281%	806% / 284%	810% / 240%
	B10T	189%	246%	164%	184%	171%
	FSCAPS (SS/Unav/Final)					
	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 1)	(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 | 3 | 3)	(4 | 4 | 4) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 3 | 3)
	Prairie 115 / Ramsey 230	(1 | 8 | 2) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 1 | 1)	(1 | 8 | 2) / (0 | 1 | 1)
	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 | 3 | 3) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	M1b-so15aa-hgs	M1b-so15aa-o2s	M1b-so15aa-mcs	m1b-so15aa-mes	m1b-so15aa-mfs
Disturbance	hgs	o2s	mcs	mes	mfs
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					

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Appendix

C

Condenser Reactive Power Analysis

Table C-1: Prior Outage of 160 MVAr Condenser

1	**Case No.**	1
2	**Case Name**	M1b-so15aa.drsy160-bjz
3	**Disturbance**	bjz
4	**Prior Outage**	None
5	**Date/Time**	MAR 08 2010 8:02
6	**Comments**	
7		
8	**Steady State Flows**	
9	NDEX / EAST BIAS	2362 / 195
10	MHEX / L20D	1956 / 243
11	ECL-ARP / PRI-BYN	810 / 28
12	MWEX / AHD-SLK	1648 / 648
13	D602F / F601C	1631 / 1318
14	B10T / MH>SPC	165 / 60
15	OH E-W / OH>MH	190 / -196
16	R50M / OH>MP	135 / 150
17	G82R	-53
18	Dorsey bipole / CU bipole	3213 / 1104
19	Dorsey Reserve / Wtrtn SVC	705 / 12
20	Forbes SVC / MSC	48 / 600
21	RCDC	0
22	**Steady State Vltgs**	
23	Dorsey 500/Dorsey 230	1.035 / 1.045
24	Roseau 500/Forbes 500	1.019 / 1.035
25	Chisago 500/EauClaire 345	1.028 / 0.992
26	Int Falls 115/Badoura 115	1.023 / 1.034
27	Drayton 230/Groton 345	1.033 / 1.023
28	**SS OS Relay Margins**	
29	D602F at Forbes/Dorsey	292% / 486%
30	G82R at Rugby/L20D at Drayton	999% / 866%
31	R50M/F3M	999% / 323%
32	B10T	343%
33	**Min/MaxTransientVltg**	
34	Arrowhd 230	1.00 | 1.02
35	Boise 115	1.01 | 1.03
36	Dorsey 230	1.01 | 1.04
37	Forbes 230	1.03 | 1.04
38	Riverton 230	1.02 | 1.03
39	Coal Creek 230	1.02 | 1.05
40	Jamestown 345	0.98 | 1.00
41	Drayton 230	1.02 | 1.04
42	Groton 345	1.02 | 1.03
43	Minong 161	1.02 | 1.05
44	Wahpeton 115	1.02 | 1.03
45	Watertown 345	1.02 | 1.03
46	**Dynamic Voltage Warnings**	
47		none
48		
49		
50		
51		
52		
53		
54	Worst Case Angle Damping	
55	Dorsey SUVP / UdHold	/ 0.133
56	Forbes DC Red (DCAR)	465%
57	K22W (max +dP @ t, d-ang)	78.0@(0.18333,-2.3)
58	K22W (max -dP @ t, d-ang)	17.4@(2.94998,3.8)
59	K22W (max d-ang @ t, dP)	-8.2@(0.62500,0.0)
60	**OS Rel Trip / Marg**	
61	MH - OH	
62	D602F at Forbes/Dorsey	275% / 460%
63	G82R at Rugby/L20D at Drayton	999% / 818%
64	R50M / F3M	922% / 281%
65	B10T	304%
66	**FSCAPS (SS/Unav/Final)**	
67	Balta 230	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A

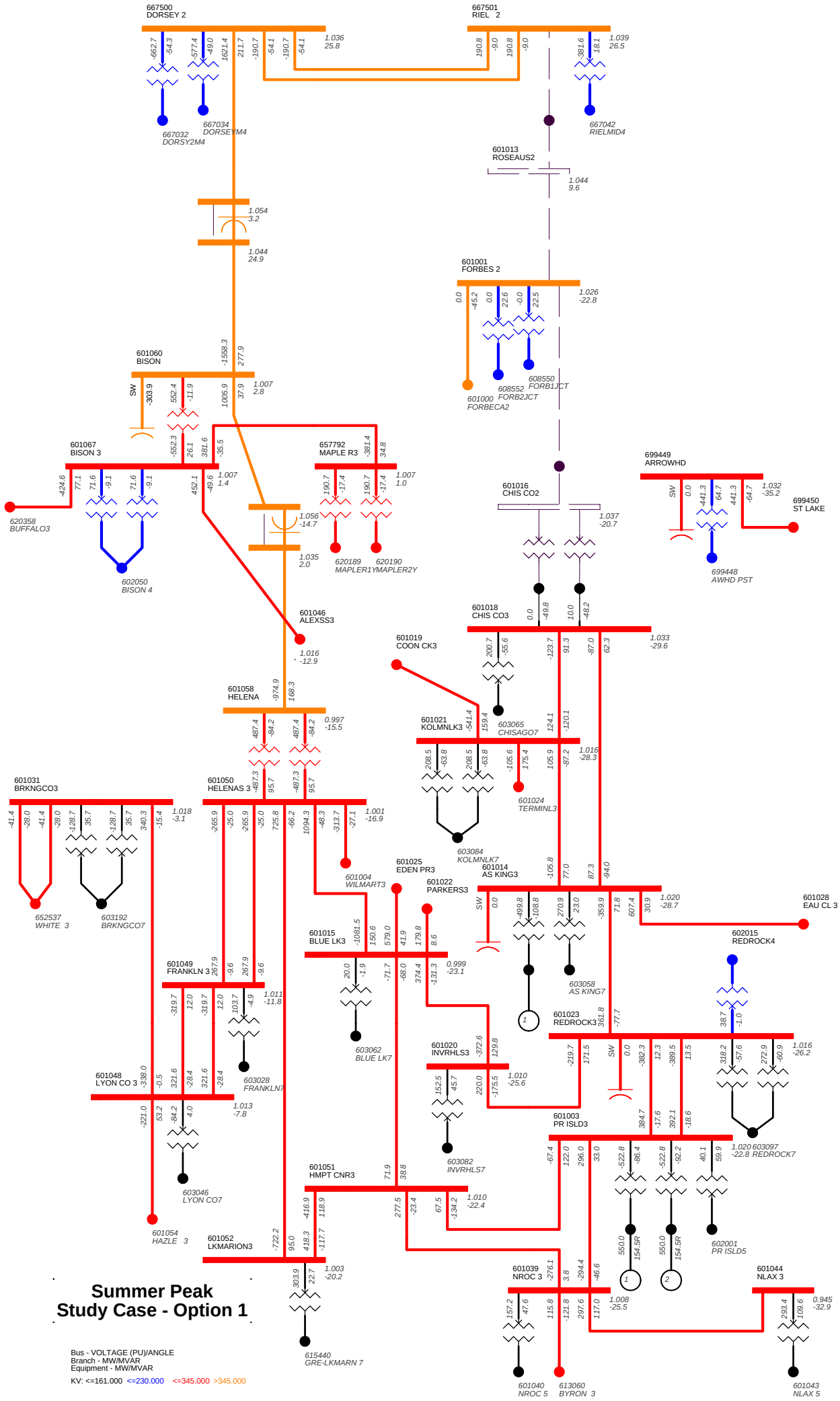
Case	M1b-so15aa.drsy160-bjz
Disturbance	bjz
System Response	OK
70% or 120% Violations	
ORWG Criteria Violations	
Line Tripping	

Appendix

D

Prior Outage Analysis Results

D.1 Case Diagrams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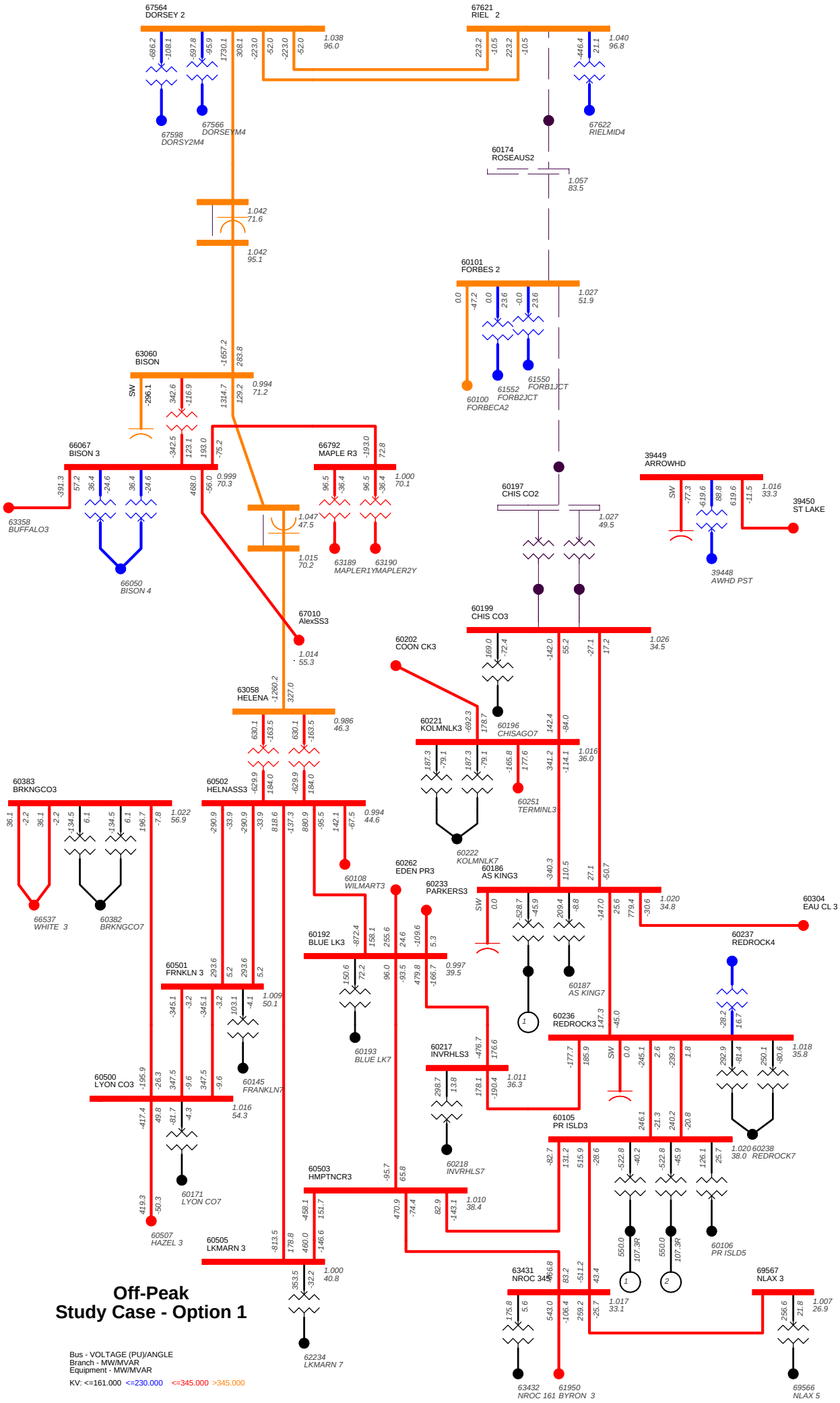
DORSEY 2
667501
RIEL 2
667032
DORSY2M4
667034
DORSEYM4
667042
RIELMID4
601013
ROSEAUS2
601001
FORBES 2
601000
FORBECA2
608552
FORB2JCT
608550
FORB1JCT
601060
BISON
601067
BISON 3
620358
BUFFALO3
602050
BISON 4
657792
MAPLE R3
620189
MAPLER1Y
620190
MAPLER2Y
601016
CHIS CO2
699449
ARROWHD
699450
ST LAKE
699448
AWHD PST
601018
CHIS CO3
601019
COON CK3
603065
CHISAGO7
601021
KOLMNLK3
601024
TERMINL3
603084
KOLMNLK7
601046
ALEXSS3
601058
HELENA
601031
BRKNGCO3
652537
WHITE 3
603192
BRKNGCO7
601050
HELENAS 3
601004
WILMART3
601025
EDEN PR3
601022
PARKERS3
601014
AS KING3
603058
AS KING7
601028
EAU CL 3
602015
REDROCK4
601015
BLUE LK3
603062
BLUE LK7
601049
FRANKLN 3
603028
FRANKLN7
601020
INVRHLS3
603082
INVRHLS7
601023
REDROCK3
601003
PR ISLD3
603097
REDROCK7
602001
PR ISLD5
601048
LYON CO 3
603046
LYON CO7
601054
HAZLE 3
601051
HMPT CNR3
601052
LKMARION3
615440
GRE-LKMARN 7
601039
NROC 3
601040
NROC 5
613060
BYRON 3
601044
NLAX 3
601043
NLAX 5
Summer Peak
Study Case - Option 1
Bus - VOLTAGE (PU)/ANGLE
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000


67564
DORSEY 2
67621
RIEL 2
1.038
96.0
1.040
96.8
67598
DORSY2M4
67566
DORSEYM4
67622
RIELMID4
60174
ROSEAUS2
1.057
83.5
1.042
71.6
1.042
95.1
60101
FORBES 2
1.027
51.9
60100
FORBECA2
61552
FORB2JCT
61550
FORB1JCT
63060
BISON
0.994
71.2
66067
BISON 3
66792
MAPLE R3
0.999
70.3
1.000
70.1
63358
BUFFALO3
66050
BISON 4
1.047
47.5
1.015
70.2
63189
MAPLER1Y
63190
MAPLER2Y
60197
CHIS CO2
1.027
49.5
39449
ARROWHD
1.016
33.3
39450
ST LAKE
39448
AWHD PST
67010
AlexSS3
1.014
55.3
60199
CHIS CO3
1.026
34.5
60202
COON CK3
60196
CHISAGO7
63058
HELENA
0.986
46.3
60221
KOLMNLK3
1.016
36.0
60251
TERMINL3
60222
KOLMNLK7
60383
BRKNGCO3
1.022
56.9
60502
HELNASS3
0.994
44.6
66537
WHITE 3
60382
BRKNGCO7
60108
WILMART3
60262
EDEN PR3
60186
AS KING3
60233
PARKERS3
1.020
34.8
60304
EAU CL 3
60187
AS KING7
60237
REDROCK4
60192
BLUE LK3
0.997
39.5
60193
BLUE LK7
60501
FRNKLN 3
1.009
50.1
60145
FRANKLN7
60236
REDROCK3
1.018
35.8
60217
INVRHLS3
1.011
36.3
60218
INVRHLS7
60500
LYON CO3
1.016
54.3
60171
LYON CO7
60105
PR ISLD3
1.020
38.0
60238
REDROCK7
60106
PR ISLD5
60503
HMPTNCR3
1.010
38.4
60507
HAZEL 3
60505
LKMARN 3
1.000
40.8
62234
LKMARN 7
63431
NROC 345
1.017
33.1
69567
NLAX 3
1.007
26.9
63432
NROC 161
61950
BYRON 3
69566
NLAX 5
Off-Peak
Study Case - Option 1
Bus - VOLTAGE (PU)/ANGLE
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000

D.2 Prior Outage - Thermal Screening

Table D-1: SUPK Thermal Violations, Significantly Affected Facilities
1855 MW Transfer Level, Riel-Forbes-Chisago Prior Outage

Monitored Element		Rate	Study Loading (MW)	Study Loading (%)	Contingency Detail
620222 ALEXAND7 115	658050 ALEXSS 7 115 1	E 160	168.5	105.3%	ALEXSS 7 115 - ALEXSWM7 115 1
620222 ALEXAND7 115	658050 ALEXSS 7 115 1	E 160	166.0	103.8%	ALEXSS3 345 - WAITEPK3 345 1
657751 CENTER 4 230	661042 HESKETT4 230 1	N (E) 428 (471)	442.3	103.3% (93.9%)	105 1 BISMARK4 230 - HILKEN 4 230 1 BISMARK4 230 - WASHBRN4 230 1 WASHBRN4 230 - LELANDO4 230 1
659120 BRDLAND3 345	659204 BRDLNDTY 345 1	N (E) 400 (480)	400.3	100.1% (83.4%)	FTTHOMP3 345 - LELANDO3 345 1
699240 SAR 138 138	699808 PETENWEL 138 1	E 72.2	91.3	126.5%	ATC-ZN1-2 AS KING3 345 - EAU CL 3 345 1 EAU CL 3 345 - ARP 345 345 1
699240 SAR 138 138	699808 PETENWEL 138 1	E 72.2	85.5	118.4%	ATC-ARP-0G2 EAU CL 3 345 - ARP 345 345 1 COC 69 69.0 - TIMBERWOLF 69.0 1 HLT 69 69.0 - MAUSTON 69.0 1 LUBLIN 69.0 - LAKEHEAD 69.0 1
699240 SAR 138 138	699808 PETENWEL 138 1	E 72.2	84.1	116.5%	ATC-ARP-0G1 AS KING3 345 - EAU CL 3 345 1 EAU CL 3 345 - ARP 345 345 1 COC 69 69.0 - TIMBERWOLF 69.0 1 HLT 69 69.0 - MAUSTON 69.0 1 LUBLIN 69.0 - LAKEHEAD 69.0 1

Table D-2: SUPK Thermal Violations, Significantly Affected Facilities
2175 MW Transfer Level, Riel-Forbes-Chisago Prior Outage

Monitored Element		Rate N/E	Rate MVA	Study Loading (MW)	Study Loading (%)	Contingency Detail
601015 BLUE LK3 345	601050 HELENAS 3 345 1	E	1511	1596.1	105.6%	HELENAS 3 345 - LKMARION3 345 1
601015 BLUE LK3 345	601050 HELENAS 3 345 1	E	1511	1587.7	105.1%	CAPX7 HELENAS 3 345 - LKMARION3 345 1 LKMARION3 345 - GRE-LKMARN 7115 1 LKMARION3 345 - HMPT CNR3 345 1
608737 NASHWAK7 115	608739 BLCKBRY7 115 1	E	158	159.0	100.6%	FORBES 4 230 - BLCKBRY4 230 1
620222 ALEXAND7 115	658050 ALEXSS 7 115 1	E	160	173.1	108.2%	ALEXSS3 345 - WAITEPK3 345 1
620222 ALEXAND7 115	658050 ALEXSS 7 115 1	E	160	168.3	105.2%	ALEXSS 7 115 - ALEXSWM7 115 1
657751 CENTER 4 230	661042 HESKETT4 230 1	N (E)	428 (471)	451.9	105.6% (95.9%)	105 1 BISMARK4 230 - HILKEN 4 230 1 BISMARK4 230 - WASHBRN4 230 1 WASHBRN4 230 - LELANDO4 230 1
659120 BRDLAND3 345	659204 BRDLNDTY 345 1	N (E)	400 (480)	411.7	102.9% (85.8%)	FTTHOMP3 345 - LELANDO3 345 1
699240 SAR 138 138	699808 PETENWEL 138 1	E	72.2	94.1	130.3%	ATC-ZN1-2 AS KING3 345 - EAU CL 3 345 1 EAU CL 3 345 - ARP 345 345 1
699240 SAR 138 138	699808 PETENWEL 138 1	E	72.2	88.1	122.0%	ATC-ARP-0G2 EAU CL 3 345 - ARP 345 345 1 COC 69 69.0 - TIMBERWOLF 69.0 1 HLT 69 69.0 - MAUSTON 69.0 1 LUBLIN 69.0 - LAKEHEAD 69.0 1
699240 SAR 138 138	699808 PETENWEL 138 1	E	72.2	86.8	120.2%	ATC-ARP-0G1 AS KING3 345 - EAU CL 3 345 1 EAU CL 3 345 - ARP 345 345 1 COC 69 69.0 - TIMBERWOLF 69.0 1 HLT 69 69.0 - MAUSTON 69.0 1 LUBLIN 69.0 - LAKEHEAD 69.0 1

D.3 Prior Outage - Stability

D.3.1 Benchmark Off Peak Case

```
                    P O W E R   F L O W   S U M M A R Y
-------------------------------------------------------------------------------
               NDEX:      2238 MW         ECL-ARP:  660 MW
               MHEX:      2178 MW         PRI-BYN:  614 MW
               MWEX:      1506 MW         AHD-SLK:  656 MW
               KING-ECL:   849 MW         SLK-GPK:  464 MW
               COOPER S:  1104 MW         WNE-WKS:  539 MW
               FTCAL S:    648 MW         GGS:     1611 MW
               GRIS-LNC:   663 MW         QC WEST:  148 MW
               BISON-ALEX: 332 MW         WIL-BOWS:-101 MW
               NROC-NLAX:  247 MW

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

Load/Losses   MW  / MW       Generation        MW       Export            MW
----------- ------ -----     --------------- ------     --------------- ------
Manitoba      2348/ 221       MH total gross    4941     ATC West Import   1404
Ont. total   22150/ 478          Wpg River       568     ATC SW Import      613
     NW        915/  37          7 Sisters       170     ATC SE Import    -1630
Sask.         2150/  82       OH total gross   21884     East Bias          148
MP            2341/ 145          northwest       717     SPC>WAPA (B10T)    166
NSP           8075/ 480       SPC total gross   2406     MH>SPC  (3-230)     62
N. Dakota     2904/ 281       MP total gross    2859     MH>SPC  (FALLS)      0
Manitoba       481 MVARS      ND Cfd AC gross   3149     OH>MH  @Kenora    -195
Ont. total   13082 MVARS                net      2978     OH>MP  @Ft Fran    151
     NW        489 MVARS       NSP East gross    1942     OH E>W @Wawa       191
Sask.          502 MVARS                net      1810     OH>East USA          0
MP             669 MVARS            West gross    3057     F601C  @Forbes    1517
NSP           1714 MVARS                 net      2895     D602F  @Riel      1777
N. Dakota      756 MVARS            Total net     6167     L20D   @Letell     287
ATC           10812/ 318       WAPA SD Hydro     1497     R50M   @Richer     138
ATC            3159 MVARS      Pleasant Valley    110     G82R   @Glenboro   -25
                               LGS/Trimont        109
                               SW MN Wind        1008
                               N DAK WIND         252
                               Swing Bus          754


Tfmrs          MVA/ Load     Ph Shifters  Deg/  MW      DC Lines          MW
------------- ---- -----     ------------ --- -----     --------------- ------
Wshell #1 7-7  105/  73%     Stinson       27/   27     CU (1,2)          1104
Wshell #2 7-7  105/  73%     Boundary Dam   3/  167     SQ BU (3,4)        455
Drayton#1 4-7   49/  35%     Whiteshell    98/  199     MH Bipole 1        992
Drayton#2 4-7   63/  33%     Int Falls    121/  150     MH Bipole 2       1121
Dorsey #1 2-4  521/  43%     St. Lawrence  16/    0     MH (BP1+BP2)      2114
Dorsey #2 2-4  598/  49%     Arrowhead      0/  656     Miles City E>W    -150
Forbes    2-4   79/  11%                               RCDC (15)            0
Stone Lk  3-5  179/  53%                               Stegall (10)         0

Dorsey SC's       I/S  MVAR  Qmax/ Qmin    SVC's              MVAR  Qmax/ Qmin
----------------- --- -----  ---- -----    ----------------- -----  ---- -----
MIL 7-9G     17.0  2     64   600/ -330    Forbes        500    17   400/ -450
SCE 1-3G     18.2  3     52   480/ -240    Fargo        13.2     4    20/ -135
SCA 4-6G     18.2  3     52   480/ -240    Watertown    20.0    15   125/  -86
                          -----  ---- -----
       Total            168  1560/ -810    Series Caps       Num In Serv
       Margin          1392                ----------------- -----------
                                           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	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	1.009	Arrowhead 230	1.000	Whiteshell 110	118.9
Alexandria 115	1.037	Badoura 115	1.037	Kenora 220	246.6
Audubon 115	1.047	Blackberry 230	1.035	Dryden 220	250.8
Bemidji 115	1.032	Boise Cascade 13.8	1.051	Fort Frances 220	244.5
Byron 345	1.019	Boise Cascade 115	1.020	Mackenzie 220	253.7
Chisago Co. 345	1.020	ETCO 115	1.007	Lakehead 220	246.2
Chisago Co. 500	1.017	Forbes 230	1.022	Marathon 220	253.0
Drayton 230	1.026	Forbes 500	1.018	Wawa 220	254.8
Eau Claire 345	1.026	Hubbard 115	1.031	Mississagi 220	250.7
WEST FARIBAULT 115	1.030	Intl Falls 115	1.020	Fort Frances 118	118.8
LaPorte 115	1.027	Minntac 115	1.015	Lakehead 118	122.8
Maple River 230	1.028	Moranville 230	1.027	Birch 118	120.2
Marshall Tap 115	1.021	Riverton 230	1.029	Marathon 118	123.3
Owatonna 161	1.005	Running 230	1.028		0.000
Prairie 115	1.033	Shannon 230	1.029	Arrowhead 345	1.001
Prairie 230	1.027	Stinson MN 115	1.011	Stone Lake 345	1.000
Ramsey 230	1.004	Jamestown 345	1.004	Stone Lake 161	1.009
Roseau County 230	1.026	Groton 345	1.021	Gardner Park 345	1.035
Roseau County 500	1.061	Watertown 230	1.030	Weston 115	1.035
Sheyenne 230	1.030	Watertown 345	1.028	Arpin 345	1.020
Thief R Falls 115	1.030		0.000	Eau Claire 161	1.034
Tioga 230	1.033	Dorsey 230	1.045	Council Creek 161	0.972
Wahpeton 230	1.022	Dorsey 500	1.043	Hydro Lane 161	1.009
Winger 115	1.049		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	336%	N/A	N/A
2) -Tioga (North)	GE OST	SLLP	690%	N/A	N/A
3) -Tioga (Em North)	GE OST	SLLP		N/A	N/A
4) D602F-RIEL	ATP ???	SLINOS	413%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	246%	N/A	N/A
6) -Forbes (Em Nrth)	APT S-PRO	SLINOS		N/A	N/A
8) F3M-Intl Falls	APT S-PRO	SLINOS	319%	N/A	N/A
9) G82R-Rugby	APT	SLINOS	-54%	N/A	N/A
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	686%	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

D.3.2 Study Off Peak Case with Riel-Forbes-Chisago Prior Outage

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

NDEX:	2348 MW	ECL-ARP:	620 MW
MHEX:	451 MW	PRI-BYN:	543 MW
MWEX:	1400 MW	AHD-SLK:	620 MW
KING-ECL:	779 MW	SLK-GPK:	432 MW
COOPER S:	1025 MW	WNE-WKS:	523 MW
FTCAL S:	608 MW	GGS:	1607 MW
GRIS-LNC:	663 MW	QC WEST:	122 MW
BISON-ALEX:	468 MW	WIL-BOWS:	-16 MW
NROC-NLAX:	259 MW	DRSY-BISN:	1730 MW
BISN-BRCO:	1314 MW	New MHEX:	2181 MW

LOAD LEVELS AS PERCENT OF 2015 SUMMER PEAK:

NORTH DAKOTA	(ZONE 90,990)	2904.1 MW,	78.3% OF	3710.2 MW
NSP	(AREA 600)	8075.1 MW,	67.9% OF	11889.2 MW
MAN HYDRO	(AREA 667)	2348.2 MW,	76.3% OF	3076.0 MW

Load/Losses	MW / MW	Generation	MW	Export	MW
Manitoba	2348/ 219	MH total gross	4941	ATC West Import	1336
Ont. total	22150/ 478	Wpg River	568	ATC SW Import	735
NW	915/ 36	7 Sisters	170	ATC SE Import	-1327
Sask.	2150/ 82	OH total gross	21884	East Bias	260
MP	2341/ 152	northwest	717	SPC>WAPA (B10T)	165
NSP	8075/ 403	SPC total gross	2406	MH>SPC (3-230)	60
N. Dakota	2904/ 291	MP total gross	2693	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	1942	OH E>W @Wawa	189
Sask.	502 MVARS	net	1810	OH>East USA	0
MP	669 MVARS	West gross	3057	F601C @Forbes	0
NSP	1714 MVARS	net	2895	D602F @Riel	0
N. Dakota	756 MVARS	Total net	6133	L20D @Letell	293
ATC	10812/ 297	WAPA SD Hydro	1497	R50M @Richer	185
ATC	3159 MVARS	Pleasant Valley	67	G82R @Glenboro	-27
		LGS/Trimont	19		
		SW MN Wind	1008		
		N DAK WIND	252		
		Swing Bus	918		

Tfmrs	MVA/ Load	Ph Shifters	Deg/ MW	DC Lines	MW
Wshell #1 7-7	103/ 72%	Stinson	24/ 30	CU (1,2)	1103
Wshell #2 7-7	103/ 72%	Boundary Dam	4/ 165	SQ BU (3,4)	455
Drayton#1 4-7	50/ 35%	Whiteshell	92/ 199	MH Bipole 1	992
Drayton#2 4-7	63/ 34%	Int Falls	105/ 149	MH Bipole 2	1121
Dorsey #1 2-4	614/ 51%	St. Lawrence	16/ 0	MH (BP1+BP2)	2114
Dorsey #2 2-4	705/ 58%	Arrowhead	0/ 620	Miles City E>W	-149
Forbes 2-4	23/ 3%			RCDC (15)	0
Stone Lk 3-5	175/ 52%			Stegall (10)	0

Dorsey SC's		I/S	MVAR	Qmax/ Qmin
MIL 7-9G	17.0	2	162	600/ -330
SCE 1-3G	18.2	3	132	480/ -240
SCA 4-6G	18.2	3	132	480/ -240
Total			428	1560/ -810
Margin			1132	

SVC's	MVAR	Qmax/ Qmin
Forbes	500	47 400/ -450
Fargo	13.2	-13 20/ -135
Watertown	20.0	36 125/ -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	0
Eau Claire(FS) 161	356	Riverton 230	47	Forbes 500	0
Kohlman Lake 115	240	Roseau Co.(FS) 230	30		0
Parkers Lk(FS) 115	0	Running (FS) 230	30	Fargo 115	81
Prairie (FS) 115	40	Running react 230	0	Watertown 20	20
Ramsey (FS) 230	30	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	1.012	Arrowhead 230	1.008	Whiteshell 110	118.9
Alexandria 115	1.020	Badoura 115	1.026	Kenora 220	246.9
Audubon 115	1.031	Blackberry 230	1.035	Dryden 220	250.4
Bemidji 115	1.018	Boise Cascade 13.8	1.057	Fort Frances 220	244.0
Byron 345	1.019	Boise Cascade 115	1.025	Mackenzie 220	253.3
Chisago Co. 345	1.026	ETCO 115	1.009	Lakehead 220	246.1
Chisago Co. 500	1.027	Forbes 230	1.023	Marathon 220	252.8
Drayton 230	1.018	Forbes 500	1.027	Wawa 220	254.7
Eau Claire 345	1.034	Hubbard 115	1.020	Mississagi 220	250.6
WEST FARIBAULT 115	1.021	Intl Falls 115	1.025	Fort Frances 118	120.3
LaPorte 115	1.014	Minntac 115	1.017	Lakehead 118	122.8
Maple River 230	1.007	Moranville 230	1.034	Birch 118	120.2
Marshall Tap 115	1.017	Riverton 230	1.024	Marathon 118	124.8
Owatonna 161	0.999	Running 230	1.025		0.000
Prairie 115	1.021	Shannon 230	1.027	Arrowhead 345	1.016
Prairie 230	1.015	Stinson MN 115	1.019	Stone Lake 345	1.014
Ramsey 230	1.021	Jamestown 345	0.988	Stone Lake 161	1.021
Roseau County 230	1.035	Groton 345	1.019	Gardner Park 345	1.035
Roseau County 500	1.057	Watertown 230	1.030	Weston 115	1.035
Sheyenne 230	1.016	Watertown 345	1.027	Arpin 345	1.027
Thief R Falls 115	1.014		0.000	Eau Claire 161	1.038
Tioga 230	1.033	Dorsey 230	1.045	Council Creek 161	0.977
Wahpeton 230	1.009	Dorsey 500	1.038	Hydro Lane 161	1.013
Winger 115	1.032		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	341%	N/A	N/A
2) -Tioga (North)	GE OST	SLLP	700%	N/A	N/A
3) -Tioga (Em North)	GE OST	SLLP		N/A	N/A
4) D602F-RIEL	ATP ???	SLINOS	999999%	N/A	N/A
5) -Forbes (Normal)	ATP ???	SLINOS	999999%	N/A	N/A
6) -Forbes (Em Nrth)	APT S-PRO	SLINOS		N/A	N/A
8) F3M-Intl Falls	APT S-PRO	SLINOS	331%	N/A	N/A
9) G82R-Rugby	APT	SLINOS	47%	N/A	N/A
10) L20D-Drayton (Normal)	APT, ASEA	SLINOS	654%	N/A	N/A
11) -Drayton (Em Nrth)	ASEA RXZF2	SLINOS		N/A	N/A
12) R50M-Moranville (Norm)	APT, West	SLINOS	664%	N/A	N/A
13) -Moranville (Em N)	ASEA RXZF2	SLINOS		N/A	N/A

D.3.3 Fast Switched Cap Summary

Table D-3: Fast Switched Capacitor Summary for Benchmark and Prior Outage Study Cases [1]

Notes
1. Top row is benchmark case summary; bottom row is prior outage study case summary
2. Explanation of summary
   - First number: number of capacitors on in the power flow case (SS)
   - Second number: maximum number of capacitors on during the simulation
   - Third number: capacitors on at the end of the simulation (FINAL).

Disturbance		Prarie	Running	Sheyenne	Roseau	Ramsey	Parkers Lake	Eau Claire	Split Rock	Balta
ag1	4 cycle SLG fault at Leland Olds 345 kV on Leland Olds-Ft Thompson line; breaker 2692 fails; clear at 11 cycles by tripping faulted line	(1|2|1) (1|2|2)	(1|1|1) (1|1|1)	(1|2|2) (1|2|2)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
ag3	4 cycle 3PH fault at Leland Olds 345 kV, trip Leland Olds-Ft Thompson line	(1|1|1) (1|2|2)	(1|1|1) (1|1|1)	(1|3|2) (1|3|3)	(0|0|0) (1|1|1)	(0|2|2) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|2|2) (1|2|2)	(0|0|0) (0|0|0)
cts	4 cycle SLG fault at Chisago 345 kV on TR10, breaker 9P20 fails, clear at 16 cycles by tripping Chisago-Forbes; cross-trip Forbes-Riel and trigger HVDC reduction	(1|7|1) Not Run	(1|3|1) Not Run	(1|5|2) Not Run	(0|1|0) Not Run	(0|2|2) Not Run	(0|0|0) Not Run	(4|4|2) Not Run	(1|2|2) Not Run	(0|2|0) Not Run
ei2	CU DC permanent bipole fault with tripping of both Coal Creek units	(1|3|1) (1|4|2)	(1|1|1) (1|1|1)	(1|4|3) (1|5|4)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|0|0) (0|0|0)	(4|4|3) (4|4|3)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
em3	5 cycle 3PH fault at Letellier 230, clear by tripping Letellier-Drayton line; trigger HVDC reduction	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
eq1	SLG fault with breaker failure at Coal Creek on CU DC pole 1 with cross-trip of Coal Creek unit #2	(1|3|1) (1|3|2)	(1|1|1) (1|1|1)	(1|4|2) (1|5|4)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|3)	(1|1|1) (1|1|1)	(0|1|0) (0|1|0)
fds	5 cycle 3PH fault at Square Butte 230 kV, clear by tripping Square Butte-Stanton line	(1|2|1) (1|3|2)	(1|1|1) (1|1|1)	(1|4|2) (1|3|3)	(0|0|0) (1|1|1)	(0|2|2) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
h13	5 cycle 3PH fault at Dorsey, trip Dorsey-Riel 500 kV line #1	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
h23	5 cycle 3PH fault at Dorsey, trip Dorsey 500/230 kV transformer #1; trigger HVDC reduction	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|3) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
h33	5 cycle 3PH fault at Riel, trip Riel-Forbes 500 kV line; trigger HVDC reduction	(1|3|2) Not Run	(1|3|2) Not Run	(1|3|3) Not Run	(0|2|1) Not Run	(0|1|1) Not Run	(0|0|0) Not Run	(4|4|2) Not Run	(1|1|1) Not Run	(0|0|0) Not Run
h43	5 cycle 3PH fault at Riel, trip Riel 500/230 kV transformer	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
h53	5 cycle 3PH fault at Helena 500 kV, trip the Helena-Bison 500 kV line	Not Run (1|2|2)	Not Run (1|4|3)	Not Run (1|5|5)	Not Run (1|2|2)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|4)	Not Run (1|2|2)	Not Run (0|0|0)
h63	5 cycle 3PH fault at Helena 345 kV, trip the Helena-Blue Lake 345 kV line	(1|1|1) (1|1|1)	(1|1|1) (1|2|2)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|2|2) (1|2|2)	(0|0|0) (0|0|0)
h7d	5 cycle 3PH fault at Dorsey 500 kV, trip the Dorsey-Bison 500 kV line; trigger HVDC reduction	Not Run (1|2|2)	Not Run (1|2|2)	Not Run (1|1|1)	Not Run (1|1|0)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|3)	Not Run (1|1|1)	Not Run (0|0|0)
h83	5 cycle 3PH fault at Bison 500 kV, trip the Bison 500/345 kV transformer	Not Run (1|2|2)	Not Run (1|1|1)	Not Run (1|1|1)	Not Run (1|1|1)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|4)	Not Run (1|2|2)	Not Run (0|0|0)
h93	5 cycle 3PH fault at Bison 345 kV, trip Bison-Alexandria SS 345 kV line	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|4|4)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|2|2)	(0|0|0) (0|0|0)
he0	5 cycle SLG fault at Dorsey 500 kV on Dorsey-Bison line, Dorsey breaker fails, clear at 16 cycles by tripping Dorsey 500-230 kV xfmr, line outage triggers HVDC reduction; block SUVC	Not Run (1|5|2)	Not Run (1|2|2)	Not Run (1|1|0)	Not Run (1|1|0)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|3)	Not Run (1|1|1)	Not Run (0|0|0)

Table D-3: Fast Switched Capacitor Summary for Benchmark and Prior Outage Study Cases [1]

Notes
1. Top row is benchmark case summary; bottom row is prior outage study case summary
2. Explanation of summary
   - First number: number of capacitors on in the power flow case (SS)
   - Second number: maximum number of capacitors on during the simulation
   - Third number: capacitors on at the end of the simulation (FINAL).

Disturbance		Prarie	Running	Sheyenne	Roseau	Ramsey	Parkers Lake	Eau Claire	Split Rock	Balta
he3	5 cycle 3PH fault at Helena 345 kV, trip the Helena-Lake Marion 345 kV line	(1|1|1) (1|1|1)	(1|1|1) (1|2|2)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|2|2) (1|2|2)	(0|0|0) (0|0|0)
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	Not Run (1|3|3)	Not Run (1|2|2)	Not Run (1|3|3)	Not Run (1|1|1)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|4)	Not Run (1|2|2)	Not Run (0|0|0)
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	(1|1|1) (1|3|3)	(1|1|1) (1|2|2)	(1|3|3) (1|3|3)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|2|2) (1|2|2)	(0|0|0) (0|0|0)
hks	5 cycle SLG fault at Bison 345 on Alexandria SS line, Bison breaker fails, clear at 16 cycles by tripping Bison 345-230 kV xfmr	(1|5|1) (1|5|3)	(1|1|1) (1|1|1)	(1|2|2) (1|3|3)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|1|0) (0|0|0)
hl0	5 cycle SLG fault at Dorsey 500 kV on Dorsey-Bison line, Dorsey breaker fails, clear at 16 cycles by tripping Dorsey-Riel 500 kV line #2; line outage triggers HVDC reduction; block SUVC	Not Run (1|5|2)	Not Run (1|2|2)	Not Run (1|1|0)	Not Run (1|1|0)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|3)	Not Run (1|1|1)	Not Run (0|0|0)
hmd	5 cycle 3PH fault at Bison 500 kV, trip the Dorsey-Bison line; trigger HVDC reduction	Not Run (1|5|2)	Not Run (1|3|2)	Not Run (1|1|0)	Not Run (1|1|0)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|2)	Not Run (1|2|2)	Not Run (0|0|0)
ho0	5 cycle SLG fault at Bison 500 kV on 500-345 kV xfmr, 500 kV breaker fails, clear at 16 cycles by tripping Dorsey-Bison; line outage triggers HVDC reduction	Not Run (1|4|1)	Not Run (1|3|2)	Not Run (1|3|0)	Not Run (1|1|0)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|3)	Not Run (1|1|1)	Not Run (0|0|0)
mc3	5 cycle 3PH fault at Richer 230 kV, clear by tripping Richer-Roseau line; trigger HVDC reduction	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(0|0|0) (1|1|0)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
mcs	4.5 cycle SLG fault at Sherburne Co. 345 kV on Coon Creek line with 8M40 stuck, clear at 12 cycles by tripping Bunker Lake and Bunker Lake TR1	(1|1|1) (1|2|2)	(1|1|1) (1|1|1)	(1|3|3) (1|3|3)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|3|3) (0|3|3)	(4|4|4) (4|4|4)	(1|2|2) (1|2|2)	(0|0|0) (0|0|0)
md3	5 cycle 3PH fault at Glenboro 230 kV, clear by tripping Glenboro-Rugby line	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
mes	4 cycle SLG fault at Monticello 345 kV on Waite Park line with 8N8 stuck, clear at 14 cycles by tripping Elm Creek line	(1|1|1) (1|2|2)	(1|1|1) (1|1|1)	(1|3|3) (1|3|3)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|3|3) (0|3|3)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
mfs	4 cycle SLG fault at Monticello 345 kV on Sherburne Co. line with 8N8 stuck; clear at 14 cycles by tripping Monticello Generator	(1|2|2) (1|2|2)	(1|1|1) (1|2|2)	(1|3|3) (1|3|3)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|3|3) (0|3|3)	(4|4|4) (4|4|3)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
mis	Bipole 2 block in the Manitoba Hydro System, Cross trip Manitoba Ontario Ties @ t=0.35s; trigger HVDC reduction	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
miz	Bipole 2 block in the Manitoba Hydro System.	Not Run (1|1|1)	Not Run (1|1|1)	Not Run (1|1|1)	Not Run (1|1|0)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|3)	Not Run (1|1|1)	Not Run (0|0|0)

Table D-3: Fast Switched Capacitor Summary for Benchmark and Prior Outage Study Cases [1]

Notes
1. Top row is benchmark case summary; bottom row is prior outage study case summary
2. Explanation of summary
   - First number: number of capacitors on in the power flow case (SS)
   - Second number: maximum number of capacitors on during the simulation
   - Third number: capacitors on at the end of the simulation (FINAL).

Disturbance		Prarie	Running	Sheyenne	Roseau	Ramsey	Parkers Lake	Eau Claire	Split Rock	Balta
mjs	4 cycle SLG fault at Chisago 345 kV on Chisago-Kohlman Lake line, breaker fails at Chisago, clear by tripping Chisago 500-345 kV xfmr	(1|1|1) Not Run	(1|1|1) Not Run	(1|2|2) Not Run	(0|0|0) Not Run	(0|1|1) Not Run	(0|0|0) Not Run	(4|4|4) Not Run	(1|1|1) Not Run	(0|0|0) Not Run
mkd	4 cycle 3 phase fault at Chisago 345 kV, clear the Chisago-King line	(1|2|2) (1|1|1)	(1|1|1) (1|1|1)	(1|3|3) (1|1|1)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|2|2) (1|1|1)	(0|0|0) (0|0|0)
mks	4.5 cycle SLG fault at Chisago 345 kV on Chisago-King line, King breaker fails, clear at 15 cycles by tripping Chisago 500-345 kV xfmr	(1|3|2) Not Run	(1|1|1) Not Run	(1|3|3) Not Run	(0|0|0) Not Run	(0|1|1) Not Run	(0|0|0) Not Run	(4|4|4) Not Run	(1|1|1) Not Run	(0|0|0) Not Run
mts	4 cycle SLG fault at Monticello 345 kV on Elm Creek line, breaker 8N6 fails, clear by tripping Monticello 345-115 kV xfmr, Monticello 345-230 kV xfmr, Monticello-Benton Co 230 kV line and Monticello-Elk River 230 kV line	(1|2|1) (1|2|2)	(1|1|1) (1|1|1)	(1|3|2) (1|3|3)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|3|3) (0|3|3)	(4|4|4) (4|4|4)	(1|1|1) (1|2|2)	(0|0|0) (0|0|0)
nad	4 cycle 3PH fault at Forbes 500 kV on M602F; trigger HVDC reduction	(1|3|2) Not Run	(1|5|3) Not Run	(1|3|3) Not Run	(0|2|0) Not Run	(0|1|1) Not Run	(0|0|0) Not Run	(4|4|3) Not Run	(1|1|1) Not Run	(0|0|0) Not Run
nmz	4 cycle 3PH fault at Chisago 500 kV on F601C, xtrip M602F, 100% reduction, leave SVC on MP system	(1|4|1) Not Run	(1|3|2) Not Run	(1|5|3) Not Run	(0|1|0) Not Run	(0|1|1) Not Run	(0|0|0) Not Run	(4|4|2) Not Run	(1|2|2) Not Run	(0|1|0) Not Run
o13	5 cycle 3PH fault at Helena 500 kV, trip Helena 500-345 kV xfmr	Not Run (1|1|1)	Not Run (1|1|1)	Not Run (1|1|1)	Not Run (1|1|1)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|4)	Not Run (1|2|2)	Not Run (0|0|0)
o2s	5 cycle SLG fault at Helena 345 kV on Lake Marion line, Helena breaker fails, clear at 16 cycles by tripping Helena-Franklin	(1|1|1) (1|2|2)	(1|1|1) (1|1|1)	(1|1|1) (1|3|3)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|2|2) (1|2|2)	(0|0|0) (0|0|0)
o3s	5 cycle SLG fault at Bison 345 kV on Alexandria line, Bison breaker fails, clear at 16 cycles by tripping Bison-Jamestown	(1|5|3) (1|4|4)	(1|1|1) (1|1|1)	(1|3|2) (1|3|3)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
o4s	5 cycle SLG fault at Bison 345 kV on Maple River line, Bison breaker fails, clear at 16 cycles by tripping Bison 345-230 kV xfmr	(1|4|1) (1|4|3)	(1|1|1) (1|1|1)	(1|3|2) (1|3|3)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
o53	5 cycle 3PH fault at Bison 500 kV, trip the Bison-Helena line	Not Run (1|2|2)	Not Run (1|3|3)	Not Run (1|5|5)	Not Run (1|2|2)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|4)	Not Run (1|2|2)	Not Run (0|0|0)
o6s	5 cycle SLG fault at Helena 500 kV on 500-345 kV xfmr, 500 kV breaker fails, clear at 16 cycles by tripping Helena-Bison	Not Run (1|2|2)	Not Run (1|3|3)	Not Run (1|5|5)	Not Run (1|2|2)	Not Run (1|1|1)	Not Run (0|0|0)	Not Run (4|4|4)	Not Run (1|2|2)	Not Run (0|0|0)
pas	5 cycle SLG fault at Forbes 500 kV on M602F, Forbes breaker fails, Forbes breakers operate at 16 cycles, clear at 17 cycles; trigger HVDC reduction	(1|2|2) Not Run	(1|3|2) Not Run	(1|3|3) Not Run	(0|0|0) Not Run	(0|1|1) Not Run	(0|0|0) Not Run	(4|4|2) Not Run	(1|1|1) Not Run	(0|0|0) Not Run
pc0	4.5 cycle SLG fault at King 345 kV on King-Eau Claire line, King breaker fails, clear at 16 cycles by tripping King-Chisago	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|2|2) (1|2|2)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|3|3) (0|3|3)	(4|4|3) (4|4|3)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)

Table D-3: Fast Switched Capacitor Summary for Benchmark and Prior Outage Study Cases [1]

Notes
1. Top row is benchmark case summary; bottom row is prior outage study case summary
2. Explanation of summary
   - First number: number of capacitors on in the power flow case (SS)
   - Second number: maximum number of capacitors on during the simulation
   - Third number: capacitors on at the end of the simulation (FINAL).

Disturbance		Prarie	Running	Sheyenne	Roseau	Ramsey	Parkers Lake	Eau Claire	Split Rock	Balta
pcs	4.5 cycle SLG fault at King 345 kV on King-Eau Claire line, King breaker fails, clear at 16 cycles by tripping King-Chisago, cross trip Eau Claire-Arpin	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|2|2) (1|2|2)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|3|3) (0|3|3)	(4|4|3) (4|4|3)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
pct	Trip of King-Eau Claire-Arpin without a fault	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|3) (4|4|3)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
pzs	4.5 cycle SLG fault Prairie Island 345 kV on Prairie Island-N Rochester, 8H9 fails, clear at 16 cycles by tripping Prairie Island xfmr #10	(1|1|1) (1|2|2)	(1|1|1) (1|1|1)	(1|2|2) (1|3|3)	(0|0|0) (1|1|1)	(0|1|1) (1|1|1)	(0|3|3) (0|3|3)	(4|4|4) (4|4|4)	(1|2|2) (1|2|2)	(0|0|0) (0|0|0)
pzt	Trip of Prairie Island-N Rochester without a fault	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
ya3	4 cycle 3 phase fault at Arrowhead 230 kV, clear the Arrowhead-Gardner park 345 kV line	(1|1|1) (1|1|1)	(1|1|1) (1|1|0)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
yas	4 cycle SLG fault at Arrowhead 345 on AHD-GDP ckt #1, AHD brkr stk, clear at 17 cycles by tripping AHD-GDP bus section	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)
yb3	4 cycle 3PH fault at Arrowhead 345 kV, trip the Arrowhead-Stone Lake line	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(1|1|1) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (1|1|1)	(0|0|0) (0|0|0)	(4|4|4) (4|4|4)	(1|1|1) (1|1|1)	(0|0|0) (0|0|0)

D.3.4 Results for Benchmark Case

Table D-4: Benchmark Case

	Case No.	1	2	3	4	5
	Case Name	MBb-so15aa-ag1	MBb-so15aa-ag3	MBb-so15aa-cts	MBb-so15aa-ei2	MBb-so15aa-em3
	Disturbance	ag1	ag3	cts	ei2	em3
	Prior Outage	None	None	None	None	None
	Date/Time	MAR 01 2010 10:45	MAR 01 2010 10:47	MAR 01 2010 10:49	MAR 01 2010 10:51	MAR 01 2010 10:53
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2264 / 148	2264 / 148	2264 / 148	2264 / 148	2264 / 148
	MHEX / L20D	2178 / 287	2178 / 287	2178 / 287	2178 / 287	2178 / 287
	ECL-ARP / PRI-BYN	660 / 74	660 / 74	660 / 74	660 / 74	660 / 74
	MWEX / AHD-SLK	1506 / 655	1506 / 655	1506 / 655	1506 / 655	1506 / 655
	D602F / F601C	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517
	B10T / MH>SPC	166 / 62	166 / 62	166 / 62	166 / 62	166 / 62
	OH E-W / OH>MH	191 / -195	191 / -195	191 / -195	191 / -195	191 / -195
	R50M / OH>MP	138 / 151	138 / 151	138 / 151	138 / 151	138 / 151
	G82R	-25	-25	-25	-25	-25
	Dorsey bipole / CU bipole	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103
	Dorsey Reserve / Wtrtn SVC	1392 / 15	1392 / 15	1392 / 15	1392 / 15	1392 / 15
	Forbes SVC / MSC	17 / 600	17 / 600	17 / 600	17 / 600	17 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
	Roseau 500/Forbes 500	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018
	Chisago 500/EauClaire 345	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026
	Int Falls 115/Badoura 115	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037
	Drayton 230/Groton 345	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	246% / 413%	246% / 413%	246% / 413%	246% / 413%	246% / 413%
	G82R at Rugby/L20D at Drayton	999% / 687%	999% / 687%	999% / 687%	999% / 687%	999% / 687%
	R50M/F3M	980% / 319%	980% / 319%	980% / 319%	980% / 319%	980% / 319%
	B10T	337%	337%	337%	337%	337%
	Min/MaxTransientVltg					
	Arrowhd 230	0.97 | 1.02	0.97 | 1.02	0.91 | 1.08	0.97 | 1.03	1.00 | 1.01
	Boise 115	1.00 | 1.03	1.00 | 1.03	0.94 | 1.03	0.99 | 1.01	1.01 | 1.02
	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.05 | 1.14	1.04 | 1.05	1.03 | 1.05
	Forbes 230	1.01 | 1.03	1.01 | 1.03	0.95 | 1.06	0.99 | 1.03	1.02 | 1.03
	Riverton 230	1.01 | 1.04	1.00 | 1.04	0.89 | 1.07	0.97 | 1.05	1.03 | 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	0.93 | 1.05	0.92 | 1.05	0.71 | 1.06	0.85 | 1.06	1.00 | 1.01
	Drayton 230	1.01 | 1.05	1.00 | 1.05	0.94 | 1.09	0.98 | 1.06	1.02 | 1.03
	Groton 345	0.92 | 1.04	0.92 | 1.04	0.79 | 1.07	0.92 | 1.06	1.02 | 1.03
	Minong 161	0.98 | 1.04	0.98 | 1.04	0.97 | 1.10	0.99 | 1.05	1.01 | 1.02
	Wahpeton 115	1.00 | 1.06	0.99 | 1.07	0.84 | 1.08	0.95 | 1.08	1.04 | 1.04
	Watertown 345	0.98 | 1.04	0.98 | 1.04	0.87 | 1.06	0.97 | 1.05	1.03 | 1.03
	Dynamic Voltage Warnings					
		none	none		none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold					/ 0.133
	Forbes DC Red (DCAR)	451%	445%	507%	507%	507%
	K22W (max +dP @ t, d-ang)	13.2@(2.39166,0.8)	16.8@(2.35832,-0.4)	119.1@(2.44999,-55.5)	66.4@(2.40832,-29.5)	30.4@(0.11667,-0.4)
	K22W (max -dP @ t, d-ang)	17.6@(0.78333,4.6)	19.1@(0.73333,5.4)	72.8@(0.45000,10.6)	1.7@(0.42500,0.0)	28.9@(0.26667,2.6)
	K22W (max d-ang @ t, dP)	6.7@(1.03333,-6.8)	7.5@(0.97500,-8.8)	-55.9@(2.55832,115.7)	-32.2@(4.99995,30.8)	-9.3@(2.44166,13.2)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	203% / 340%	199% / 334%	0.36667 sec / 0.36667 sec	178% / 299%	207% / 348%
	G82R at Rugby/L20D at Drayton	999% / 585%	999% / 571%	999% / 258%	999% / 509%	999% / 0.18333 sec
	R50M / F3M	844% / 275%	833% / 272%	365% / 160%	827% / 220%	814% / 284%
	B10T	203%	190%	1%	108%	243%
	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 | 2 | 2)	(1 | 7 | 1) / (0 | 2 | 2)	(1 | 3 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)
	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 1 | 0) / (1 | 3 | 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 | 5 | 2) / (1 | 2 | 2)	(1 | 4 | 3) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	MBb-so15aa-ag1	MBb-so15aa-ag3	MBb-so15aa-cts	MBb-so15aa-ei2	MBb-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)8		(3T)

Table D-4: Benchmark Case

	Case No.	6	7	8	9	10
2	**Case Name**	MBb-so15aa-eq1	MBb-so15aa-fds	MBb-so15aa-mc3	MBb-so15aa-md3	MBb-so15aa-mis
3	**Disturbance**	eq1	fds	mc3	md3	mis
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAR 01 2010 10:55	MAR 01 2010 10:57	MAR 01 2010 10:59	MAR 01 2010 11:01	MAR 01 2010 11:03
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2264 / 148	2264 / 148	2264 / 148	2264 / 148	2264 / 148
10	MHEX / L20D	2178 / 287	2178 / 287	2178 / 287	2178 / 287	2178 / 287
11	ECL-ARP / PRI-BYN	660 / 74	660 / 74	660 / 74	660 / 74	660 / 74
12	MWEX / AHD-SLK	1506 / 655	1506 / 655	1506 / 655	1506 / 655	1506 / 655
13	D602F / F601C	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517
14	B10T / MH>SPC	166 / 62	166 / 62	166 / 62	166 / 62	166 / 62
15	OH E-W / OH>MH	191 / -195	191 / -195	191 / -195	191 / -195	191 / -195
16	R50M / OH>MP	138 / 151	138 / 151	138 / 151	138 / 151	138 / 151
17	G82R	-25	-25	-25	-25	-25
18	Dorsey bipole / CU bipole	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103
19	Dorsey Reserve / Wtrtn SVC	1392 / 15	1392 / 15	1392 / 15	1392 / 15	1392 / 15
20	Forbes SVC / MSC	17 / 600	17 / 600	17 / 600	17 / 600	17 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018
25	Chisago 500/EauClaire 345	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026
26	Int Falls 115/Badoura 115	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037
27	Drayton 230/Groton 345	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	246% / 413%	246% / 413%	246% / 413%	246% / 413%	246% / 413%
30	G82R at Rugby/L20D at Drayton	999% / 687%	999% / 687%	999% / 687%	999% / 687%	999% / 687%
31	R50M/F3M	980% / 319%	980% / 319%	980% / 319%	980% / 319%	980% / 319%
32	B10T	337%	337%	337%	337%	337%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.98 | 1.02	0.96 | 1.01	1.00 | 1.01	1.00 | 1.00	1.00 | 1.01
35	Boise 115	1.00 | 1.02	1.01 | 1.03	1.00 | 1.02	1.02 | 1.02	1.04 | 1.06
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.03 | 1.05	1.03 | 1.05	1.04 | 1.05
37	Forbes 230	1.01 | 1.03	1.01 | 1.03	1.02 | 1.03	1.02 | 1.02	1.02 | 1.03
38	Riverton 230	1.00 | 1.06	1.00 | 1.05	1.03 | 1.03	1.03 | 1.03	1.03 | 1.03
39	Coal Creek 230	0.99 | 1.16	0.97 | 1.12	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04
40	Jamestown 345	0.88 | 1.08	0.84 | 1.08	1.00 | 1.00	1.00 | 1.00	1.00 | 1.00
41	Drayton 230	1.02 | 1.07	1.00 | 1.06	1.02 | 1.03	1.02 | 1.03	1.02 | 1.03
42	Groton 345	0.95 | 1.06	0.95 | 1.06	1.02 | 1.02	1.02 | 1.02	1.02 | 1.02
43	Minong 161	1.00 | 1.04	0.98 | 1.02	1.01 | 1.02	1.01 | 1.01	1.01 | 1.02
44	Wahpeton 115	0.98 | 1.08	0.97 | 1.08	1.04 | 1.04	1.04 | 1.04	1.04 | 1.04
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					
55	Dorsey SUVP / UdHold			/ 0.133	/ 0.133	
56	Forbes DC Red (DCAR)	507%	457%	493%	495%	482%
57	K22W (max +dP @ t, d-ang)	46.3@(2.30833,-18.6)	13.1@(2.40832,-1.5)	28.4@(0.11667,0.3)	20.5@(0.11667,-0.4)	195.8@(0.35000,-11.9)
58	K22W (max -dP @ t, d-ang)	2.5@(0.29167,0.1)	12.6@(0.73333,2.4)	22.9@(1.03333,-4.6)	12.8@(0.24167,0.8)	0.0@(0.35000,0.0)
59	K22W (max d-ang @ t, dP)	-18.9@(2.53332,39.6)	4.5@(1.01666,-4.0)	-6.8@(2.29166,-13.7)	0.8@(0.26667,-11.7)	-43.4@(0.96666,195.8)
60	**OS Rel Trip / Marg**					
61	MH - OH					0.35000 sec
62	D602F at Forbes/Dorsey	203% / 341%	216% / 363%	224% / 377%	241% / 404%	234% / 393%
63	G82R at Rugby/L20D at Drayton	45% / 532%	999% / 585%	999% / 626%	999% / 674%	999% / 652%
64	R50M / F3M	880% / 247%	868% / 281%	980% / 205%	955% / 314%	615% / 319%
65	B10T	124%	184%	317%	100%	329%
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 | 3 | 1) / (0 | 2 | 2)	(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 | 4 | 2) / (1 | 1 | 1)	(1 | 4 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	MBb-so15aa-eq1	MBb-so15aa-fds	MBb-so15aa-mc3	MBb-so15aa-md3	MBb-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 D-4: Benchmark Case

	Case No.	11	12	13	14	15
2	**Case Name**	MBb-so15aa-mjs	MBb-so15aa-mkd	MBb-so15aa-mks	MBb-so15aa-nad	MBb-so15aa-nmz
3	**Disturbance**	mjs	mkd	mks	nad	nmz
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAR 01 2010 11:05	MAR 01 2010 11:07	MAR 01 2010 11:09	MAR 01 2010 11:11	MAR 01 2010 11:13
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2264 / 148	2264 / 148	2264 / 148	2264 / 148	2264 / 148
10	MHEX / L20D	2178 / 287	2178 / 287	2178 / 287	2178 / 287	2178 / 287
11	ECL-ARP / PRI-BYN	660 / 74	660 / 74	660 / 74	660 / 74	660 / 74
12	MWEX / AHD-SLK	1506 / 655	1506 / 655	1506 / 655	1506 / 655	1506 / 655
13	D602F / F601C	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517
14	B10T / MH>SPC	166 / 62	166 / 62	166 / 62	166 / 62	166 / 62
15	OH E-W / OH>MH	191 / -195	191 / -195	191 / -195	191 / -195	191 / -195
16	R50M / OH>MP	138 / 151	138 / 151	138 / 151	138 / 151	138 / 151
17	G82R	-25	-25	-25	-25	-25
18	Dorsey bipole / CU bipole	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103
19	Dorsey Reserve / Wtrtn SVC	1392 / 15	1392 / 15	1392 / 15	1392 / 15	1392 / 15
20	Forbes SVC / MSC	17 / 600	17 / 600	17 / 600	17 / 600	17 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018
25	Chisago 500/EauClaire 345	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026
26	Int Falls 115/Badoura 115	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037
27	Drayton 230/Groton 345	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	246% / 413%	246% / 413%	246% / 413%	246% / 413%	246% / 413%
30	G82R at Rugby/L20D at Drayton	999% / 687%	999% / 687%	999% / 687%	999% / 687%	999% / 687%
31	R50M/F3M	980% / 319%	980% / 319%	980% / 319%	980% / 319%	980% / 319%
32	B10T	337%	337%	337%	337%	337%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.02	0.94 | 1.01	0.96 | 1.02	1.00 | 1.06	0.92 | 1.07
35	Boise 115	1.01 | 1.02	1.01 | 1.03	1.01 | 1.03	0.91 | 1.03	0.95 | 1.03
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.06	1.04 | 1.07	1.05 | 1.07
37	Forbes 230	1.02 | 1.03	1.01 | 1.03	1.02 | 1.04	1.01 | 1.03	1.00 | 1.04
38	Riverton 230	1.00 | 1.03	0.97 | 1.03	0.99 | 1.04	0.99 | 1.05	0.94 | 1.05
39	Coal Creek 230	0.97 | 1.07	0.97 | 1.07	0.97 | 1.08	0.99 | 1.07	0.95 | 1.07
40	Jamestown 345	0.92 | 1.02	0.92 | 1.03	0.92 | 1.03	0.93 | 1.02	0.85 | 1.04
41	Drayton 230	1.00 | 1.03	0.99 | 1.04	1.00 | 1.06	0.96 | 1.07	0.96 | 1.07
42	Groton 345	0.98 | 1.03	0.97 | 1.03	0.97 | 1.03	0.98 | 1.04	0.92 | 1.05
43	Minong 161	1.01 | 1.04	0.96 | 1.03	0.98 | 1.04	1.02 | 1.07	0.96 | 1.09
44	Wahpeton 115	0.99 | 1.05	0.98 | 1.05	0.99 | 1.06	0.98 | 1.05	0.93 | 1.07
45	Watertown 345	1.00 | 1.03	1.00 | 1.03	1.00 | 1.04	1.00 | 1.04	0.96 | 1.05
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping					
55	Dorsey SUVP / UdHold		/ 0.133		/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	443%	319%	370%	507%	507%
57	K22W (max +dP @ t, d-ang)	2.1@(2.28333,1.4)	6.7@(0.10833,1.5)	8.2@(2.27499,0.2)	104.4@(2.03333,-45.2)	103.5@(2.17499,-46.4)
58	K22W (max -dP @ t, d-ang)	21.9@(0.35833,3.5)	32.8@(1.21666,13.0)	34.6@(0.37500,6.3)	89.4@(0.26667,9.8)	66.1@(0.25000,6.6)
59	K22W (max d-ang @ t, dP)	6.6@(0.77500,-7.0)	16.2@(0.84166,-19.1)	11.2@(0.74166,-8.2)	-52.0@(4.99995,35.9)	-48.0@(2.43332,87.9)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	229% / 390%	230% / 385%	212% / 365%	0.16667 sec / 0.16667 sec	0.18333 sec / 0.18333 sec
63	G82R at Rugby/L20D at Drayton	999% / 579%	999% / 491%	999% / 553%	999% / 339%	999% / 346%
64	R50M / F3M	870% / 315%	785% / 319%	811% / 309%	364% / 117%	429% / 152%
65	B10T	211%	152%	178%	101%	59%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 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 | 2 | 2) / (0 | 1 | 1)	(1 | 3 | 2) / (0 | 1 | 1)	(1 | 4 | 2) / (0 | 1 | 1)	(1 | 4 | 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 | 2 | 0) / (1 | 5 | 3)	(0 | 1 | 0) / (1 | 3 | 2)
71	Shey 115 / Split Rock 115	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 5 | 3) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	MBb-so15aa-mjs	MBb-so15aa-mkd	MBb-so15aa-mks	MBb-so15aa-nad	MBb-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 D-4: Benchmark Case

	Case No.	16	17	18	19	20
	Case Name	MBb-so15aa-pas	MBb-so15aa-pc0	MBb-so15aa-pcs	MBb-so15aa-pct	MBb-so15aa-pzs
	Disturbance	pas	pc0	pcs	pct	pzs
	Prior Outage	None	None	None	None	None
	Date/Time	MAR 01 2010 11:15	MAR 01 2010 11:17	MAR 01 2010 11:19	MAR 01 2010 11:21	MAR 01 2010 11:23
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2264 / 148	2264 / 148	2264 / 148	2264 / 148	2264 / 148
	MHEX / L20D	2178 / 287	2178 / 287	2178 / 287	2178 / 287	2178 / 287
	ECL-ARP / PRI-BYN	660 / 74	660 / 74	660 / 74	660 / 74	660 / 74
	MWEX / AHD-SLK	1506 / 655	1506 / 655	1506 / 655	1506 / 655	1506 / 655
	D602F / F601C	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517
	B10T / MH>SPC	166 / 62	166 / 62	166 / 62	166 / 62	166 / 62
	OH E-W / OH>MH	191 / -195	191 / -195	191 / -195	191 / -195	191 / -195
	R50M / OH>MP	138 / 151	138 / 151	138 / 151	138 / 151	138 / 151
	G82R	-25	-25	-25	-25	-25
	Dorsey bipole / CU bipole	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103
	Dorsey Reserve / Wtrtn SVC	1392 / 15	1392 / 15	1392 / 15	1392 / 15	1392 / 15
	Forbes SVC / MSC	17 / 600	17 / 600	17 / 600	17 / 600	17 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
	Roseau 500/Forbes 500	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018
	Chisago 500/EauClaire 345	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026
	Int Falls 115/Badoura 115	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037
	Drayton 230/Groton 345	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	246% / 413%	246% / 413%	246% / 413%	246% / 413%	246% / 413%
	G82R at Rugby/L20D at Drayton	999% / 687%	999% / 687%	999% / 687%	999% / 687%	999% / 687%
	R50M/F3M	980% / 319%	980% / 319%	980% / 319%	980% / 319%	980% / 319%
	B10T	337%	337%	337%	337%	337%
	Min/MaxTransientVltg					
	Arrowhd 230	1.01 | 1.05	0.92 | 0.99	0.91 | 0.98	0.95 | 0.98	0.99 | 1.04
	Boise 115	0.97 | 1.02	1.01 | 1.04	1.01 | 1.04	1.02 | 1.03	1.00 | 1.04
	Dorsey 230	1.05 | 1.07	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.06
	Forbes 230	1.00 | 1.05	1.01 | 1.04	1.01 | 1.04	1.01 | 1.02	1.02 | 1.05
	Riverton 230	1.00 | 1.05	1.02 | 1.04	1.02 | 1.04	1.03 | 1.03	1.02 | 1.05
	Coal Creek 230	0.99 | 1.07	0.98 | 1.08	0.98 | 1.08	1.02 | 1.04	0.98 | 1.08
	Jamestown 345	0.93 | 1.01	0.96 | 1.03	0.96 | 1.03	1.00 | 1.02	0.96 | 1.03
	Drayton 230	0.97 | 1.06	1.02 | 1.05	1.01 | 1.04	1.02 | 1.03	1.02 | 1.04
	Groton 345	0.97 | 1.04	0.99 | 1.03	0.99 | 1.03	1.01 | 1.03	0.99 | 1.04
	Minong 161	1.03 | 1.09	0.91 | 1.00	0.90 | 0.99	0.94 | 0.98	0.99 | 1.05
	Wahpeton 115	0.98 | 1.05	1.02 | 1.05	1.02 | 1.05	1.04 | 1.05	1.02 | 1.06
	Watertown 345	1.00 | 1.04	1.01 | 1.03	1.01 | 1.03	1.02 | 1.03	1.01 | 1.04
	Dynamic Voltage Warnings					
		none	none	none	none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold	/ 0.150				
	Forbes DC Red (DCAR)	507%	256%	250%	330%	315%
	K22W (max +dP @ t, d-ang)	88.0@(2.13333,-42.9)	2.3@(3.34164,2.9)	1.2@(0.10000,0.4)	0.0@(0.10000,0.0)	26.3@(2.40832,-5.6)
	K22W (max -dP @ t, d-ang)	61.3@(0.27500,5.6)	33.4@(1.57500,11.0)	39.4@(1.58333,13.1)	28.4@(2.05833,11.6)	26.2@(0.61666,9.2)
	K22W (max d-ang @ t, dP)	-48.0@(4.99995,39.1)	16.9@(0.99166,-26.2)	18.9@(1.00833,-28.8)	11.6@(1.91666,-28.1)	13.4@(0.91666,-15.3)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	0.38333 sec / 0.18333 sec	213% / 356%	221% / 369%	245% / 411%	195% / 326%
	G82R at Rugby/L20D at Drayton	999% / 404%	999% / 587%	999% / 555%	999% / 648%	999% / 566%
	R50M / F3M	455% / 169%	795% / 319%	785% / 319%	897% / 319%	782% / 281%
	B10T	119%	198%	185%	289%	159%
	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 | 2) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 3 | 3)
	Prairie 115 / Ramsey 230	(1 | 2 | 2) / (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)
	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 3 | 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)
	Shey 115 / Split Rock 115	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 2 | 2)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	MBb-so15aa-pas	MBb-so15aa-pc0	MBb-so15aa-pcs	MBb-so15aa-pct	MBb-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 D-4: Benchmark Case

1	**Case No.**	21	22	23	24	25
2	**Case Name**	MBb-so15aa-pzt	MBb-so15aa-ya3	MBb-so15aa-yas	MBb-so15aa-yb3	MBb-so15aa-h13
3	**Disturbance**	pzt	ya3	yas	yb3	h13
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAR 01 2010 11:25	MAR 01 2010 11:27	MAR 01 2010 11:29	MAR 01 2010 11:31	MAR 01 2010 11:32
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2264 / 148	2264 / 148	2264 / 148	2264 / 148	2264 / 148
10	MHEX / L20D	2178 / 287	2178 / 287	2178 / 287	2178 / 287	2178 / 287
11	ECL-ARP / PRI-BYN	660 / 74	660 / 74	660 / 74	660 / 74	660 / 74
12	MWEX / AHD-SLK	1506 / 655	1506 / 655	1506 / 655	1506 / 655	1506 / 655
13	D602F / F601C	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517
14	B10T / MH>SPC	166 / 62	166 / 62	166 / 62	166 / 62	166 / 62
15	OH E-W / OH>MH	191 / -195	191 / -195	191 / -195	191 / -195	191 / -195
16	R50M / OH>MP	138 / 151	138 / 151	138 / 151	138 / 151	138 / 151
17	G82R	-25	-25	-25	-25	-25
18	Dorsey bipole / CU bipole	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103
19	Dorsey Reserve / Wtrtn SVC	1392 / 15	1392 / 15	1392 / 15	1392 / 15	1392 / 15
20	Forbes SVC / MSC	17 / 600	17 / 600	17 / 600	17 / 600	17 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018
25	Chisago 500/EauClaire 345	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026
26	Int Falls 115/Badoura 115	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037
27	Drayton 230/Groton 345	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	246% / 413%	246% / 413%	246% / 413%	246% / 413%	246% / 413%
30	G82R at Rugby/L20D at Drayton	999% / 687%	999% / 687%	999% / 687%	999% / 687%	999% / 687%
31	R50M/F3M	980% / 319%	980% / 319%	980% / 319%	980% / 319%	980% / 319%
32	B10T	337%	337%	337%	337%	337%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.99 | 1.00	1.02 | 1.02	0.97 | 1.00	1.03 | 1.04	0.99 | 1.01
35	Boise 115	1.02 | 1.02	1.02 | 1.04	1.02 | 1.04	1.02 | 1.03	1.01 | 1.02
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.06	1.04 | 1.05	1.03 | 1.05
37	Forbes 230	1.02 | 1.02	1.02 | 1.03	1.01 | 1.03	1.02 | 1.03	1.01 | 1.03
38	Riverton 230	1.03 | 1.03	1.02 | 1.02	1.01 | 1.03	1.02 | 1.03	1.03 | 1.03
39	Coal Creek 230	1.03 | 1.04	1.02 | 1.04	1.00 | 1.05	1.02 | 1.04	1.03 | 1.05
40	Jamestown 345	1.00 | 1.01	1.00 | 1.02	0.99 | 1.02	1.00 | 1.01	0.99 | 1.01
41	Drayton 230	1.02 | 1.03	1.02 | 1.03	1.02 | 1.04	1.02 | 1.03	1.02 | 1.03
42	Groton 345	1.02 | 1.02	1.01 | 1.02	1.01 | 1.02	1.01 | 1.02	1.01 | 1.03
43	Minong 161	1.00 | 1.00	0.98 | 0.99	0.97 | 1.01	0.98 | 1.01	1.00 | 1.02
44	Wahpeton 115	1.04 | 1.04	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04
45	Watertown 345	1.03 | 1.03	1.02 | 1.02	1.02 | 1.03	1.02 | 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					
55	Dorsey SUVP / UdHold					/ 0.133
56	Forbes DC Red (DCAR)	473%	371%	424%	405%	475%
57	K22W (max +dP @ t, d-ang)	0.0@(0.10000,0.0)	4.0@(0.11667,0.7)	2.4@(0.11667,0.3)	2.6@(0.10833,0.4)	105.2@(0.15833,-2.4)
58	K22W (max -dP @ t, d-ang)	5.6@(1.61666,2.3)	27.9@(1.63333,12.3)	23.8@(1.60000,9.6)	20.6@(1.59166,8.6)	18.8@(0.84166,-4.3)
59	K22W (max d-ang @ t, dP)	2.4@(2.09999,-5.4)	12.6@(1.89166,-24.9)	10.3@(1.03333,-14.5)	8.9@(1.85000,-18.0)	-6.2@(0.64166,2.9)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	246% / 413%	244% / 411%	240% / 403%	245% / 412%	232% / 389%
63	G82R at Rugby/L20D at Drayton	999% / 678%	999% / 620%	999% / 630%	999% / 636%	999% / 618%
64	R50M / F3M	968% / 319%	980% / 319%	965% / 319%	980% / 319%	894% / 264%
65	B10T	325%	266%	269%	206%	282%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	MBb-so15aa-pzt	MBb-so15aa-ya3	MBb-so15aa-yas	MBb-so15aa-yb3	MBb-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 D-4: Benchmark Case

	Case No.	26	27	28	29	30
2	**Case Name**	MBb-so15aa-h23	MBb-so15aa-h33	MBb-so15aa-h43	mbb-so15aa-h93	mbb-so15aa-hks
3	**Disturbance**	h23	h33	h43	h93	hks
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	MAR 01 2010 11:34	MAR 01 2010 11:36	MAR 01 2010 11:39	APR 08 2010 11:49	APR 08 2010 11:54
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2264 / 148	2264 / 148	2264 / 148	2264 / 148	2264 / 148
10	MHEX / L20D	2178 / 287	2178 / 287	2178 / 287	2178 / 287	2178 / 287
11	ECL-ARP / PRI-BYN	660 / 74	660 / 74	660 / 74	660 / 74	660 / 74
12	MWEX / AHD-SLK	1506 / 655	1506 / 655	1506 / 655	1506 / 655	1506 / 655
13	D602F / F601C	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517
14	B10T / MH>SPC	166 / 62	166 / 62	166 / 62	166 / 62	166 / 62
15	OH E-W / OH>MH	191 / -195	191 / -195	191 / -195	191 / -195	191 / -195
16	R50M / OH>MP	138 / 151	138 / 151	138 / 151	138 / 151	138 / 151
17	G82R	-25	-25	-25	-25	-25
18	Dorsey bipole / CU bipole	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103
19	Dorsey Reserve / Wtrtn SVC	1392 / 15	1392 / 15	1392 / 15	1392 / 15	1392 / 15
20	Forbes SVC / MSC	17 / 600	17 / 600	17 / 600	17 / 600	17 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018
25	Chisago 500/EauClaire 345	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026
26	Int Falls 115/Badoura 115	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037
27	Drayton 230/Groton 345	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	246% / 413%	246% / 413%	246% / 413%	246% / 413%	246% / 413%
30	G82R at Rugby/L20D at Drayton	999% / 687%	999% / 687%	999% / 687%	999% / 687%	999% / 687%
31	R50M/F3M	980% / 319%	980% / 319%	980% / 319%	980% / 319%	980% / 319%
32	B10T	337%	337%	337%	337%	337%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.02 | 1.04	1.03 | 1.08	0.99 | 1.01	0.98 | 1.01	1.00 | 1.03
35	Boise 115	1.02 | 1.03	0.91 | 1.02	1.01 | 1.02	1.01 | 1.03	1.01 | 1.03
36	Dorsey 230	1.04 | 1.06	1.05 | 1.07	1.02 | 1.04	1.04 | 1.05	1.04 | 1.06
37	Forbes 230	1.03 | 1.04	1.05 | 1.08	1.01 | 1.02	1.02 | 1.03	1.02 | 1.04
38	Riverton 230	1.04 | 1.05	1.02 | 1.06	1.02 | 1.03	1.01 | 1.03	1.03 | 1.05
39	Coal Creek 230	1.03 | 1.05	1.01 | 1.08	1.03 | 1.05	1.00 | 1.06	0.99 | 1.10
40	Jamestown 345	0.99 | 1.02	0.93 | 1.02	0.99 | 1.01	0.99 | 1.03	0.97 | 1.05
41	Drayton 230	1.04 | 1.06	0.97 | 1.06	1.01 | 1.02	1.03 | 1.04	1.02 | 1.09
42	Groton 345	1.01 | 1.04	0.98 | 1.04	1.01 | 1.03	1.00 | 1.02	1.00 | 1.04
43	Minong 161	1.03 | 1.05	1.04 | 1.08	1.00 | 1.02	0.98 | 1.02	1.00 | 1.03
44	Wahpeton 115	1.03 | 1.05	0.98 | 1.05	1.03 | 1.04	1.02 | 1.04	1.03 | 1.07
45	Watertown 345	1.03 | 1.04	1.01 | 1.04	1.02 | 1.03	1.01 | 1.03	1.02 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping					
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133		
56	Forbes DC Red (DCAR)	477%	507%	485%	472%	395%
57	K22W (max +dP @ t, d-ang)	114.8@(1.32500,-31.4)	98.5@(0.15000,-2.0)	98.5@(0.15000,-2.0)	5.5@(2.25833,-0.1)	12.8@(2.25833,-2.2)
58	K22W (max -dP @ t, d-ang)	0.0@(-0.01667,0.0)	44.2@(0.27500,2.9)	24.5@(2.19999,5.1)	9.9@(0.23333,1.0)	10.9@(0.39166,1.8)
59	K22W (max d-ang @ t, dP)	-38.8@(4.99995,67.7)	-55.1@(4.99995,39.7)	6.1@(2.58332,-14.2)	4.8@(0.85000,-6.3)	4.0@(0.83333,-5.1)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	246% / 413%	0.18333 sec / 0.18333 sec	239% / 399%	215% / 361%	218% / 367%
63	G82R at Rugby/L20D at Drayton	999% / 687%	999% / 405%	999% / 566%	999% / 687%	999% / 531%
64	R50M / F3M	980% / 245%	359% / 117%	790% / 263%	883% / 301%	887% / 291%
65	B10T	315%	150%	275%	279%	225%
66	**FSCAPS (SS/Unav/Final)**					
67	Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 0)
68	Eau Cl 345 / Park Lk 115	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 2) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 4 | 2) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 5 | 1) / (0 | 1 | 1)
70	Roseau 230 / Running 230	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 2 | 1) / (1 | 3 | 2)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	MBb-so15aa-h23	MBb-so15aa-h33	MBb-so15aa-h43	mbb-so15aa-h93	mbb-so15aa-hks
Disturbance	h23	h33	h43	h93	hks
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping		(5T)(6T)			

Table D-4: Benchmark Case

	Case No.	31	32	33	34	35
	Case Name	mbb-so15aa-o3s	mbb-so15aa-o4s	mbb-so15aa-h63	mbb-so15aa-he3	mbb-so15aa-hjs
	Disturbance	o3s	o4s	h63	he3	hjs
	Prior Outage	None	None	None	None	None
	Date/Time	APR 08 2010 11:23	APR 08 2010 11:26	APR 08 2010 11:45	APR 08 2010 11:33	APR 08 2010 11:30
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2264 / 148	2264 / 148	2264 / 148	2264 / 148	2264 / 148
	MHEX / L20D	2178 / 287	2178 / 287	2178 / 287	2178 / 287	2178 / 287
	ECL-ARP / PRI-BYN	660 / 74	660 / 74	660 / 74	660 / 74	660 / 74
	MWEX / AHD-SLK	1506 / 655	1506 / 655	1506 / 655	1506 / 655	1506 / 655
	D602F / F601C	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517
	B10T / MH>SPC	166 / 62	166 / 62	166 / 62	166 / 62	166 / 62
	OH E-W / OH>MH	191 / -195	191 / -195	191 / -195	191 / -195	191 / -195
	R50M / OH>MP	138 / 151	138 / 151	138 / 151	138 / 151	138 / 151
	G82R	-25	-25	-25	-25	-25
	Dorsey bipole / CU bipole	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103
	Dorsey Reserve / Wtrtn SVC	1392 / 15	1392 / 15	1392 / 15	1392 / 15	1392 / 15
	Forbes SVC / MSC	17 / 600	17 / 600	17 / 600	17 / 600	17 / 600
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
	Roseau 500/Forbes 500	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018
	Chisago 500/EauClaire 345	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026
	Int Falls 115/Badoura 115	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037
	Drayton 230/Groton 345	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	246% / 413%	246% / 413%	246% / 413%	246% / 413%	246% / 413%
	G82R at Rugby/L20D at Drayton	999% / 687%	999% / 687%	999% / 687%	999% / 687%	999% / 687%
	R50M/F3M	980% / 319%	980% / 319%	980% / 319%	980% / 319%	980% / 319%
	B10T	337%	337%	337%	337%	337%
	Min/MaxTransientVltg					
	Arrowhd 230	0.98 | 1.00	0.99 | 1.01	0.98 | 1.03	0.98 | 1.03	0.99 | 1.03
	Boise 115	1.01 | 1.02	1.01 | 1.03	1.00 | 1.04	1.00 | 1.04	1.00 | 1.04
	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.06
	Forbes 230	1.02 | 1.02	1.02 | 1.03	1.01 | 1.04	1.01 | 1.04	1.01 | 1.06
	Riverton 230	1.02 | 1.03	1.03 | 1.04	1.02 | 1.04	1.02 | 1.04	1.03 | 1.04
	Coal Creek 230	1.00 | 1.05	1.00 | 1.08	1.01 | 1.06	1.01 | 1.06	1.02 | 1.06
	Jamestown 345	1.03 | 1.07	0.99 | 1.04	0.99 | 1.01	0.99 | 1.01	1.00 | 1.02
	Drayton 230	1.03 | 1.08	1.02 | 1.08	1.01 | 1.04	1.01 | 1.04	1.02 | 1.06
	Groton 345	0.99 | 1.01	1.01 | 1.03	1.01 | 1.03	1.01 | 1.03	1.01 | 1.04
	Minong 161	0.99 | 1.01	0.99 | 1.02	0.98 | 1.05	0.98 | 1.05	0.99 | 1.05
	Wahpeton 115	1.02 | 1.05	1.03 | 1.06	1.03 | 1.05	1.03 | 1.05	1.04 | 1.05
	Watertown 345	1.01 | 1.02	1.02 | 1.03	1.02 | 1.04	1.02 | 1.04	1.02 | 1.04
	Dynamic Voltage Warnings					
		none	none	none	none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold					
	Forbes DC Red (DCAR)	488%	444%	352%	352%	348%
	K22W (max +dP @ t, d-ang)	1.5@(0.10833,0.1)	7.6@(2.22499,-1.0)	23.3@(2.35832,-3.9)	22.3@(2.36666,-3.8)	27.3@(2.42499,-5.2)
	K22W (max -dP @ t, d-ang)	6.6@(1.00000,2.2)	6.8@(0.35833,1.1)	24.8@(0.54166,9.2)	24.4@(0.54166,9.1)	25.4@(0.65833,10.1)
	K22W (max d-ang @ t, dP)	2.2@(0.97500,-6.6)	2.6@(0.81666,-3.1)	14.1@(0.87500,-15.4)	13.9@(0.87500,-15.3)	13.9@(0.93333,-15.6)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	216% / 363%	229% / 385%	195% / 326%	195% / 327%	190% / 318%
	G82R at Rugby/L20D at Drayton	999% / 611%	999% / 628%	999% / 588%	999% / 593%	999% / 576%
	R50M / F3M	885% / 298%	923% / 301%	782% / 281%	784% / 283%	773% / 277%
	B10T	337%	258%	183%	186%	172%
	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 | 5 | 3) / (0 | 1 | 1)	(1 | 4 | 1) / (0 | 1 | 1)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 0 | 0)	(1 | 1 | 1) / (0 | 1 | 1)
	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 | 3 | 2) / (1 | 1 | 1)	(1 | 3 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 2 | 2)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	mbb-so15aa-o3s	mbb-so15aa-o4s	mbb-so15aa-h63	mbb-so15aa-he3	mbb-so15aa-hjs
Disturbance	o3s	o4s	h63	he3	hjs
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					

Table D-4: Benchmark Case

	Case No.	36	37	38	39	40
2	**Case Name**	mbb-so15aa-o2s	mbb-so15aa-mcs	mbb-so15aa-mes	mbb-so15aa-mfs	mbb-so15aa-mts
3	**Disturbance**	o2s	mcs	mes	mfs	mts
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 08 2010 11:20	APR 06 2010 9:46	APR 08 2010 14:00	APR 08 2010 14:02	APR 06 2010 9:52
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2264 / 148	2264 / 148	2264 / 148	2264 / 148	2264 / 148
10	MHEX / L20D	2178 / 287	2178 / 287	2178 / 287	2178 / 287	2178 / 287
11	ECL-ARP / PRI-BYN	660 / 74	660 / 74	660 / 74	660 / 74	660 / 74
12	MWEX / AHD-SLK	1506 / 655	1506 / 655	1506 / 655	1506 / 655	1506 / 655
13	D602F / F601C	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517	1777 / 1517
14	B10T / MH>SPC	166 / 62	166 / 62	166 / 62	166 / 62	166 / 62
15	OH E-W / OH>MH	191 / -195	191 / -195	191 / -195	191 / -195	191 / -195
16	R50M / OH>MP	138 / 151	138 / 151	138 / 151	138 / 151	138 / 151
17	G82R	-25	-25	-25	-25	-25
18	Dorsey bipole / CU bipole	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103	2114 / 1103
19	Dorsey Reserve / Wtrtn SVC	1392 / 15	1392 / 15	1392 / 15	1392 / 15	1392 / 15
20	Forbes SVC / MSC	17 / 600	17 / 600	17 / 600	17 / 600	17 / 600
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045	1.043 / 1.045
24	Roseau 500/Forbes 500	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018	1.030 / 1.018
25	Chisago 500/EauClaire 345	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026	1.017 / 1.026
26	Int Falls 115/Badoura 115	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037	1.020 / 1.037
27	Drayton 230/Groton 345	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021	1.026 / 1.021
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	246% / 413%	246% / 413%	246% / 413%	246% / 413%	246% / 413%
30	G82R at Rugby/L20D at Drayton	999% / 687%	999% / 687%	999% / 687%	999% / 687%	999% / 687%
31	R50M/F3M	980% / 319%	980% / 319%	980% / 319%	980% / 319%	980% / 319%
32	B10T	337%	337%	337%	337%	337%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.00 | 1.03	0.96 | 1.03	0.96 | 1.03	0.98 | 1.05	0.96 | 1.03
35	Boise 115	1.01 | 1.03	1.00 | 1.04	1.00 | 1.04	0.99 | 1.04	1.00 | 1.04
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.03 | 1.06	1.03 | 1.05	1.04 | 1.05
37	Forbes 230	1.02 | 1.04	1.01 | 1.04	1.01 | 1.04	1.01 | 1.04	1.01 | 1.04
38	Riverton 230	1.03 | 1.04	1.00 | 1.05	1.01 | 1.05	1.00 | 1.04	1.00 | 1.06
39	Coal Creek 230	1.00 | 1.05	0.96 | 1.08	1.00 | 1.08	1.00 | 1.07	0.96 | 1.08
40	Jamestown 345	1.00 | 1.01	0.95 | 1.04	1.01 | 1.04	0.98 | 1.01	0.94 | 1.05
41	Drayton 230	1.02 | 1.04	1.02 | 1.05	1.02 | 1.05	1.02 | 1.05	1.03 | 1.06
42	Groton 345	1.02 | 1.03	0.97 | 1.04	1.00 | 1.03	1.00 | 1.03	0.96 | 1.04
43	Minong 161	1.01 | 1.05	0.97 | 1.06	0.96 | 1.06	0.99 | 1.07	0.97 | 1.05
44	Wahpeton 115	1.03 | 1.04	1.01 | 1.07	1.04 | 1.06	1.02 | 1.05	1.00 | 1.07
45	Watertown 345	1.03 | 1.03	1.00 | 1.04	1.01 | 1.03	1.01 | 1.04	0.99 | 1.04
46	**Dynamic Voltage Warnings**					
47		none	none	none	none	none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping					
55	Dorsey SUVP / UdHold					
56	Forbes DC Red (DCAR)	422%	347%	308%	439%	337%
57	K22W (max +dP @ t, d-ang)	13.4@(2.34166,-2.9)	29.9@(2.41666,-7.0)	27.0@(2.42499,-6.0)	58.8@(2.31666,-20.7)	28.5@(2.43332,-6.1)
58	K22W (max -dP @ t, d-ang)	12.3@(0.58333,4.6)	26.4@(0.55000,9.8)	28.6@(0.63333,11.3)	20.3@(0.40000,4.5)	27.2@(0.61666,9.6)
59	K22W (max d-ang @ t, dP)	6.5@(0.86666,-7.1)	14.9@(0.90833,-18.6)	15.9@(0.92500,-17.1)	-22.7@(2.65832,44.3)	14.1@(0.92500,-17.0)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	215% / 360%	182% / 304%	186% / 311%	177% / 297%	189% / 317%
63	G82R at Rugby/L20D at Drayton	999% / 643%	999% / 569%	999% / 585%	999% / 541%	999% / 569%
64	R50M / F3M	864% / 294%	759% / 278%	760% / 278%	748% / 238%	779% / 280%
65	B10T	247%	148%	168%	148%	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 | 3 | 3)	(4 | 4 | 4) / (0 | 3 | 3)	(4 | 4 | 4) / (0 | 3 | 3)	(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 | 8 | 2) / (0 | 1 | 1)	(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 | 1 | 1)	(0 | 0 | 0) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 2) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	mbb-so15aa-o2s	mbb-so15aa-mcs	mbb-so15aa-mes	mbb-so15aa-mfs	mbb-so15aa-mts
Disturbance	o2s	mcs	mes	mfs	mts
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping					

D.3.5 Results for Study Off Peak Case with Riel-Forbes-Chisago Prior Outage

Table D-5: Study Case with Riel-Forbes-Chisago Outage

Case No.	1	2	3	4	5
Case Name	m1b-so15aa.c2175-ag1	m1b-so15aa.c2175-ag3	m1b-so15aa.c2175-ei2	m1b-so15aa.c2175-em3	m1b-so15aa.c2175-eq1
Disturbance	ag1	ag3	ei2	em3	eq1
Prior Outage	None	None	None	None	None
Date/Time	APR 05 2010 11:16	APR 05 2010 11:18	APR 05 2010 11:19	APR 05 2010 11:21	APR 05 2010 11:23
Comments					
Steady State Flows					
NDEX / EAST BIAS	2376 / 260	2376 / 260	2376 / 260	2376 / 260	2376 / 260
MHEX / L20D	451 / 293	451 / 293	451 / 293	451 / 293	451 / 293
ECL-ARP / PRI-BYN	620 / 63	620 / 63	620 / 63	620 / 63	620 / 63
MWEX / AHD-SLK	1400 / 619	1400 / 619	1400 / 619	1400 / 619	1400 / 619
D602F / F601C	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
OH E-W / OH>MH	189 / -196	189 / -196	189 / -196	189 / -196	189 / -196
R50M / OH>MP	185 / 150	185 / 150	185 / 150	185 / 150	185 / 150
G82R	-27	-27	-27	-27	-27
Dorsey bipole / CU bipole	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103
Dorsey Reserve / Wtrtn SVC	1132 / 36	1132 / 36	1132 / 36	1132 / 36	1132 / 36
Forbes SVC / MSC	47 / 0	47 / 0	47 / 0	47 / 0	47 / 0
RCDC	0	0	0	0	0
Steady State Vltgs					
Dorsey 500/Dorsey 230	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045
Roseau 500/Forbes 500	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027
Chisago 500/EauClaire 345	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034
Int Falls 115/Badoura 115	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026
Drayton 230/Groton 345	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019
SS OS Relay Margins					
D602F at Forbes/Dorsey	999% / 999%	999% / 999%	999% / 999%	999% / 999%	999% / 999%
G82R at Rugby/L20D at Drayton	999% / 655%	999% / 655%	999% / 655%	999% / 655%	999% / 655%
R50M/F3M	664% / 332%	664% / 332%	664% / 332%	664% / 332%	664% / 332%
B10T	343%	343%	343%	343%	343%
Min/MaxTransientVltg					
Arrowhd 230	0.99 | 1.01	0.99 | 1.01	0.97 | 1.04	1.01 | 1.02	0.99 | 1.03
Boise 115	1.01 | 1.03	1.01 | 1.03	1.00 | 1.02	1.01 | 1.03	1.01 | 1.03
Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.03 | 1.05	1.03 | 1.05	1.04 | 1.05
Forbes 230	1.01 | 1.03	1.01 | 1.03	1.01 | 1.03	1.02 | 1.03	1.01 | 1.03
Riverton 230	1.00 | 1.03	1.00 | 1.03	0.96 | 1.05	1.02 | 1.03	0.99 | 1.05
Coal Creek 230	0.97 | 1.11	0.97 | 1.11	1.02 | 1.10	1.03 | 1.04	0.99 | 1.16
Jamestown 345	0.93 | 1.02	0.92 | 1.02	0.85 | 1.03	0.98 | 1.00	0.87 | 1.04
Drayton 230	1.00 | 1.04	0.99 | 1.04	0.96 | 1.06	1.01 | 1.02	1.00 | 1.05
Groton 345	0.92 | 1.04	0.92 | 1.04	0.91 | 1.06	1.02 | 1.03	0.94 | 1.06
Minong 161	1.00 | 1.03	0.99 | 1.03	1.00 | 1.05	1.02 | 1.03	1.01 | 1.05
Wahpeton 115	0.99 | 1.04	0.98 | 1.04	0.93 | 1.06	1.02 | 1.03	0.96 | 1.06
Watertown 345	0.98 | 1.04	0.98 | 1.04	0.95 | 1.05	1.02 | 1.03	0.98 | 1.05
Dynamic Voltage Warnings					
	none	none	none	none	none
Worst Case Angle Damping					
Dorsey SUVP / UdHold				/ 0.133	
Forbes DC Red (DCAR)	999%	999%	999%	999%	999%
K22W (max +dP @ t, d-ang)	9.0@(2.29166,2.0)	13.3@(2.25833,0.5)	77.4@(2.34166,-30.7)	30.0@(0.11667,-0.5)	56.1@(2.26666,-20.4)
K22W (max -dP @ t, d-ang)	22.3@(1.70833,1.0)	23.0@(0.66666,5.4)	13.5@(0.55000,2.0)	30.4@(0.27500,2.8)	11.8@(0.52500,1.6)
K22W (max d-ang @ t, dP)	7.2@(0.99166,-7.6)	8.0@(0.94166,-8.4)	-32.3@(2.64165,60.7)	-10.9@(2.44166,17.7)	-21.2@(2.49999,44.2)
OS Rel Trip / Marg					
MH - OH					
D602F at Forbes/Dorsey	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se
G82R at Rugby/L20D at Drayton	999% / 587%	999% / 580%	999% / 517%	999% / 0.18333 sec	46% / 520%
R50M / F3M	547% / 295%	544% / 292%	500% / 246%	532% / 291%	544% / 272%
B10T	203%	195%	110%	260%	129%
FSCAPS (SS/Unav/Final)					
Balta 230	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 0 | 0)	(0 | 1 | 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 | 3) / (0 | 0 | 0)
Prairie 115 / Ramsey 230	(1 | 8 | 2) / (1 | 1 | 1)	(1 | 3 | 2) / (1 | 1 | 1)	(1 | 4 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 4 | 2) / (1 | 1 | 1)
Roseau 230 / Running 230	(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)
Shey 115 / Split Rock 115	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 2 | 2)	(1 | 5 | 4) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 5 | 4) / (1 | 1 | 1)
Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	m1b-so15aa.c2175-ag1	m1b-so15aa.c2175-ag3	m1b-so15aa.c2175-ei2	m1b-so15aa.c2175-em3	m1b-so15aa.c2175-eq1
Disturbance	ag1	ag3	ei2	em3	eq1
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(5T)(6T)	(5T)(6T)	(5T)(6T)	(3T)(5T)(6T)	(5T)(6T)

Table D-5: Study Case with Riel-Forbes-Chisago Outage

	Case No.	6	7	8	9	10
	Case Name	m1b-so15aa.c2175-fds	m1b-so15aa.c2175-mc3	m1b-so15aa.c2175-md3	m1b-so15aa.c2175-mis	m1b-so15aa.c2175-miz
	Disturbance	fds	mc3	md3	mis	miz
	Prior Outage	None	None	None	None	None
	Date/Time	APR 05 2010 11:25	APR 05 2010 11:27	APR 05 2010 11:29	APR 05 2010 11:31	APR 05 2010 11:33
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2376 / 260	2376 / 260	2376 / 260	2376 / 260	2376 / 260
	MHEX / L20D	451 / 293	451 / 293	451 / 293	451 / 293	451 / 293
	ECL-ARP / PRI-BYN	620 / 63	620 / 63	620 / 63	620 / 63	620 / 63
	MWEX / AHD-SLK	1400 / 619	1400 / 619	1400 / 619	1400 / 619	1400 / 619
	D602F / F601C	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
	OH E-W / OH>MH	189 / -196	189 / -196	189 / -196	189 / -196	189 / -196
	R50M / OH>MP	185 / 150	185 / 150	185 / 150	185 / 150	185 / 150
	G82R	-27	-27	-27	-27	-27
	Dorsey bipole / CU bipole	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103
	Dorsey Reserve / Wtrtn SVC	1132 / 36	1132 / 36	1132 / 36	1132 / 36	1132 / 36
	Forbes SVC / MSC	47 / 0	47 / 0	47 / 0	47 / 0	47 / 0
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045
	Roseau 500/Forbes 500	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027
	Chisago 500/EauClaire 345	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034
	Int Falls 115/Badoura 115	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026
	Drayton 230/Groton 345	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	999% / 999%	999% / 999%	999% / 999%	999% / 999%	999% / 999%
	G82R at Rugby/L20D at Drayton	999% / 655%	999% / 655%	999% / 655%	999% / 655%	999% / 655%
	R50M/F3M	664% / 332%	664% / 332%	664% / 332%	664% / 332%	664% / 332%
	B10T	343%	343%	343%	343%	343%
	Min/MaxTransientVltg					
	Arrowhd 230	0.97 | 1.02	1.01 | 1.02	1.01 | 1.01	1.01 | 1.02	1.02 | 1.05
	Boise 115	0.99 | 1.04	1.00 | 1.02	1.02 | 1.03	1.04 | 1.06	1.02 | 1.05
	Dorsey 230	1.03 | 1.05	1.03 | 1.05	1.03 | 1.05	1.04 | 1.05	1.05 | 1.07
	Forbes 230	1.00 | 1.04	1.02 | 1.03	1.02 | 1.02	1.02 | 1.03	1.02 | 1.04
	Riverton 230	0.98 | 1.04	1.02 | 1.03	1.02 | 1.02	1.02 | 1.03	1.03 | 1.06
	Coal Creek 230	0.97 | 1.12	1.03 | 1.04	1.03 | 1.04	1.03 | 1.04	1.03 | 1.06
	Jamestown 345	0.84 | 1.04	0.98 | 0.99	0.98 | 0.99	0.99 | 0.99	1.01 | 1.03
	Drayton 230	0.97 | 1.05	1.00 | 1.02	1.01 | 1.02	1.01 | 1.02	1.04 | 1.06
	Groton 345	0.95 | 1.05	1.02 | 1.02	1.02 | 1.02	1.02 | 1.02	1.03 | 1.05
	Minong 161	0.99 | 1.03	1.02 | 1.03	1.02 | 1.02	1.02 | 1.03	1.03 | 1.06
	Wahpeton 115	0.95 | 1.05	1.02 | 1.03	1.02 | 1.02	1.02 | 1.03	1.04 | 1.06
	Watertown 345	0.98 | 1.04	1.02 | 1.03	1.02 | 1.03	1.03 | 1.03	1.03 | 1.05
	Dynamic Voltage Warnings					
		none	none	none	none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold		/ 0.133	/ 0.133		
	Forbes DC Red (DCAR)	999%	999%	999%	999%	999%
	K22W (max +dP @ t, d-ang)	17.2@(2.36666,-3.4)	25.8@(0.11667,0.1)	20.1@(0.11667,-0.5)	196.1@(0.35000,-11.7)	124.1@(1.26666,-36.9)
	K22W (max -dP @ t, d-ang)	24.9@(0.55833,3.3)	32.3@(1.05000,-5.3)	13.5@(0.24167,0.8)	0.0@(0.35000,0.0)	0.0@(0.00000,0.0)
	K22W (max d-ang @ t, dP)	5.5@(0.86666,-5.8)	-8.9@(2.29166,-21.0)	0.9@(0.48333,-1.4)	-41.9@(0.96666,196.1)	-40.2@(1.65833,111.1)
	OS Rel Trip / Marg					
	MH - OH				0.35000 sec	
	D602F at Forbes/Dorsey	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se
	G82R at Rugby/L20D at Drayton	999% / 608%	999% / 582%	999% / 641%	999% / 625%	999% / 655%
	R50M / F3M	480% / 269%	664% / 178%	631% / 325%	420% / 332%	664% / 277%
	B10T	182%	278%	325%	325%	343%
	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 | 3) / (0 | 0 | 0)
	Prairie 115 / Ramsey 230	(1 | 4 | 2) / (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)
	Roseau 230 / Running 230	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 0) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 0) / (1 | 1 | 1)
	Shey 115 / Split Rock 115	(1 | 3 | 3) / (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)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	m1b-so15aa.c2175-fds	m1b-so15aa.c2175-mc3	m1b-so15aa.c2175-md3	m1b-so15aa.c2175-mis	m1b-so15aa.c2175-miz
Disturbance	fds	mc3	md3	mis	miz
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(5T)(6T)	(5T)(6T)	(5T)(6T)	(1T)(5T)(6T)	(5T)(6T)

Table D-5: Study Case with Riel-Forbes-Chisago Outage

1	**Case No.**	11	12	13	14	15
2	**Case Name**	m1b-so15aa.c2175-mkd	m1b-so15aa.c2175-pc0	m1b-so15aa.c2175-pcs	m1b-so15aa.c2175-pct	m1b-so15aa.c2175-pzs
3	**Disturbance**	mkd	pc0	pcs	pct	pzs
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 05 2010 14:58	APR 05 2010 11:38	APR 05 2010 11:40	APR 05 2010 11:42	APR 05 2010 11:44
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2376 / 260	2376 / 260	2376 / 260	2376 / 260	2376 / 260
10	MHEX / L20D	451 / 293	451 / 293	451 / 293	451 / 293	451 / 293
11	ECL-ARP / PRI-BYN	620 / 63	620 / 63	620 / 63	620 / 63	620 / 63
12	MWEX / AHD-SLK	1400 / 619	1400 / 619	1400 / 619	1400 / 619	1400 / 619
13	D602F / F601C	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
14	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
15	OH E-W / OH>MH	189 / -196	189 / -196	189 / -196	189 / -196	189 / -196
16	R50M / OH>MP	185 / 150	185 / 150	185 / 150	185 / 150	185 / 150
17	G82R	-27	-27	-27	-27	-27
18	Dorsey bipole / CU bipole	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103
19	Dorsey Reserve / Wtrtn SVC	1132 / 36	1132 / 36	1132 / 36	1132 / 36	1132 / 36
20	Forbes SVC / MSC	47 / 0	47 / 0	47 / 0	47 / 0	47 / 0
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045
24	Roseau 500/Forbes 500	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027
25	Chisago 500/EauClaire 345	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034
26	Int Falls 115/Badoura 115	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026
27	Drayton 230/Groton 345	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	999% / 999%	999% / 999%	999% / 999%	999% / 999%	999% / 999%
30	G82R at Rugby/L20D at Drayton	999% / 655%	999% / 655%	999% / 655%	999% / 655%	999% / 655%
31	R50M/F3M	664% / 332%	664% / 332%	664% / 332%	664% / 332%	664% / 332%
32	B10T	343%	343%	343%	343%	343%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.98 | 1.01	0.96 | 1.01	0.96 | 1.01	0.97 | 1.00	1.00 | 1.04
35	Boise 115	1.01 | 1.03	1.00 | 1.04	1.00 | 1.04	1.02 | 1.03	1.00 | 1.04
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.06
37	Forbes 230	1.02 | 1.03	1.01 | 1.03	1.01 | 1.03	1.02 | 1.03	1.01 | 1.04
38	Riverton 230	1.01 | 1.03	1.02 | 1.04	1.02 | 1.04	1.02 | 1.03	1.01 | 1.05
39	Coal Creek 230	0.99 | 1.07	0.99 | 1.08	0.99 | 1.08	1.03 | 1.05	0.98 | 1.08
40	Jamestown 345	0.94 | 1.00	0.96 | 1.02	0.96 | 1.02	0.99 | 1.01	0.95 | 1.03
41	Drayton 230	1.00 | 1.02	1.00 | 1.03	1.00 | 1.03	1.02 | 1.03	1.01 | 1.05
42	Groton 345	0.98 | 1.03	1.00 | 1.04	1.00 | 1.04	1.02 | 1.03	0.99 | 1.04
43	Minong 161	0.99 | 1.02	0.95 | 1.02	0.95 | 1.02	0.96 | 1.01	1.01 | 1.07
44	Wahpeton 115	1.00 | 1.03	1.02 | 1.05	1.02 | 1.04	1.02 | 1.04	1.01 | 1.06
45	Watertown 345	1.01 | 1.03	1.02 | 1.04	1.02 | 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					
55	Dorsey SUVP / UdHold					
56	Forbes DC Red (DCAR)	999%	999%	999%	999%	999%
57	K22W (max +dP @ t, d-ang)	11.8@(2.34166,-0.9)	6.9@(3.30831,-0.4)	6.5@(3.30831,-0.3)	0.0@(0.10000,0.0)	31.3@(2.39166,-7.2)
58	K22W (max -dP @ t, d-ang)	20.0@(0.50833,5.3)	33.2@(1.43333,10.1)	32.7@(1.43333,9.9)	23.1@(2.19166,7.8)	34.8@(0.46666,7.0)
59	K22W (max d-ang @ t, dP)	8.2@(0.85833,-8.8)	14.8@(0.95000,-16.2)	14.6@(0.95000,-16.1)	7.8@(1.99166,-22.2)	14.1@(0.88333,-12.2)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se
63	G82R at Rugby/L20D at Drayton	999% / 586%	999% / 564%	999% / 565%	999% / 636%	999% / 536%
64	R50M / F3M	564% / 311%	484% / 300%	486% / 300%	592% / 332%	483% / 276%
65	B10T	224%	206%	208%	310%	161%
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 | 3) / (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) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 1 | 1)
70	Roseau 230 / Running 230	(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)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1b-so15aa.c2175-mkd	m1b-so15aa.c2175-pc0	m1b-so15aa.c2175-pcs	m1b-so15aa.c2175-pct	m1b-so15aa.c2175-pzs
Disturbance	mkd	pc0	pcs	pct	pzs
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)

Table D-5: Study Case with Riel-Forbes-Chisago Outage

1	**Case No.**	16	17	18	19	20
2	**Case Name**	m1b-so15aa.c2175-pzt	m1b-so15aa.c2175-ya3	m1b-so15aa.c2175-yas	m1b-so15aa.c2175-yb3	m1b-so15aa.c2175-h13
3	**Disturbance**	pzt	ya3	yas	yb3	h13
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 05 2010 11:46	APR 05 2010 11:47	APR 05 2010 11:49	APR 05 2010 11:51	APR 05 2010 11:53
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2376 / 260	2376 / 260	2376 / 260	2376 / 260	2376 / 260
10	MHEX / L20D	451 / 293	451 / 293	451 / 293	451 / 293	451 / 293
11	ECL-ARP / PRI-BYN	620 / 63	620 / 63	620 / 63	620 / 63	620 / 63
12	MWEX / AHD-SLK	1400 / 619	1400 / 619	1400 / 619	1400 / 619	1400 / 619
13	D602F / F601C	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
14	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
15	OH E-W / OH>MH	189 / -196	189 / -196	189 / -196	189 / -196	189 / -196
16	R50M / OH>MP	185 / 150	185 / 150	185 / 150	185 / 150	185 / 150
17	G82R	-27	-27	-27	-27	-27
18	Dorsey bipole / CU bipole	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103
19	Dorsey Reserve / Wtrtn SVC	1132 / 36	1132 / 36	1132 / 36	1132 / 36	1132 / 36
20	Forbes SVC / MSC	47 / 0	47 / 0	47 / 0	47 / 0	47 / 0
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045
24	Roseau 500/Forbes 500	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027
25	Chisago 500/EauClaire 345	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034
26	Int Falls 115/Badoura 115	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026
27	Drayton 230/Groton 345	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	999% / 999%	999% / 999%	999% / 999%	999% / 999%	999% / 999%
30	G82R at Rugby/L20D at Drayton	999% / 655%	999% / 655%	999% / 655%	999% / 655%	999% / 655%
31	R50M/F3M	664% / 332%	664% / 332%	664% / 332%	664% / 332%	664% / 332%
32	B10T	343%	343%	343%	343%	343%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.00 | 1.01	1.01 | 1.02	0.96 | 1.00	1.02 | 1.04	1.00 | 1.02
35	Boise 115	1.02 | 1.03	1.03 | 1.06	1.03 | 1.06	1.04 | 1.06	1.02 | 1.03
36	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.04 | 1.05	1.03 | 1.05
37	Forbes 230	1.02 | 1.02	1.02 | 1.04	1.01 | 1.10	1.02 | 1.04	1.02 | 1.03
38	Riverton 230	1.02 | 1.03	1.00 | 1.02	1.00 | 1.02	1.01 | 1.02	1.02 | 1.03
39	Coal Creek 230	1.03 | 1.04	1.02 | 1.04	1.00 | 1.05	1.02 | 1.04	1.02 | 1.06
40	Jamestown 345	0.99 | 0.99	0.98 | 1.00	0.98 | 1.00	0.98 | 0.99	0.98 | 1.00
41	Drayton 230	1.02 | 1.02	1.01 | 1.03	1.01 | 1.03	1.01 | 1.03	1.01 | 1.02
42	Groton 345	1.02 | 1.02	1.01 | 1.02	1.00 | 1.02	1.01 | 1.02	1.01 | 1.03
43	Minong 161	1.01 | 1.02	0.97 | 0.99	0.96 | 1.02	0.98 | 1.00	1.01 | 1.03
44	Wahpeton 115	1.02 | 1.03	1.01 | 1.03	1.01 | 1.03	1.01 | 1.02	1.02 | 1.03
45	Watertown 345	1.03 | 1.03	1.02 | 1.02	1.02 | 1.02	1.02 | 1.02	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					
55	Dorsey SUVP / UdHold					/ 0.133
56	Forbes DC Red (DCAR)	999%	999%	999%	999%	999%
57	K22W (max +dP @ t, d-ang)	0.0@(0.10000,0.0)	5.5@(0.11667,0.7)	4.5@(3.49164,5.8)	3.8@(0.11667,0.5)	102.2@(0.15000,-2.7)
58	K22W (max -dP @ t, d-ang)	4.5@(2.10833,1.9)	18.9@(1.69166,13.0)	17.7@(1.57500,10.4)	14.3@(1.64166,9.3)	15.9@(2.24166,3.2)
59	K22W (max d-ang @ t, dP)	1.9@(2.21666,-4.4)	13.3@(1.98333,-14.5)	11.1@(1.10833,-7.1)	9.5@(1.94166,-10.7)	-4.5@(0.65833,2.3)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se
63	G82R at Rugby/L20D at Drayton	999% / 651%	999% / 639%	999% / 634%	999% / 647%	999% / 608%
64	R50M / F3M	657% / 332%	664% / 332%	664% / 332%	664% / 332%	608% / 288%
65	B10T	334%	269%	278%	285%	106%
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) / (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)
70	Roseau 230 / Running 230	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 0)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

Case	m1b-so15aa.c2175-pzt	m1b-so15aa.c2175-ya3	m1b-so15aa.c2175-yas	m1b-so15aa.c2175-yb3	m1b-so15aa.c2175-h13
Disturbance	pzt	ya3	yas	yb3	h13
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)

Table D-5: Study Case with Riel-Forbes-Chisago Outage

1	**Case No.**	21	22	23	24	25
2	**Case Name**	m1b-so15aa.c2175-h23	m1b-so15aa.c2175-h7d	m1b-so15aa.c2175-he0	m1b-so15aa.c2175-hl0	m1b-so15aa.c2175-h43
3	**Disturbance**	h23	h7d	he0	hl0	h43
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 05 2010 11:55	APR 05 2010 11:57	APR 05 2010 11:59	APR 05 2010 12:01	APR 05 2010 12:03
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2376 / 260	2376 / 260	2376 / 260	2376 / 260	2376 / 260
10	MHEX / L20D	451 / 293	451 / 293	451 / 293	451 / 293	451 / 293
11	ECL-ARP / PRI-BYN	620 / 63	620 / 63	620 / 63	620 / 63	620 / 63
12	MWEX / AHD-SLK	1400 / 619	1400 / 619	1400 / 619	1400 / 619	1400 / 619
13	D602F / F601C	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
14	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
15	OH E-W / OH>MH	189 / -196	189 / -196	189 / -196	189 / -196	189 / -196
16	R50M / OH>MP	185 / 150	185 / 150	185 / 150	185 / 150	185 / 150
17	G82R	-27	-27	-27	-27	-27
18	Dorsey bipole / CU bipole	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103
19	Dorsey Reserve / Wtrtn SVC	1132 / 36	1132 / 36	1132 / 36	1132 / 36	1132 / 36
20	Forbes SVC / MSC	47 / 0	47 / 0	47 / 0	47 / 0	47 / 0
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045
24	Roseau 500/Forbes 500	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027
25	Chisago 500/EauClaire 345	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034
26	Int Falls 115/Badoura 115	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026
27	Drayton 230/Groton 345	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	999% / 999%	999% / 999%	999% / 999%	999% / 999%	999% / 999%
30	G82R at Rugby/L20D at Drayton	999% / 655%	999% / 655%	999% / 655%	999% / 655%	999% / 655%
31	R50M/F3M	664% / 332%	664% / 332%	664% / 332%	664% / 332%	664% / 332%
32	B10T	343%	343%	343%	343%	343%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	1.00 | 1.02	1.02 | 1.06	1.02 | 1.06	1.02 | 1.06	1.00 | 1.02
35	Boise 115	1.02 | 1.03	0.97 | 1.03	0.97 | 1.03	0.97 | 1.03	1.02 | 1.03
36	Dorsey 230	1.03 | 1.05	1.05 | 1.07	1.05 | 1.24	1.05 | 1.23	1.03 | 1.05
37	Forbes 230	1.02 | 1.03	1.01 | 1.04	1.01 | 1.04	1.01 | 1.04	1.02 | 1.03
38	Riverton 230	1.02 | 1.03	1.03 | 1.06	1.03 | 1.06	1.03 | 1.06	1.02 | 1.03
39	Coal Creek 230	1.02 | 1.06	1.03 | 1.06	1.02 | 1.07	1.02 | 1.07	1.02 | 1.05
40	Jamestown 345	0.98 | 1.00	0.94 | 1.03	0.96 | 1.03	0.96 | 1.03	0.98 | 1.00
41	Drayton 230	1.01 | 1.02	0.97 | 1.06	0.99 | 1.07	0.99 | 1.07	1.01 | 1.02
42	Groton 345	1.01 | 1.03	1.00 | 1.05	1.00 | 1.05	1.00 | 1.05	1.01 | 1.03
43	Minong 161	1.01 | 1.03	1.03 | 1.08	1.03 | 1.08	1.03 | 1.08	1.01 | 1.03
44	Wahpeton 115	1.01 | 1.03	1.02 | 1.06	1.03 | 1.07	1.03 | 1.07	1.02 | 1.03
45	Watertown 345	1.02 | 1.03	1.02 | 1.05	1.02 | 1.05	1.02 | 1.05	1.02 | 1.03
46	**Dynamic Voltage Warnings**					
47		none	none			none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping					
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	999%	999%	999%	999%	999%
57	K22W (max +dP @ t, d-ang)	102.2@(0.15000,-2.7)	119.7@(1.93333,-50.5)	135.8@(1.99166,-52.2)	135.5@(2.00000,-52.2)	98.9@(0.15833,-2.8)
58	K22W (max -dP @ t, d-ang)	18.8@(2.24166,4.0)	44.4@(0.27500,3.1)	106.6@(0.40833,10.8)	105.3@(0.40833,10.8)	20.0@(2.95832,4.6)
59	K22W (max d-ang @ t, dP)	5.0@(2.63332,-11.3)	-56.8@(4.99995,63.0)	-56.5@(4.99995,63.3)	-56.3@(4.99995,63.2)	5.3@(2.62499,-12.1)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se
63	G82R at Rugby/L20D at Drayton	999% / 580%	999% / 320%	999% / 207%	999% / 207%	999% / 581%
64	R50M / F3M	591% / 288%	450% / 177%	270% / 165%	271% / 163%	578% / 294%
65	B10T	283%	92%	75%	74%	295%
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 | 3) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 3) / (0 | 0 | 0)	(4 | 4 | 4) / (0 | 0 | 0)
69	Prairie 115 / Ramsey 230	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 5 | 2) / (1 | 1 | 1)	(1 | 5 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
70	Roseau 230 / Running 230	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 0) / (1 | 2 | 2)	(1 | 1 | 0) / (1 | 2 | 2)	(1 | 1 | 0) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 0) / (1 | 1 | 1)	(1 | 1 | 0) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

	Case	m1b-so15aa.c2175-h23	m1b-so15aa.c2175-h7d	m1b-so15aa.c2175-he0	m1b-so15aa.c2175-hl0	m1b-so15aa.c2175-h43
	Disturbance	h23	h7d	he0	hl0	h43
	System Response	OK	OK	OK	OK	OK
	70% or 120% Violations					
	ORWG Criteria Violations					
	Line Tripping	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)

Table D-5: Study Case with Riel-Forbes-Chisago Outage

1	**Case No.**	26	27	28	29	30
2	**Case Name**	m1b-so15aa.c2175-h83	m1b-so15aa.c2175-hmd	m1b-so15aa.c2175-o53	m1b-so15aa.c2175-ho0	m1b-so15aa.c2175-h93
3	**Disturbance**	h83	hmd	o53	ho0	h93
4	**Prior Outage**	None	None	None	None	None
5	**Date/Time**	APR 05 2010 12:13	APR 05 2010 12:15	APR 07 2010 14:48	APR 05 2010 12:17	APR 05 2010 12:20
6	**Comments**					
7						
8	**Steady State Flows**					
9	NDEX / EAST BIAS	2376 / 260	2376 / 260	2376 / 260	2376 / 260	2376 / 260
10	MHEX / L20D	451 / 293	451 / 293	451 / 293	451 / 293	451 / 293
11	ECL-ARP / PRI-BYN	620 / 63	620 / 63	620 / 63	620 / 63	620 / 63
12	MWEX / AHD-SLK	1400 / 619	1400 / 619	1400 / 619	1400 / 619	1400 / 619
13	D602F / F601C	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
14	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
15	OH E-W / OH>MH	189 / -196	189 / -196	189 / -196	189 / -196	189 / -196
16	R50M / OH>MP	185 / 150	185 / 150	185 / 150	185 / 150	185 / 150
17	G82R	-27	-27	-27	-27	-27
18	Dorsey bipole / CU bipole	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103
19	Dorsey Reserve / Wtrtn SVC	1132 / 36	1132 / 36	1132 / 36	1132 / 36	1132 / 36
20	Forbes SVC / MSC	47 / 0	47 / 0	47 / 0	47 / 0	47 / 0
21	RCDC	0	0	0	0	0
22	**Steady State Vltgs**					
23	Dorsey 500/Dorsey 230	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045
24	Roseau 500/Forbes 500	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027
25	Chisago 500/EauClaire 345	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034
26	Int Falls 115/Badoura 115	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026
27	Drayton 230/Groton 345	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019
28	**SS OS Relay Margins**					
29	D602F at Forbes/Dorsey	999% / 999%	999% / 999%	999% / 999%	999% / 999%	999% / 999%
30	G82R at Rugby/L20D at Drayton	999% / 655%	999% / 655%	999% / 655%	999% / 655%	999% / 655%
31	R50M/F3M	664% / 332%	664% / 332%	664% / 332%	664% / 332%	664% / 332%
32	B10T	343%	343%	343%	343%	343%
33	**Min/MaxTransientVltg**					
34	Arrowhd 230	0.98 | 1.01	1.00 | 1.06	0.94 | 1.01	1.00 | 1.05	0.97 | 1.01
35	Boise 115	0.99 | 1.02	0.95 | 1.04	0.98 | 1.03	0.97 | 1.04	1.00 | 1.03
36	Dorsey 230	1.02 | 1.05	1.04 | 1.07	1.02 | 1.05	1.06 | 1.21	1.03 | 1.05
37	Forbes 230	1.02 | 1.03	1.01 | 1.04	1.01 | 1.03	1.01 | 1.04	1.01 | 1.03
38	Riverton 230	1.00 | 1.04	1.01 | 1.06	0.96 | 1.00	1.03 | 1.06	0.99 | 1.02
39	Coal Creek 230	0.98 | 1.08	0.98 | 1.07	0.97 | 1.07	1.00 | 1.08	0.98 | 1.07
40	Jamestown 345	0.94 | 1.02	0.90 | 1.04	0.97 | 1.01	1.00 | 1.07	0.94 | 1.01
41	Drayton 230	0.98 | 1.02	0.95 | 1.07	0.98 | 1.02	0.99 | 1.11	0.99 | 1.02
42	Groton 345	0.99 | 1.03	0.98 | 1.07	0.94 | 0.98	1.00 | 1.05	0.98 | 1.02
43	Minong 161	0.99 | 1.03	1.02 | 1.07	0.96 | 1.04	1.01 | 1.07	0.98 | 1.02
44	Wahpeton 115	1.00 | 1.05	1.00 | 1.07	0.96 | 1.01	1.04 | 1.09	0.98 | 1.02
45	Watertown 345	1.01 | 1.03	1.01 | 1.06	0.97 | 1.01	1.02 | 1.05	1.00 | 1.03
46	**Dynamic Voltage Warnings**					
47		none		none		none
48						
49						
50						
51						
52						
53						
54	Worst Case Angle Damping					
55	Dorsey SUVP / UdHold	/ 0.133	/ 0.133	/ 0.133	/ 0.133	/ 0.133
56	Forbes DC Red (DCAR)	999%	999%	999%	999%	999%
57	K22W (max +dP @ t, d-ang)	20.5@(0.11667,0.9)	149.0@(2.05000,-52.5)	20.5@(0.11667,0.9)	116.0@(2.20833,-46.0)	16.7@(0.10833,0.6)
58	K22W (max -dP @ t, d-ang)	61.8@(0.30000,8.1)	106.9@(0.29167,11.4)	89.2@(1.24166,25.0)	84.2@(0.42500,9.3)	53.1@(0.28333,6.7)
59	K22W (max d-ang @ t, dP)	14.0@(0.61666,-15.3)	-55.1@(4.99995,61.0)	25.7@(1.43333,-83.8)	-49.6@(4.99995,52.9)	12.1@(0.61666,-11.2)
60	**OS Rel Trip / Marg**					
61	MH - OH					
62	D602F at Forbes/Dorsey	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se
63	G82R at Rugby/L20D at Drayton	999% / 398%	999% / 225%	999% / 411%	999% / 340%	999% / 527%
64	R50M / F3M	396% / 273%	278% / 172%	281% / 274%	376% / 179%	443% / 298%
65	B10T	156%	34%	139%	77%	200%
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 | 2) / (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 | 8 | 2) / (1 | 1 | 1)	(1 | 6 | 2) / (1 | 1 | 1)	(1 | 3 | 2) / (1 | 1 | 1)	(1 | 4 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
70	Roseau 230 / Running 230	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 0) / (1 | 3 | 2)	(1 | 2 | 2) / (1 | 3 | 3)	(1 | 1 | 0) / (1 | 3 | 2)	(1 | 1 | 1) / (1 | 1 | 1)
71	Shey 115 / Split Rock 115	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 0) / (1 | 2 | 2)	(1 | 5 | 5) / (1 | 2 | 2)	(1 | 3 | 0) / (1 | 1 | 1)	(1 | 4 | 4) / (1 | 2 | 2)
72	**Damping Performance**	N/A	N/A	N/A	N/A	N/A

	Case	m1b-so15aa.c2175-h83	m1b-so15aa.c2175-hmd	m1b-so15aa.c2175-o53	m1b-so15aa.c2175-ho0	m1b-so15aa.c2175-h93
	Disturbance	h83	hmd	o53	ho0	h93
	System Response	OK	OK	OK	OK	OK
	70% or 120% Violations					
	ORWG Criteria Violations					
	Line Tripping	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)

Table D-5: Study Case with Riel-Forbes-Chisago Outage

	Case No.	31	32	33	34	35
	Case Name	m1b-so15aa.c2175-hks	m1b-so15aa.c2175-o3s	m1b-so15aa.c2175-o4s	m1b-so15aa.c2175-h53	m1b-so15aa.c2175-o13
	Disturbance	hks	o3s	o4s	h53	o13
	Prior Outage	None	None	None	None	None
	Date/Time	APR 05 2010 12:21	APR 05 2010 12:27	APR 05 2010 12:29	APR 05 2010 12:05	APR 05 2010 12:23
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2376 / 260	2376 / 260	2376 / 260	2376 / 260	2376 / 260
	MHEX / L20D	451 / 293	451 / 293	451 / 293	451 / 293	451 / 293
	ECL-ARP / PRI-BYN	620 / 63	620 / 63	620 / 63	620 / 63	620 / 63
	MWEX / AHD-SLK	1400 / 619	1400 / 619	1400 / 619	1400 / 619	1400 / 619
	D602F / F601C	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
	OH E-W / OH>MH	189 / -196	189 / -196	189 / -196	189 / -196	189 / -196
	R50M / OH>MP	185 / 150	185 / 150	185 / 150	185 / 150	185 / 150
	G82R	-27	-27	-27	-27	-27
	Dorsey bipole / CU bipole	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103
	Dorsey Reserve / Wtrtn SVC	1132 / 36	1132 / 36	1132 / 36	1132 / 36	1132 / 36
	Forbes SVC / MSC	47 / 0	47 / 0	47 / 0	47 / 0	47 / 0
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045
	Roseau 500/Forbes 500	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027
	Chisago 500/EauClaire 345	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034
	Int Falls 115/Badoura 115	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026
	Drayton 230/Groton 345	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	999% / 999%	999% / 999%	999% / 999%	999% / 999%	999% / 999%
	G82R at Rugby/L20D at Drayton	999% / 655%	999% / 655%	999% / 655%	999% / 655%	999% / 655%
	R50M/F3M	664% / 332%	664% / 332%	664% / 332%	664% / 332%	664% / 332%
	B10T	343%	343%	343%	343%	343%
	Min/MaxTransientVltg					
	Arrowhd 230	0.99 | 1.01	0.99 | 1.01	1.00 | 1.01	0.94 | 1.03	0.97 | 1.04
	Boise 115	1.02 | 1.03	1.01 | 1.02	1.02 | 1.03	0.96 | 1.08	1.00 | 1.04
	Dorsey 230	1.03 | 1.09	1.03 | 1.05	1.03 | 1.06	1.03 | 1.05	1.04 | 1.05
	Forbes 230	1.02 | 1.03	1.02 | 1.03	1.02 | 1.03	1.01 | 1.03	1.01 | 1.04
	Riverton 230	1.02 | 1.04	1.01 | 1.02	1.02 | 1.04	0.95 | 1.01	1.00 | 1.03
	Coal Creek 230	0.98 | 1.08	1.00 | 1.05	1.00 | 1.07	0.99 | 1.07	1.01 | 1.07
	Jamestown 345	0.96 | 1.02	1.04 | 1.06	0.97 | 1.01	0.96 | 1.02	0.96 | 1.00
	Drayton 230	1.03 | 1.07	1.02 | 1.04	1.03 | 1.06	0.97 | 1.03	1.00 | 1.02
	Groton 345	1.00 | 1.03	0.99 | 1.00	1.01 | 1.03	0.92 | 0.99	1.00 | 1.03
	Minong 161	1.00 | 1.03	1.01 | 1.02	1.01 | 1.02	0.95 | 1.06	0.97 | 1.07
	Wahpeton 115	1.02 | 1.05	1.00 | 1.02	1.03 | 1.05	0.95 | 1.01	1.01 | 1.03
	Watertown 345	1.02 | 1.03	1.01 | 1.02	1.02 | 1.03	0.96 | 1.01	1.01 | 1.04
	Dynamic Voltage Warnings					
		none	none	none	none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold	/ 0.133	/ 0.141	/ 0.141	/ 0.133	/ 0.133
	Forbes DC Red (DCAR)	999%	999%	999%	999%	999%
	K22W (max +dP @ t, d-ang)	14.5@(2.19166,-2.9)	5.0@(0.10833,0.1)	9.2@(2.15833,-2.0)	196.1@(1.61666,9.7)	17.8@(3.17498,-5.0)
	K22W (max -dP @ t, d-ang)	40.9@(0.38333,5.3)	33.5@(0.35000,4.0)	31.0@(0.35000,3.6)	100.5@(1.58333,28.8)	38.6@(0.25833,4.6)
	K22W (max d-ang @ t, dP)	6.5@(0.60000,-4.0)	5.0@(0.55833,-5.0)	4.5@(0.57500,-3.8)	-39.2@(2.22499,196.1)	13.9@(0.80833,-11.6)
	OS Rel Trip / Marg					
	MH - OH				1.61666 sec	
	D602F at Forbes/Dorsey	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se
	G82R at Rugby/L20D at Drayton	999% / 482%	999% / 524%	999% / 518%	999% / 380%	999% / 534%
	R50M / F3M	483% / 312%	500% / 298%	528% / 314%	164% / 254%	463% / 284%
	B10T	229%	343%	253%	107%	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 | 5 | 3) / (1 | 1 | 1)	(1 | 4 | 4) / (1 | 1 | 1)	(1 | 4 | 3) / (1 | 1 | 1)	(1 | 4 | 3) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)
	Roseau 230 / Running 230	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 4 | 2)	(1 | 1 | 1) / (1 | 1 | 1)
	Shey 115 / Split Rock 115	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 5 | 5) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	m1b-so15aa.c2175-hks	m1b-so15aa.c2175-o3s	m1b-so15aa.c2175-o4s	m1b-so15aa.c2175-h53	m1b-so15aa.c2175-o13
Disturbance	hks	o3s	o4s	h53	o13
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(5T)(6T)	(5T)(6T)	(5T)(6T)	(1T)(5T)(6T)	(5T)(6T)

Table D-5: Study Case with Riel-Forbes-Chisago Outage

	Case No.	36	37	38	39	40
	Case Name	m1b-so15aa.c2175-o6s	m1b-so15aa.c2175-h63	m1b-so15aa.c2175-he3	m1b-so15aa.c2175-hgs	m1b-so15aa.c2175-hjs
	Disturbance	o6s	h63	he3	hgs	hjs
	Prior Outage	None	None	None	None	None
	Date/Time	APR 07 2010 15:18	APR 05 2010 12:07	APR 08 2010 11:17	APR 05 2010 12:10	APR 05 2010 12:12
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2376 / 260	2376 / 260	2376 / 260	2376 / 260	2376 / 260
	MHEX / L20D	451 / 293	451 / 293	451 / 293	451 / 293	451 / 293
	ECL-ARP / PRI-BYN	620 / 63	620 / 63	620 / 63	620 / 63	620 / 63
	MWEX / AHD-SLK	1400 / 619	1400 / 619	1400 / 619	1400 / 619	1400 / 619
	D602F / F601C	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
	OH E-W / OH>MH	189 / -196	189 / -196	189 / -196	189 / -196	189 / -196
	R50M / OH>MP	185 / 150	185 / 150	185 / 150	185 / 150	185 / 150
	G82R	-27	-27	-27	-27	-27
	Dorsey bipole / CU bipole	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103
	Dorsey Reserve / Wtrtn SVC	1132 / 36	1132 / 36	1132 / 36	1132 / 36	1132 / 36
	Forbes SVC / MSC	47 / 0	47 / 0	47 / 0	47 / 0	47 / 0
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045
	Roseau 500/Forbes 500	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027
	Chisago 500/EauClaire 345	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034
	Int Falls 115/Badoura 115	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026
	Drayton 230/Groton 345	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	999% / 999%	999% / 999%	999% / 999%	999% / 999%	999% / 999%
	G82R at Rugby/L20D at Drayton	999% / 655%	999% / 655%	999% / 655%	999% / 655%	999% / 655%
	R50M/F3M	664% / 332%	664% / 332%	664% / 332%	664% / 332%	664% / 332%
	B10T	343%	343%	343%	343%	343%
	Min/MaxTransientVltg					
	Arrowhd 230	0.97 | 1.01	0.98 | 1.04	0.98 | 1.04	0.99 | 1.04	0.98 | 1.04
	Boise 115	0.97 | 1.03	0.99 | 1.04	0.99 | 1.04	0.99 | 1.04	0.99 | 1.04
	Dorsey 230	1.04 | 1.10	1.04 | 1.05	1.04 | 1.05	1.04 | 1.07	1.04 | 1.07
	Forbes 230	1.01 | 1.04	1.01 | 1.03	1.01 | 1.03	1.01 | 1.04	1.01 | 1.04
	Riverton 230	0.97 | 1.01	0.99 | 1.03	1.00 | 1.03	1.01 | 1.04	1.00 | 1.04
	Coal Creek 230	1.00 | 1.07	0.99 | 1.07	0.99 | 1.07	1.00 | 1.07	1.00 | 1.07
	Jamestown 345	0.97 | 1.05	0.96 | 1.00	0.96 | 1.00	0.97 | 1.01	0.97 | 1.01
	Drayton 230	0.98 | 1.07	0.99 | 1.02	0.99 | 1.02	1.01 | 1.05	1.01 | 1.05
	Groton 345	0.95 | 1.01	0.99 | 1.03	0.99 | 1.03	1.00 | 1.04	0.99 | 1.04
	Minong 161	0.99 | 1.04	0.99 | 1.07	0.99 | 1.07	1.00 | 1.07	0.99 | 1.07
	Wahpeton 115	0.96 | 1.04	1.00 | 1.03	1.00 | 1.03	1.01 | 1.04	1.00 | 1.04
	Watertown 345	0.99 | 1.01	1.00 | 1.04	1.00 | 1.04	1.01 | 1.04	1.00 | 1.04
	Dynamic Voltage Warnings					
		none	none	none	none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold		/ 0.133	/ 0.133		
	Forbes DC Red (DCAR)	999%	999%	999%	999%	999%
	K22W (max +dP @ t, d-ang)	0.4@(0.10000,0.3)	16.8@(3.21664,-5.8)	17.0@(3.23331,-5.2)	16.6@(3.24164,-6.1)	17.1@(3.19998,-6.4)
	K22W (max -dP @ t, d-ang)	85.3@(1.65833,22.1)	41.4@(0.25833,5.0)	41.5@(0.26667,5.3)	44.4@(0.40000,7.0)	51.9@(0.40000,8.1)
	K22W (max d-ang @ t, dP)	24.7@(1.13333,-54.5)	17.5@(0.86666,-21.3)	18.1@(0.88333,-22.3)	15.8@(0.87500,-15.0)	17.4@(0.87500,-17.2)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se
	G82R at Rugby/L20D at Drayton	999% / 418%	999% / 507%	999% / 510%	999% / 522%	999% / 508%
	R50M / F3M	291% / 248%	414% / 274%	422% / 281%	424% / 266%	415% / 271%
	B10T	140%	359%	174%	174%	162%
	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 | 8 | 2) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)
	Roseau 230 / Running 230	(1 | 2 | 2) / (1 | 3 | 3)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)
	Shey 115 / Split Rock 115	(1 | 5 | 5) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 2 | 2)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	m1b-so15aa.c2175-o6s	m1b-so15aa.c2175-h63	m1b-so15aa.c2175-he3	m1b-so15aa.c2175-hgs	m1b-so15aa.c2175-hjs
Disturbance	o6s	h63	he3	hgs	hjs
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)

Table D-5: Study Case with Riel-Forbes-Chisago Outage

	Case No.	41	42	43	44	45
	Case Name	m1b-so15aa.c2175-o2s	m1b-so15aa.c2175-mcs	m1b-so15aa.c2175-mes	m1b-so15aa.c2175-mfs	m1b-so15aa.c2175-mts
	Disturbance	o2s	mcs	mes	mfs	mts
	Prior Outage	None	None	None	None	None
	Date/Time	APR 08 2010 11:14	APR 05 2010 12:31	APR 08 2010 13:56	APR 08 2010 13:58	APR 05 2010 12:37
	Comments					
	Steady State Flows					
	NDEX / EAST BIAS	2376 / 260	2376 / 260	2376 / 260	2376 / 260	2376 / 260
	MHEX / L20D	451 / 293	451 / 293	451 / 293	451 / 293	451 / 293
	ECL-ARP / PRI-BYN	620 / 63	620 / 63	620 / 63	620 / 63	620 / 63
	MWEX / AHD-SLK	1400 / 619	1400 / 619	1400 / 619	1400 / 619	1400 / 619
	D602F / F601C	0 / 0	0 / 0	0 / 0	0 / 0	0 / 0
	B10T / MH>SPC	165 / 60	165 / 60	165 / 60	165 / 60	165 / 60
	OH E-W / OH>MH	189 / -196	189 / -196	189 / -196	189 / -196	189 / -196
	R50M / OH>MP	185 / 150	185 / 150	185 / 150	185 / 150	185 / 150
	G82R	-27	-27	-27	-27	-27
	Dorsey bipole / CU bipole	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103	2113 / 1103
	Dorsey Reserve / Wtrtn SVC	1132 / 36	1132 / 36	1132 / 36	1132 / 36	1132 / 36
	Forbes SVC / MSC	47 / 0	47 / 0	47 / 0	47 / 0	47 / 0
	RCDC	0	0	0	0	0
	Steady State Vltgs					
	Dorsey 500/Dorsey 230	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045	1.038 / 1.045
	Roseau 500/Forbes 500	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027	1.016 / 1.027
	Chisago 500/EauClaire 345	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034	1.027 / 1.034
	Int Falls 115/Badoura 115	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026	1.025 / 1.026
	Drayton 230/Groton 345	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019	1.018 / 1.019
	SS OS Relay Margins					
	D602F at Forbes/Dorsey	999% / 999%	999% / 999%	999% / 999%	999% / 999%	999% / 999%
	G82R at Rugby/L20D at Drayton	999% / 655%	999% / 655%	999% / 655%	999% / 655%	999% / 655%
	R50M/F3M	664% / 332%	664% / 332%	664% / 332%	664% / 332%	664% / 332%
	B10T	343%	343%	343%	343%	343%
	Min/MaxTransientVltg					
	Arrowhd 230	0.98 | 1.01	0.98 | 1.04	0.98 | 1.04	0.99 | 1.05	0.98 | 1.04
	Boise 115	1.01 | 1.03	0.99 | 1.04	0.99 | 1.05	0.98 | 1.04	1.00 | 1.04
	Dorsey 230	1.04 | 1.05	1.04 | 1.05	1.03 | 1.06	1.03 | 1.05	1.04 | 1.05
	Forbes 230	1.01 | 1.03	1.01 | 1.04	1.01 | 1.04	1.01 | 1.04	1.01 | 1.04
	Riverton 230	1.01 | 1.03	0.99 | 1.05	1.00 | 1.05	0.99 | 1.04	0.99 | 1.05
	Coal Creek 230	0.99 | 1.05	0.95 | 1.07	0.99 | 1.08	1.00 | 1.07	0.95 | 1.08
	Jamestown 345	0.98 | 1.00	0.93 | 1.03	0.97 | 1.02	0.95 | 1.00	0.92 | 1.03
	Drayton 230	1.02 | 1.03	1.01 | 1.04	1.01 | 1.04	1.00 | 1.04	1.01 | 1.05
	Groton 345	1.01 | 1.03	0.97 | 1.04	1.00 | 1.03	0.99 | 1.03	0.97 | 1.04
	Minong 161	0.98 | 1.02	0.99 | 1.07	0.98 | 1.07	1.00 | 1.08	0.99 | 1.07
	Wahpeton 115	1.02 | 1.03	1.00 | 1.05	1.01 | 1.05	0.99 | 1.04	0.99 | 1.06
	Watertown 345	1.02 | 1.03	1.00 | 1.04	1.01 | 1.04	1.01 | 1.04	0.99 | 1.04
	Dynamic Voltage Warnings					
		none	none	none	none	none
	Worst Case Angle Damping					
	Dorsey SUVP / UdHold					
	Forbes DC Red (DCAR)	999%	999%	999%	999%	999%
	K22W (max +dP @ t, d-ang)	7.6@(3.16665,-1.6)	30.3@(2.43332,-5.9)	26.1@(2.45832,-5.7)	51.9@(2.38332,-19.5)	33.0@(2.41666,-7.4)
	K22W (max -dP @ t, d-ang)	27.6@(0.36667,4.0)	38.9@(0.54166,10.6)	31.9@(0.53333,9.0)	29.6@(0.39166,5.1)	35.5@(0.55000,9.7)
	K22W (max d-ang @ t, dP)	8.9@(0.80833,-5.7)	17.8@(0.92500,-17.4)	16.4@(0.94166,-14.4)	-22.1@(2.74998,40.2)	15.3@(0.90000,-14.4)
	OS Rel Trip / Marg					
	MH - OH					
	D602F at Forbes/Dorsey	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se	0.01667 sec / -0.01667 se
	G82R at Rugby/L20D at Drayton	999% / 589%	999% / 521%	999% / 536%	999% / 515%	999% / 533%
	R50M / F3M	536% / 308%	457% / 280%	451% / 270%	449% / 235%	482% / 281%
	B10T	241%	149%	178%	165%	155%
	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 | 3 | 3)	(4 | 4 | 4) / (0 | 3 | 3)	(4 | 4 | 3) / (0 | 3 | 3)	(4 | 4 | 4) / (0 | 3 | 3)
	Prairie 115 / Ramsey 230	(1 | 8 | 2) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 2 | 2) / (1 | 1 | 1)	(1 | 8 | 2) / (1 | 1 | 1)	(1 | 7 | 2) / (1 | 1 | 1)
	Roseau 230 / Running 230	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 1 | 1)	(1 | 1 | 1) / (1 | 2 | 2)	(1 | 1 | 1) / (1 | 1 | 1)
	Shey 115 / Split Rock 115	(1 | 3 | 3) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 2 | 2)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 1 | 1)	(1 | 3 | 3) / (1 | 2 | 2)
	Damping Performance	N/A	N/A	N/A	N/A	N/A

Case	m1b-so15aa.c2175-o2s	m1b-so15aa.c2175-mcs	m1b-so15aa.c2175-mes	m1b-so15aa.c2175-mfs	m1b-so15aa.c2175-mts
Disturbance	o2s	mcs	mes	mfs	mts
System Response	OK	OK	OK	OK	OK
70% or 120% Violations					
ORWG Criteria Violations					
Line Tripping	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)	(5T)(6T)