Report R164-08

MHEB Group TSR System Impact Study Out-Year Analysis; MH to US Requests

Prepared for

Midwest ISO

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Executive Summary

Several requests for long term firm transmission service have been made under the Midwest ISO's Open Access Transmission and Energy Markets Tariff. This report presents the results of a steady-state power flow analysis performed to evaluate the requests for transmission service shown in Table E-1. These requests seek to reserve 1540 MW of transmission service from Manitoba Hydro to various sinks in US. The out-year analysis was performed for a 2017 summer peak scenario.

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

Oasis Ref No	Service Type	Start time	Stop Time	POR	POD	Requested Capacity	Queue Date	Study Number
76703520	P-to-P	May-2007	May-2009	MHEB-MISO	CIN	80	11/15/2006	A339
76703521	P-to-P	May-2007	May-2009	MHEB-MISO	NSP	80	11/15/2006	A340
76703536	Network	Nov-2014	Nov-2024	MHEB-MISO	GRE	200	12/7/2006	A388
76703535	Network	Apr-2008	Apr-2013	MHEB-MISO	NSP	30	1/26/2007	A351
76703671	Network	Jun-2017	Jun-2027	MHEB-MISO	WPS	500	6/12/2007	A380
76703672	Network	Jun-2017	Jun-2037	MHEB-MISO	MP	250	7/6/2007	A383
76703685	P-to-P	Nov-2009	Nov-2014	MHEB-MISO	NSP	250	2/4/2008	A406
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)	1540		

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

Transmission Upgrade Options and Impacts

The objective of this study is to develop a transmission plan to accommodate the requested transmission service. Three network upgrade options are being evaluated:

1) Dorsey-Maple River-Helena 500 kV line
2) Dorsey-Maple River-Arrowhead 500 kV line with Arrowhead-Chisago-King 345 kV line
3) Dorsey-King 500 kV line

All three transmission upgrades include a 345 kV line from North LaCrosse to West Middleton.

Each transmission upgrade option was added to a summer peak benchmark case without the study TSRs in order to identify transmission impacts. The highest post-contingency loading in each case was compared with the highest post-contingency loading in the benchmark case. Impacts to the Mallard-Rugby 115 kV line and Fargo 230/115 kV transformer are significant in that these facilities do not overload before adding the transmission upgrades. All three upgrade options impact Mallard-Rugby; the Fargo transformer is only impacted by options 1 and 2. The Mallard-Rugby 115 kV line and Fargo transformer are impacted by the transmission upgrade options but are not further impacted by the requested transmission service. The post-contingency loading of the Fargo transformer does not exceed the emergency rating.

Table E-2: Impacts of Transmission Upgrade Options

Constraint	Rating (MVA)	Highest Post-Contingency Loading [1]			
		Benchmark	Benchmark with Option 1	Benchmark with Option 2	Benchmark with Option 3
Mallard-Rugby 115 kV line	80	100.1	115.8	114.0	114.6
Fargo 230/115 kV transformer #1	100	97.5	110.1	112.2	

Note 1: Blank cell indicates facility is not significantly affected

Transmission Service Impacts

TSR study cases were created by modeling the requested transmission service in the summer peak benchmark case along with one of the three transmission upgrade options. A nonlinear (ac) contingency analysis was performed on the benchmark and study cases and the incremental impact of the requested transmission service was evaluated by comparing flows and voltages without and with the service. Linear (dc) analysis was used to calculate distribution factors and estimate element loading for each TSR.

Facilities on which one or more TSR have a significant thermal impact are shown in Table E-3. A thermal impact is considered significant if the facility loading exceeds the applicable limit and the impact has a PTDF greater than 5% or an OTDF greater than 3%.

Table E-3: Significantly Affected Facilities

Monitored Element	Owner	Rating (MVA)	Option 1 Study Case	Option 2 Study Case	Option 3 Study Case	Contingency
Flowgate 3175:PALXFMMONSPE	MISO	295	X	X	X	OTDF Flowgate
Flowgate 3216:BYNCHEBYNCHE	PJM	1499	X	X	X	OTDF Flowgate
Flowgate 3218:BYRCHEBYRCHE	PJM	1499	X	X	X	OTDF Flowgate
Flowgate 6186:GENLACGENCOU	MISO	260	X	X	X	OTDF Flowgate
SHEYNNE-Fargo 230 kV line	NSP	403.9			X	C:Buffalo-Jamestown 345 kV line
Stone Lake 345/161 kV transformer	ATC	399		X		C:Stone Lake-Gardner Park 345 kV line
Eau Claire-Wheaton 161 kV line	NSP	300			X	C:B_XEL_KING-EAU_CLA
Jackson 161/69 kV transformer	NSP	47	X	X	X	Base Case
LaCrosse-Monroe County 161 kV line	NSP	167	X	X	X	Multiple Contingencies: C:North LaCrosse-West Middleton 345 kV line C: Stone Lake-Gardner Park 345 kV line C:B_XEL_KING-EAU_CLA C:ATC-ARP-OG1 C:ATC-ARP-OG2 C:ATC-ARP-OG3 C:ATC-ZN1-2
Fondulac-Hibbard 115 kV line	MP	44		X		Multiple Contingencies: C:Potlatch-Cloquet 115 kV line C:Cloquet-Arrowhead 115 kV line
Grand Rapids-20L Tap 115 kV line	MP	132		X		C:Blandin-20L Tap 115 kV line
Lake Marrion-Kenrick 115 kV line	GRE	201	X			Multiple Contingencies: C:Air Lake-Lake Marrion 115 kV line C:Blue Lake-Helena 345 kV line
Huron-Broadland 230 kV line	BEPC	400	X	X	X	C:Fort Thompson-Leland Olds 345 kV line
Broadland 345/230 kV transformer	BEPC	400	X	X	X	C:Fort Thompson-Leland Olds 345 kV line
Saratoga-Petenwell 138 kV line	ATC	72.2	X		X	Multiple Contingencies: C:ATC-ARP-OG1 C:ATC-ARP-OG2 C:ATC-ZN1-2
East Krok-Kewaunee 138 kV line	ATC	272.6	X	X	X	C:North Appleton-Kewaunee 345 kV line

A339 (80 MW MHEB-MISO to CIN)

A339 is a request for 80 MW of point-to-point transmission service from MHEB-MISO to CIN. A339 constraints are summarized in Table E-4.

Table E-4: A339 Flow-Based Analysis Constraints

Study	Constraint	Rating (MVA)	Significant Thermal Impacts - Highest Loading[1]		
			Option 1	Option 2	Option 3
A339	3175:PALXFMMONSPE	295	123.3%	122.8%	123.5%
	3218:BYRCHEBYRCHE	1499	103.0%	102.6%	102.9%

Note 1: Blank cell indicates facility is not significantly affected

A340 (80 MW MHEB-MISO to NSP)

A340 is a request for 80 MW of point-to-point transmission service from MHEB-MISO to NSP. A340 constraints are summarized in Table E-5.

Table E-5: A340 Flow-Based Analysis Constraints

Study	Constraint	Rating (MVA)	Significant Thermal Impacts - Highest Loading[1]		
			Option 1	Option 2	Option 3
A340	Lake Marrion-Kenrick 115 kV line	201	101.6%	100.3%	

Note 1: Blank cell indicates facility is not significantly affected

A388 (200 MW MHEB-MISO to GRE)

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

A351 (30 MW MHEB-MISO to NSP)

A351 is a request for 30 MW of network transmission service from MHEB-MISO to NSP. A339 constraints are summarized in Table E-6.

Table E-6: A351 Flow-Based Analysis Constraints

Study	Constraint	Rating (MVA)	Significant Thermal Impacts - Highest Loading[1]		
			Option 1	Option 2	Option 3
A351	Lake Marrion-Kenrick 115 kV line	201	100.3%		

Note 1: Blank cell indicates facility is not significantly affected

A380 (500 MW MHEB-MISO to WPS)

A380 is a request for 500 MW of network transmission service from MHEB-MISO to WPS. A380 constraints are summarized in Table E-7.

Table E-7: A380 Flow-Based Analysis Constraints

Study	Constraint	Rating (MVA)	Significant Thermal Impacts - Highest Loading[1]		
			Option 1	Option 2	Option 3
A380	3216:BYNCHEBYNCHE	1499	100.9%	100.4%	100.7%
	3218:BYRCHEBYRCHE	1499	104.1%	103.6%	104.0%
	Stone Lake 345/161 kV transformer	399		105.7%	
	Eau Claire-Wheaton 161 kV line	300			103.1%
	LaCrosse-Monroe County 161 kV line	167	118.6%	112.0%	118.8%
	Huron-Broadland 230 kV line	400		102.0%	
	Broadland 345/230 kV transformer	400		103.4%	
	Saratoga-Petenwell 138 kV line	72.2	114.4%		114.0%
	East Krok-Kewaunee 138 kV line	272.6	101.7%	100.2%	101.3%

Note 1: Blank cell indicates facility is not significantly affected

A383 (250 MW MHEB-MISO to MP)

A383 is a request for 250 MW of network transmission service from MHEB-MISO to MP. A383 constraints are summarized in Table E-8.

Table E-8: A383 Flow-Based Analysis Constraints

Study	Constraint	Rating (MVA)	Significant Thermal Impacts - Highest Loading[1]		
			Option 1	Option 2	Option 3
A383	SHEYNNE-Fargo 230 kV line	403.9			105.8%
	Fondulac-Hibbard 115 kV line	44		154.7%	
	Grand Rapids-20L Tap 115 kV line	132		102.1%	

Note 1: Blank cell indicates facility is not significantly affected

A406 (250 MW MHEB-MISO to NSP)

A406 is a request for 250 MW of point-to-point transmission service from MHEB-MISO to NSP. A406 constraints are summarized in Table E-9.

Table E-9: A406 Flow-Based Analysis Constraints

Study	Constraint	Rating (MVA)	Significant Thermal Impacts - Highest Loading[1]		
			Option 1	Option 2	Option 3
A406	Stone Lake 345/161 kV transformer	399		107.7%	
	Lake Marrion-Kenrick 115 kV line	201	105.9%		

Note 1: Blank cell indicates facility is not significantly affected

A416 (50 MW MHEB-MISO to NSP/WPPI)

A416 is a request for 250 MW of network transmission service from MHEB-MISO to NSP. A416 constraints are summarized in Table E-10.

Table E-10: A416 Flow-Based Analysis Constraints

Study	Constraint	Rating (MVA)	Significant Thermal Impacts - Highest Loading[1]		
			Option 1	Option 2	Option 3
A416	6186:GENLACGENCOU	260	126.5%	123.6%	123.0%
	Stone Lake 345/161 kV transformer	399		109.0%	
	Jackson 161/69 kV transformer	47	103.3%	101.1%	103.3%

Note 1: Blank cell indicates facility is not significantly affected

A417 (100 MW MHEB-MISO to WEC)

A417 is a request for 250 MW of network transmission service from MHEB-MISO to WEC. A417 constraints are summarized in Table E-11.

Table E-11: A417 Flow-Based Analysis Constraints

Study	Constraint	Rating (MVA)	Significant Thermal Impacts - Highest Loading[1]		
			Option 1	Option 2	Option 3
A417	3216:BYNCHEBYNCHE	1499	101.3%	100.8%	101.1%
	3218:BYRCHEBYRCHE	1499	104.6%	104.0%	104.4%
	Stone Lake 345/161 kV transformer	399		111.6%	
	LaCrosse-Monroe County 161 kV line	167			120.9%
	Huron-Broadland 230 kV line	400		105.8%	
	Broadland 345/230 kV transformer	400		107.5%	

Note 1: Blank cell indicates facility is not significantly affected

Section

1

Steady-State Analysis

1.1 Methodology

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

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

1.2 Computer Programs

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

1.3 Model Development

1.3.1 Summer Peak Benchmark Case

A 2017 Summer Peak benchmark case without the study TSRs or associated transmission upgrades was developed. The source was a MTEP08 case that includes the projects listed in Appendix A and all existing MH to US firm transmission service commitments.

The summer peak benchmark case was developed by adding confirmed and study transmission service requests not already included in the MTEP08 case, along with several MH area updates including the 3rd dc bipole at Riel and miscellaneous updates and corrections as described in the following sections.

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

1.3.1.1 Existing MH to US Firm Transmission Service

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

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

TSR Ref#	Capacity (MW)	Start Time	End Time	Service
76703190	30	11/1/2008	12/1/2009	YEARLY FIRM PTP
76703232	30	5/1/2009	5/1/2012	YEARLY FIRM PTP
76703181	50	5/1/2009	5/1/2015	YEARLY FIRM PTP
76703231	50	11/1/2008	11/1/2014	YEARLY FIRM PTP
76703238	55	11/1/2008	5/1/2010	YEARLY FIRM PTP
76703207	64	5/1/2009	5/1/2013	YEARLY FIRM PTP
76703187	70	11/1/2008	5/1/2011	YEARLY FIRM PTP
76703185	100	11/1/2008	6/1/2009	YEARLY FIRM PTP
76703186	100	11/1/2008	5/1/2010	YEARLY FIRM PTP
76703221	150	5/1/2009	11/1/2009	YEARLY FIRM PTP
76703222	150	5/1/2009	11/1/2009	YEARLY FIRM PTP
76703218	200	5/1/2009	11/1/2009	YEARLY FIRM PTP
76703237	213	11/1/2008	11/1/2009	YEARLY FIRM PTP
76703234	529	11/1/2008	5/1/2015	YEARLY FIRM PTP
76735261	50	5/1/2009	5/1/2014	YEARLY FIRM PTP
Total	1841 MW			

1.3.1.2 WAPA TSRs

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

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

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

1.3.1.3 Prior-Queued Midwest ISO TSRs

Table 1-2 shows prior-queued Midwest ISO TSRs and confirmed requests that were added to the 2017 benchmark case using sources and sinks provided by Midwest ISO.

Table 1-2: Midwest ISO TSRs Added to the 2017 SuPk Case

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

1.3.1.4 Midwest ISO Network Resource Generation

The NR generating facilities listed in Table 1-3 were added to the summer peak benchmark case.

Table 1-3: Midwest ISO NR Generation Added to the 2017 SuPk Case

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

1.3.1.5 Manitoba Hydro (MH) System Updates

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

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

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

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

1.3.1.6 Miscellaneous Updates and Corrections

Table 1-4 shows other miscellaneous model updates.

Table 1-4: Miscellaneous Updates and Corrections

Area	Description
ATC LLC	Redispatched generation in control areas ALTE and WEC so that area slack generator output is within limits
WAPA	Topology corrections at Penn 115 kV and Hilken 230 kV buses
XEL	Removed extraneous BRIGO facilities
XEL	Dispatched River Falls generation
MH, SPC	Reduced net flow on MH-SPC ties to 0 MW
XEL/ WAPA	Turned on Forbes SVC and adjust SVC output at Forbes, Fargo and Watertown
WAPA	Purged extraneous 230/115/13.2 kV transformer at Winger and Canby 345 kV-Granite Falls 230 kV line.
WAPA	Dispatched Leland Olds Unit #1 at 225 MW

1.3.2 Summer Peak Study Cases

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

1.3.2.1 Transmission Upgrade Options

The transmission upgrade options proposed by the ad hoc study group are summarized in Table 1-5. Diagrams depicting the proposed upgrades are included in Appendix B.

Table 1-5: Transmission Upgrade Options

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

The cost estimates shown in Table 1-6 are based on $/mile costs taken from the JCSP 2008 Interim Stakeholder Meeting Introduction Presentation and adjusted down from 2024 dollars to 2018 dollars using a 3% escalation factor.

Table 1-6: Cost Estimates

Option	Cost in 2018
Option 1	$1,434,401,161
Option 2	$1,697,371,217
Option 3	$1,354,944,842

1.3.2.2 Source and Sinks for Study TSRs

The TSR source is the Dorsey inverter station and the 1540 MW aggregate study TSRs were sourced by increasing the injection from the existing two dc bipoles from 1740 MW in the benchmark case to 3280 MW in the study case. The study TSRs were sunk at the generators shown in Table 1-7.

Table 1-7: MH to US TSR Sinks

Bus #	Generator Name	MW
	REMOVED	

1.4 Contingency Criteria

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

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

Existing 500 kV and 230 kV HVDC reduction Special Protection Schemes (SPS) were simulated in the contingency analysis. The only significant impacts were due to outage of one Dorsey 500/230 kV transformer or outage of the Riel 500/230 kV transformer; impacts for the transformer outages have been screened from the results since the Dorsey scheme will be adjusted when bipole 3 goes in service.

HVDC reduction assumed for network upgrade options is summarized in Table 1-8.

Table 1-8: HVDC Reduction Assumed for Network Upgrade Options

Option	Initiating Event	Flow Measurement	% Reduction at Dorsey Based on Measured Flow
1, 2	Dorsey-Maple River 500 kV line trip	Dorsey-Maple River	100%
1, 2	Maple River 500/230 kV transformer trip	Dorsey-Maple River	None
1	Maple River-Helena 500 kV line trip	Dorsey-Maple River	100%
1	Helena 500/230 kV transformer trip	Dorsey-Maple River	100%
2	Arrowhead 500/230 kV transformer trip	Dorsey-Maple River	100%
2	Maple River-Arrowhead 500 kV line trip	Dorsey-Maple River	100%
3	Dorsey-King 500 kV line trip	Dorsey-King	100%
3	King 500/230 kV transformer trip	Dorsey-King	100%

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

1.5 Monitored Facilities

Monitored facilities and associated thermal and voltage limits are shown in Table 1-9.

Table 1-9: Monitored Facilities and Limits

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

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

1.6 Reliability Margins

Capacity benefit margin (CBM) and transmission reliability margin (TRM) are accounted for in the flowgate definitions. All other system elements were monitored as shown in Table 1-9.

1.7 Performance Criteria

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

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

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

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

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

1.8 Network Analysis Results

1.8.1 Transmission Upgrade Impacts

Each transmission upgrade option was added to the summer peak benchmark case without the study TSRs in order to identify transmission impacts. The highest post-contingency loading in each case was compared with the highest post-contingency loading in the benchmark case; differences exceeding 2% of the monitored element rating are shown in Appendix C, Table C-1.

Impacts to the Mallard-Rugby 115 kV line and Fargo 230/115 kV transformer are significant in that the highest post-contingency loading is less than the facility rating before adding the transmission upgrades. All three upgrade options impact Mallard-Rugby; the Fargo transformer is only impacted by options 1 and 2. The post-contingency loading of the Fargo transformer does not exceed the emergency rating.

1.8.2 Transmission Service Impacts

Facilities on which one or more TSR have a significant thermal impact are shown in Appendix C, Table C-2. A thermal impact is considered significant if the facility loading exceeds the limit shown in Table 1-9 and the impact has a PTDF greater than 5% or an OTDF greater than 3%. There are no significant voltage impacts attributable to any TSR.

1.8.2.1 A339 (80 MW MHEB-MISO to CIN)

A339 is a request for 80 MW of point-to-point transmission service from MHEB-MISO to CIN. Request A339 has a significant impact on the Palmyra transformer flowgate (#3175) and the Byron-Cherry flowgate (#3218) as shown in Table 1-10; impacts and loading are similar for each of the transmission upgrade options.

1.8.2.2 A340 (80 MW MHEB-MISO to NSP)

A340 is a request for 80 MW of point-to-point transmission service from MHEB-MISO to NSP. With respect to request A340, no significantly affected facilities were identified for transmission upgrade options 2 or 3. With upgrade option 1, outage of the Blue Lake-Helena 345 kV line results in a 102% loading on the Lake Marion-Kenrick 115 kV line as shown in Table 1-11.

1.8.2.3 A388 (200 MW MHEB-MISO to GRE)

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

1.8.2.4 A351 (30 MW MHEB-MISO to NSP)

A351 is a request for 30 MW of network transmission service from MHEB-MISO to NSP. With respect to request A351, no significantly affected facilities were identified for transmission upgrade options 2 or 3. With upgrade option 1, outage of the Blue Lake-Helena 345 kV line results in a 100.3% loading on the Lake Marion-Kenrick 115 kV line as shown in Table 1-13.

1.8.2.5 A380 (500 MW MHEB-MISO to WPS)

A380 is a request for 500 MW of network transmission service from MHEB-MISO to WPS. Multiple constraints have been identified for request A406 as shown in Table 1-14.

Four of the significantly affected facilities are common to all three transmission upgrade options: the Byron-Cherry flowgates (#3216 and #3218), the LaCrosse-Monroe County 161 kV line, and the East Krok-Kewaunee 138 kV line. There are at least one other significantly affected facility for each upgrade option. Post-contingency loading on the Broadland 345/230 kV transformer and the Huron-Broadland 230 kV line is within emergency limits.

1.8.2.6 A383 (250 MW MHEB-MISO to MP)

A383 is a request for 250 MW of network transmission service from MHEB-MISO to MP. Multiple constraints have been identified for request A383 as shown in Table 1-15.

With respect to request A383, no significantly affected facilities were identified for transmission upgrade option 1. With upgrade option 2, request A406 has a significant thermal impact on the Fondulac-Hibbard 115 kV line and the Grand Rapids-20L Tap 115 kV line. With upgrade option 3, A406 has a significant impact on the Sheynne-Fargo 230 kV line.

1.8.2.7 A406 (250 MW MHEB-MISO to NSP)

A406 is a request for 250 MW of point-to-point transmission service from MHEB-MISO to NSP. Request A406 has a significant thermal impact on the facilities shown in Table 1-16.

With transmission upgrade option 1, request A406 has a significant impact on the Lake Marion-Kenrick 115 kV line. With upgrade option 2, request A406 has a significant thermal impact on the Stone Lake 345/161 kV transformer. No significantly affected facilities were identified for transmission upgrade option 3.

1.8.2.8 A416 (50 MW MHEB-MISO to NSP/WPPI)

A416 is a request for 250 MW of network transmission service from MHEB-MISO to NSP. Request A416 has a significant thermal impact on the facilities shown in Table 1-17.

With each of the transmission upgrade options, request A416 has a significant impact on the Jackson 161/69 kV transformer and the Genoa-LaCrosse flowgate (#6186). With option 2, A416 also has a significant thermal impact on the Stone Lake 345/161 kV transformer.

1.8.2.9 A417 (100 MW MHEB-MISO to WEC)

A417 is a request for 250 MW of network transmission service from MHEB-MISO to WEC. Multiple constraints have been identified for request A417 as shown in Table 1-18.

With transmission upgrade option 1, request A417 has a significant impact on two Byron-Cherry flowgates (#3216 and #3218). With upgrade option 2, request A417 has a significant thermal impact on the Byron-Cherry flowgates, the Stone Lake 345/161 kV transformer, the Broadland 345/230 kV transformer, and the Broadland-Huron 230 kV line. With upgrade option 3, A417 has a significant impact on the Byron-Cherry flowgates and the LaCrosse-Monroe County 345 kV line. Post-contingency loading on the Broadland 345/230 kV transformer and Huron-Broadland 230 kV line is within emergency limits.

Table 1-10: A339 Thermal Constraints (80 MW; MHEB-MISO to CIN)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
3175:PALXFMMONSPE	MISO	295	122.0	123.3	5.0	C:Contingency of FlowGate 3175
3218:BYRCHEBYRCHE	PJM	1499	102.7	103.0	5.3	C:Contingency of FlowGate 3218

Option 2

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
3175:PALXFMMONSPE	MISO	295	121.4	122.8	5.0	C:Contingency of FlowGate 3175
3218:BYRCHEBYRCHE	PJM	1499	102.3	102.6	5.2	C:Contingency of FlowGate 3218

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
3175:PALXFMMONSPE	MISO	295	122.1	123.5	5.0	C:Contingency of FlowGate 3175
3218:BYRCHEBYRCHE	PJM	1499	102.6	102.9	5.2	C:Contingency of FlowGate 3218

Table 1-11: A340 Thermal Constraints (80 MW MHEB-MISO to NSP)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
615440 GRE-LKMARN 7 115 616929 GRE-KENRICK7 115 1	GRE	201	100.3	101.6	3.2	C:601015 BLUE LK3 345 601050 HELENAS 3 345 1

Option 2

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

Option 3

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

Table 1-12: A388 Thermal Constraints (200 MW MHEB-MISO to GRE)

Option 1

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

Option 2

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

Option 3

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

Table 1-13: A351 Thermal Constraints (30 MW MHEB-MISO to NSP)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
615440 GRE-LKMARN 7 115 616929 GRE-KENRICK7 115 1	GRE	201	99.8	100.2	3.2	C:601015 BLUE LK3 345 601050 HELENAS 3 345 1

Option 2

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

Option 3

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

Table 1-14: A380 Thermal Constraints (500 MW MHEB-MISO to WPS)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
3216:BYNCHEBYNCHE	PJM	1499	99.7	100.9	3.4	C:Contingency of FlowGate 3216
3218:BYRCHEBYRCHE	PJM	1499	102.9	104.1	3.6	C:Contingency of FlowGate 3218
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	105.6	118.6	4.4	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	104.1	117.1	4.3	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	99.8	111.9	4	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	97.9	107.7	3.3	C:601044 NLAX 3 345 699829 WMD345 345 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	95.9	105.4	3.2	C:B_XEL_KING-EAU_CLA Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 602021 EAU CLA5 161 9
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	91.5	103.1	3.9	C:ATC-ARP-OG3 Open 699244 ARP 345 345 699785 ROCKY RN 345 1 Open 699241 POE 138 138 699939 SAL 138 138 1 Open 698948 HOLYWOOD 138 699241 POE 138 138 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	92.7	102.3	3.2	C:699450 ST LAKE 345 699676 GARDR PK 345 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	81.3	114.4	4.8	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	75.4	107.4	4.6	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	72.4	104.1	4.6	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699619 EAST KRK 138 699620 KEWAUNEE 138 1	ATC	272.6	88.2	101.7	7.4	C:699359 N APP 1 345 699630 KEWAUNEE 345 1

Table 1-14 (continued): A380 Thermal Constraints (500 MW MHEB-MISO to WPS)

Option 2

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
3218:BYRCHEBYRCHE	PJM	1499	102.5	103.6	3.3	C:Contingency of FlowGate 3218
3216:BYNCHEBYNCHE	PJM	1499	99.3	100.4	3.2	C:Contingency of FlowGate 3216
602017 ST LAKE5 161 699450 ST LAKE 345 1	XEL	399	96	105.7	7.8	C:699450 ST LAKE 345 699676 GARDR PK 345 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	100.1	112	4	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	98.3	110	3.9	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	94.3	105.3	3.7	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	91.7	101.1	3.1	C:699450 ST LAKE 345 699676 GARDR PK 345 1
652514 HURON 4 230 659205 BRDLAND4 230 1	BEPC	400	98.3	102	3.0	C:652506 FTTHOMP3 345 659105 LELANDO3 345 1
659120 BRDLAND3 345 659204 BRDLNDTY 345 1	BEPC	400	99.7	103.4	3.0	C:652506 FTTHOMP3 345 659105 LELANDO3 345 1
699619 EAST KRK 138 699620 KEWAUNEE 138 1	ATC	272.6	86.9	100.2	7.3	C:699359 N APP 1 345 699630 KEWAUNEE 345 1

Table 1-14 (continued): A380 Thermal Constraints (500 MW MHEB-MISO to WPS)

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
3216:BYNCHEBYNCHE	PJM	1499	99.6	100.7	3.3	C:Contingency of FlowGate 3216
3218:BYRCHEBYRCHE	PJM	1499	102.8	104	3.5	C:Contingency of FlowGate 3218
602021 EAU CLA5 161 602030 WHT 14 5 161 1	XEL	300	93.7	103.1	5.7	C:B_XEL_KING-EAU_CLA Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 602021 EAU CLA5 161 9
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	105.8	118.8	4.4	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	104.2	117.1	4.3	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	99.8	111.9	4	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	97	106.6	3.2	C:601044 NLAX 3 345 699829 WMD345 345 1
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	95.8	105.2	3.1	C:B_XEL_KING-EAU_CLA Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 602021 EAU CLA5 161 9
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	91.5	103.2	3.9	C:ATC-ARP-OG3 Open 699244 ARP 345 345 699785 ROCKY RN 345 1 Open 699241 POE 138 138 699939 SAL 138 138 1 Open 698948 HOLYWOOD 138 699241 POE 138 138 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	81.1	114	4.7	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	75.8	107.6	4.6	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699240 SAR 138 138 699808 PETENWEL 138 1	ATC	72.2	72.2	103.7	4.5	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699619 EAST KRK 138 699620 KEWAUNEE 138 1	ATC	272.6	87.9	101.3	7.3	C:699359 N APP 1 345 699630 KEWAUNEE 345 1

Table 1-15: A383 Thermal Constraints (250 MW MHEB-MISO to MP)

Option 1

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

Option 2

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
608666 FONDULAC 115 608676 HIBBARD7 115 1	MP	44	59.3	154.7	16.8	C:608667 POTLTCH7 115 608668 CLOQUET7 115 1
608666 FONDULAC 115 608676 HIBBARD7 115 1	MP	44	67.3	146.1	13.9	C:608668 CLOQUET7 115 608673 ARROWHD7 115 1
608740 GR RPDS7 115 608781 20L TAP7 115 1	MP	132	62.4	102.1	21.0	C:608779 BLANDIN7 115 608781 20L TAP7 115 1

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
602006 SHEYNNE4 230 652435 FARGO 4 230 1	NSP	403.9	103.7	105.8	3.4	C:620358 BUFFALO3 345 620369 JAMESTN3 345 1

Table 1-16: A406 Thermal Constraints (250 MW MHEB-MISO to NSP)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
615440 GRE-LKMARN 7 115 616929 GRE-KENRICK7 115 1	GRE	201	101.9	105.9	3.2	C:601015 BLUE LK3 345 601050 HELENAS 3 345 1
615440 GRE-LKMARN 7 115 616929 GRE-KENRICK7 115 1	GRE	201	98.5	102.4	3.1	C:603131 AIRLAKE7 115 615440 GRE-LKMARN 7 115 1

Option 2

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
602017 ST LAKE5 161 699450 ST LAKE 345 1	ATC	399	105.5	107.7	3.6	C:699450 ST LAKE 345 699676 GARDR PK 345 1

Option 3

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

Table 1-17: A416 Thermal Constraints (50 MW MHEB-MISO to NSP)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6186:GENLACGENCOU	MISO	260	125.9	126.5	3.5	C:Contingency of FlowGate 6186
602022 JACKSON5 161 605309 JACKCO 8 69.0 1	XEL	47	97.4	103.3	5.5	** Base Case **

Option 2

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6186:GENLACGENCOU	MISO	260	123.0	123.6	3.3	C:Contingency of FlowGate 6186
602017 ST LAKE5 161 699450 ST LAKE 345 1	ATC	399	107.7	109.0	9.9	C:699450 ST LAKE 345 699676 GARDR PK 345 1
602022 JACKSON5 161 605309 JACKCO 8 69.0 1	XEL	47	95.2	101.1	5.5	** Base Case **

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
6186:GENLACGENCOU	MISO	260	122.3	123.0	3.2	C:Contingency of FlowGate 6186
602022 JACKSON5 161 605309 JACKCO 8 69.0 1	XEL	47	97.5	103.3	5.5	** Base Case **

Table 1-18: A417 Thermal Constraints (100 MW MHEB-MISO to WEC)

Option 1

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
3216:BYNCHEBYNCHE	PJM	1499	100.9	101.3	5.1	C:Contingency of FlowGate 3216
3218:BYRCHEBYRCHE	PJM	1499	104.2	104.6	5.3	C:Contingency of FlowGate 3218

Option 2

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
3216:BYNCHEBYNCHE	PJM	1499	100.4	100.8	5.1	C:Contingency of FlowGate 3216
3218:BYRCHEBYRCHE	PJM	1499	103.6	104.0	5.3	C:Contingency of FlowGate 3218
602017 ST LAKE5 161 699450 ST LAKE 345 1	ATC	399	109.0	111.6	6.8	C:699450 ST LAKE 345 699676 GARDR PK 345 1
652514 HURON 4 230 659205 BRDLAND4 230 1	BEPC	400	104.5	105.8	3.3	C:652506 FTTHOMP3 345 659105 LELANDO3 345 1
659120 BRDLAND3 345 659204 BRDLNDTY 345 1	BEPC	400	105.9	107.5	3.3	C:652506 FTTHOMP3 345 659105 LELANDO3 345 1

Option 3

Monitored Branches	Owner	Rating	Pre TSR Loading (%)	Post TSR Loading (%)	DF (%)	Contingency
3218:BYRCHEBYRCHE	PJM	1499	104.0	104.4	5.2	C:Contingency of FlowGate 3218
3216:BYNCHEBYNCHE	PJM	1499	100.7	101.2	5.0	C:Contingency of FlowGate 3216
602023 LACROSS5 161 602025 MONROCO5 161 1	XEL	167	119.1	120.9	3.0	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1

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Appendix

A

MTEP Projects Applied from MOD

Project ID	Project Name	Phase ID	Phase Name	Effective Date
3125	ATC_(345)_new-Clintonville-Wern	3443	ATC_(345)_new-Clintonville-Wern	11/24/2008
3520	XEL-1486-MARYLAKE-BUFFALO	3855	XEL-MARYLAKE-BUFFALO	12/1/2008
4572	XEL-GRANDMEADOW	5155	GRANDMEDOW	12/1/2008
4050	XEL-MTEP-PROJECT-2119-G417	4550	XEL-KODA-ENERGY-CENTER	12/1/2008
4588	SMP-GRANDMEADOW-WF	5172	SMP-GRANDMEADOW-WF	12/31/2008
4770	ITCT-MISO-905-MRYPP_DECOMMISSIO	5338	Marysville Decommissioning	12/31/2008
4263	ALTW_1758_Beaver_Channel-2nd_AV	4810	Rebuild 2.5 mi of 69 kV to 161	12/31/2008
3644	ALTW_Hills-Washington-1755_69kV	3987	69kV Rbld Hills-Kalona-N_Crane	12/31/2008
4960	ITCM_1752_Jefferson_Co_69_kV_31	5547	Jefferson Co 69 kV 31.2 MVAR CA	12/31/2008
4959	ITCM_1751_Jefferson_Co_161-69_k	5546	Jefferson Co 161-69 kV 100 MVA	12/31/2008
3713	ALTW_1289_Marshalltown-Toledo_1	4074	Rbld Marshalltowm-Toledo 1115kV	12/31/2008
4544	SMP-MISO-LAKECITY-1367-AREA [08	5127	SMP-MISO-LAKECITY-AREA-ADD	1/15/2009
3132	ATC_(352)_CON-IRGR138_v29	3450	ATC_(352)_CON-IRGR138_v29	3/12/2009
3697	ALTW_1522_6th-Beverly_161kV	4054	6th Street-Beverly	4/1/2009
4380	ATC_(570)_ROR_to_ELK_138R_Conv_	4941	ATC_(570)_ROR_to_ELK_138R_Conv_	4/15/2009
3121	ATC_(177)_J36Rebuild_WHB-CAR	3439	ATC_(177)_J36Rebuild_WHB-CAR	4/30/2009
3126	ATC_(345)_rebuilding-Badger-Cli	3444	ATC_(345)_rebuilding-Badger-Cli	4/30/2009
4508	ATC_1268_(Z3)_Artesian_138_Cap_	5089	ATC_1268_(Z3)_Artesian_138_Cap_	4/30/2009
3183	ATC_(1677)_Cornell-Chandler_167	3501	ATC_(1677)_Cornell-Chandler_167	5/1/2009
3508	XEL-1371-BLACKDOG-WILSON2-UPGRA	3841	XEL-BLACKDOG-WILSON2	6/1/2009
3527	XEL-1457-HAZEL	3865	XEL-HAZLE	6/1/2009
3533	XEL-1548-LACROSSE	3871	XEL-LACROSSE_CAPBANK	6/1/2009
3558	XEL-385-825WIND	3901	XEL-NOBLES_TR-RATING	6/1/2009
3553	XEL-1489-WOODBURY-TANNERSLAKE	3892	XEL-WOODBURY-TANNERSLAKE	6/1/2009
4958	ITCM_1341_Hazleton_161-69_kV_75	5545	Replace both Hazleton 161-69 kV	6/1/2009
3632	ALTW_Salem-1287_345-161kV_448_M	3975	345-161KV_448_MVA_Xfmr	6/1/2009
3547	XEL-1487-SOMMERSET	3886	XEL-SOMMERSET	6/1/2009
3541	XEL-1368-1369-1370-NEWRICHMOND	3879	NEW_RICHMOND_AREA_2009	6/1/2009
3539	XEL-1548-MONROECO_CAPBANK	3877	XEL-MONROECO_CAPBANK	6/1/2009
3544	XEL-1455-MERP-RIVERSIDE	3883	XEL-RIVERSIDE	6/1/2009
3542	XEL-1373-NEWULM-TS	3881	XEL-NEWULM_TS	6/1/2009
4741	XEL-1457-BRIGO	5309	XEL-BRIGO	6/1/2009
3159	ATC_(1279)_North_Beaver_Dam_Cap	3477	ATC_(1279)_North_Beaver_Dam_Cap	6/1/2009
4772	ITCT-MISO-1488-DURANT	5340	Durant	6/1/2009
3127	ATC_(345)_rebuilding-Badger-WSh	3445	ATC_(345)_rebuilding-Badger-WSh	6/1/2009
3701	XEL-552-IRONWOOD_2ND_TR	4058	XEL-IRONWOOD2NDTR	6/1/2009
3186	ATC_(1681)_Uprate_NLG_to_LG_69k	3504	ATC_(1681)_Uprate_NLG_to_LG_69k	6/1/2009
3205	ATC_(1944)_Concord_G3-4-generat	3523	ATC_(1944)_Concord_G3-4-generat	6/1/2009
4499	ATC_(1682)_Rebuild_Crivitz-HiFa	5080	ATC_(1682)_Rebuild_Crivitz-HiFa	6/1/2009
3184	ATC_(1679)_Richland_Center_Olso	3502	ATC_(1679)_Richland_Center_Olso	6/2/2009
3754	OTP-MTEPA-2091-CASSLKXFMR	4127	REPLACE XFMR	7/1/2009
3755	OTP-MTEPA-2092-SOCASCADE	4128	NEW 115 TO S CASCADE	7/1/2009
4018	GRE-MRO-PROJECT-BBP(20143)	4497	BBP-PHASE1	8/1/2009
3169	ATC_(1555)_Perkins_Cap_2x16_3_v	3487	ATC_(1555)_Perkins_Cap_2x16_3_v	8/15/2009
4777	ITCT-MISO-1871-HURST	5345	Hurst	8/31/2009

Project ID	Project Name	Phase ID	Phase Name	Effective Date
3535	XEL-1545-MANKATO_115KV_LOOP	3873	XEL-MANKATO_LOOP	9/1/2009
3182	ATC_(1676)_LAnse_Cap_1x4_08	3500	ATC_(1676)_LAnse_Cap_1x4_08	9/15/2009
3167	ATC_(1553)_Hiawatha_Cap_1x16_3_	3485	ATC_(1553)_Hiawatha_Cap_1x16_3_	9/15/2009
3134	ATC_(352)_IRGR-ASPN138	3452	ATC_(352)_IRGR-ASPN138	9/15/2009
3124	ATC_(339)_Remove_Boxelder_Tempo	3442	ATC_(339)_Remove_Boxelder_Tempo	9/30/2009
4396	ATC_(339)_Jefferson-Stonybrook_	4958	ATC_(339)_Jefferson-Stonybrook_	9/30/2009
3128	ATC_(345)_rebuilding-WhiteClay-	3446	ATC_(345)_rebuilding-WhiteClay-	10/1/2009
3165	ATC_(1463)_Twin_Creeks-G384	3483	ATC_(1463)_Twin_Creeks-G384	10/1/2009
4107	OTP-MTEPC-1792-CSLTN ETHANOL	4644	BUFFALO-CSLTN ETOH	10/1/2009
3176	ATC_(1667)_Pine_River_Ring_Bus_	3494	ATC_(1667)_Pine_River_Ring_Bus_	11/14/2009
3120	ATC_(177)_GDP-HWY22_345_T2-1113	3438	ATC_(177)_GDP-HWY22_345_T2-1113	12/1/2009
4016	GRE-PROJECT4495-ENTPPK_CRKDLK(2	4495	115/69 line and xfmr	12/1/2009
4254	XEL-1956-WILMARTH-BLUELAKE	4795	XEL-WILMARTH-BLUELAKE-UPGRADE	12/1/2009
4776	ITCT-MISO-1870-CLYDE	5344	Clyde	12/2/2009
3387	ATC_(345)_revised_Morgan-CW-Wer	3707	ATC_(345)_revised_Morgan-CW-Wer	12/2/2009
3641	ALTW_Grand_Junction-1644_161kV_	3984	Grand Junciton161kV 50MVAR	12/31/2009
3642	ALTW_Leon-1645_69kV_7MVAR	3985	Leon 69kV 7.2MVAR	12/31/2009
3640	ALTW_Anita-1643_161kV_24MVAR	3983	Anita 161kV 50MVAR	12/31/2009
3631	ALTW_Arnold-Washburn_1739-161kV	3974	Arnld-Vin-Dysart-Wash_161kV lin	12/31/2009
3638	ALTW_Ottumwa-1641_161kV_50MVAR	3981	OGS 161kV 50MVAR	12/31/2009
3645	ALTW_N_Cntrville_69kV-1772_7MVA	3988	69kV Cap	12/31/2009
3699	ITCM_Grand_Mound-1619_161kV	4056	Add G Mnd 161-69kV TRF and Loop	12/31/2009
4871	MP-MISO-PROJECT-LL-BAD-PINE-PEQ	5444	Preliminary	1/1/2010
4017	GRE-PROJECT-TOWER(1021)(for mp)	4496	TOWER	1/1/2010
4509	ATC_1268_(Z3)_Kilbourn_138_Cap_	5090	ATC_1268_(Z3)_Kilbourn_138_Cap_	2/1/2010
3202	ATC_(1938)_Randolph-G366_Windfa	3520	ATC_(1938)_Randolph-G366_Windfa	3/1/2010
3395	ATC_(1937)_Lafayette-G282_Windf	3715	ATC_(1937)_Lafayette-G282_Windf	3/1/2010
3395	ATC_(1937)_Lafayette-G282_Windf	3716	ATC_(TtoD)_Lafayette-G282_Windf	3/2/2010
4232	ATC_(2057)_Warrens_T-D_w_line_e	4775	ATC_(2057)_Warrens_T-D_w_line_e	3/31/2010
3206	ATC_(1945)_Upgrade_Sheepskin_Ca	3524	ATC_(1945)_Upgrade_Sheepskin_Ca	4/12/2010
4502	ATC_(1680)_Walworth-North_Lake_	5083	ATC_(1680)_Walworth-North_Lake_	4/15/2010
4272	XEL-1959-YANKEEDOODLE-PILOTKNOB	4833	YANKEEDOODLE-PILOTKNOB	5/1/2010
3203	ATC_(1939)_MEWD_CT_G588	3521	ATC_(1939)_MEWD_CT_G588	5/1/2010
4018	GRE-MRO-PROJECT-BBP(20143)	4498	BBP-phase2	5/1/2010
3131	ATC_(352)_ASPN-TWFL138	3449	ATC_(352)_ASPN-TWFL138	6/1/2010
3541	XEL-1368-1369-1370-NEWRICHMOND	3880	NEW_RICHMOND_AREA_2010	6/1/2010
3135	ATC_(352)_TWFL-PLNS138	3453	ATC_(352)_TWFL-PLNS138	6/1/2010
3389	ATC_(1683)_Rebuild_SunsetPt-Pea	3709	ATC_(1683)_Rebuild_SunsetPt-Pea	6/1/2010
4779	ITCT-MISO-1873-TAHOE	5347	Tahoe	6/1/2010
2568	FE-MISO-Barberton 138 kV Cap_13	2874	BarbCap_2194	6/1/2010
4697	ITCM_1342_Hiawatha-Lws_Flds_161	5260	Lewis Fields 161-115kV TRF and	6/1/2010
3156	ATC_(1267)_Oakridge-Verona_138_	3474	ATC_(1267)_Oakridge-Verona_138_	6/1/2010
4742	XEL-56-CHISAGO-STCROIXFLS [08-1	5310	XEL-CHISAGO-STCROIXFALLS	10/1/2010
3821	OTP-973-BSII	4201	BIG STONE-CANBY 230	11/1/2010
4206	XEL-1953-SAUKRIVER-STCLOUD	4747	XEL-SAUKRIVER-STCLOUD-UPGRADE	12/1/2010
4255	XEL-1961_LAKEEMILY_CAP	4796	XEL-LAKE-EMILY-CAP	12/1/2010
4872	MP-MISO-PROJECT-1482-Pepin-Lk-r	5445	Phase 1	12/30/2010
4486	OTP-971-WINGERXFMR-20080613 [08	5067	WINGER XFMR	12/31/2010
3634	ALTW_Hazelton-1288_345-161kV_33	3977	345-161KV_335_MVA_Xfmr	12/31/2010
3714	ALTW_Toledo-Belle-1289_Plaine_S	4075	Rbld Toledo-Belle Plaine-Stoney	12/31/2010
4937	ITCM_1618_Heron Lake-Lakefield_	5524	Rbld Heron Lake-Lakefield 161kV	12/31/2010
4256	XEL-1960-TRAVERSE-STPETER	4797	XEL-TRAVERSE-STPETER-UPGRADE	4/1/2011
4385	XEL-675-SCOTTCO-WESTGATE	4946	SCOTTCO-WESTGATE	6/1/2011
4747	XEL-1285-GLENCOE-WESTWACONIA	5315	GLENCOE-WESTWACONIA	6/1/2011
4384	XEL-2109-G609	4945	G609	6/1/2011
4259	XEL-1954-WSIOUXFALLS-PATHFINDER	4801	WSIOUXFALLS-PATHFINDER	6/1/2011
3750	OTP-1033-SLVRLK	4123	NEW 230/41.6 TRANSFORMER	6/30/2011
3821	OTP-973-BSII	4202	BIG STONE-BROWNS VALLEY	7/1/2011

Project ID	Project Name	Phase ID	Phase Name	Effective Date
4194	XEL-PROJECT-1380-WWACONIA-SCOTT	4734	XEL-WWACONI-SCOTTCO	12/1/2011
4771	ITCT-MISO-907-OAKLAND	5339	Oakland	12/31/2011
3696	ALTW_Quad-RkCrk-Salem-1345_Term	4053	Quad-RkCrk-Salem_Terminals	12/31/2011
3667	ALTW_Salem-Lore-Hazelton-1340_3	4010	345kV line_Lore 345kV bus_335MV	12/31/2011
4847	ITCT-MISO-692-BISMARK-TROY	5420	Bismark-Troy	12/31/2011
3821	OTP-973-BSII	4203	JOHNSON-MORRIS 230	6/1/2012
4715	ATC_(1470)_Brodhead-South_Monro	5283	ATC_(1470)_Brodhead-South_Monro	6/1/2012
4199	XEL-PROJECT-1957-EAUCLAIRE-P2	4739	EAUCLAIRE-PHASE2-2012	6/1/2012
3708	XEL-973-CANBY-HAZEL	4069	XEL-CANBY-HAZLE-GRANITEFALLS-23	6/2/2012
4160	OTP-PROJECT-279-CAPX-WILTON_BOS	4697	WILTON-BOSWELL-1	7/1/2012
4198	XEL-PROJECT-1958-STONELK-COUDER	4738	STONELAKE-COUDERAY161KVLINE	12/1/2012
3171	ATC_(1617)_NED_3_G527	3489	ATC_(1617)_NED_3_G527	2/1/2013
3142	ATC_(574)_COC-PET_Uprate	3460	ATC_(574)_COC-PET_Uprate	6/1/2013
4553	ATC_(574)_MOC-COC_161-1a	5136	ATC_(574)_MOC-COC_161-1a	6/1/2013
3136	ATC_(356)_ROE-WMD_345_kV_North_	3454	ATC_(356)_ROE-WMD_345_kV_North_	6/1/2013
3821	OTP-973-BSII	4204	BIG STONE-JOHNSON 230	11/1/2013
3703	XEL-PROJECT-286-287-CAPX-MAPLR_	4060	MAPLERIVER-MONTICELLO	1/1/2014
4199	XEL-PROJECT-1957-EAUCLAIRE-P2	4740	EAUCLAIRE-PHASE2-2014	6/1/2014
4996	XEL-1203-SWMN-TC-345KV-PROJECT	5583	XEL-SWMN-TC-345KV	1/1/2015
3821	OTP-973-BSII	4205	BIG STONE-CANBY 345	1/1/2015
3707	XEL-PROJECT-1024-CAPX-HAMP_ROCH	4068	HAMPTONCORNER_NLAX	1/2/2015
3685	OTP-585-PRTURKEY	4020	PELICAN TURKEY	7/15/2017

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Appendix

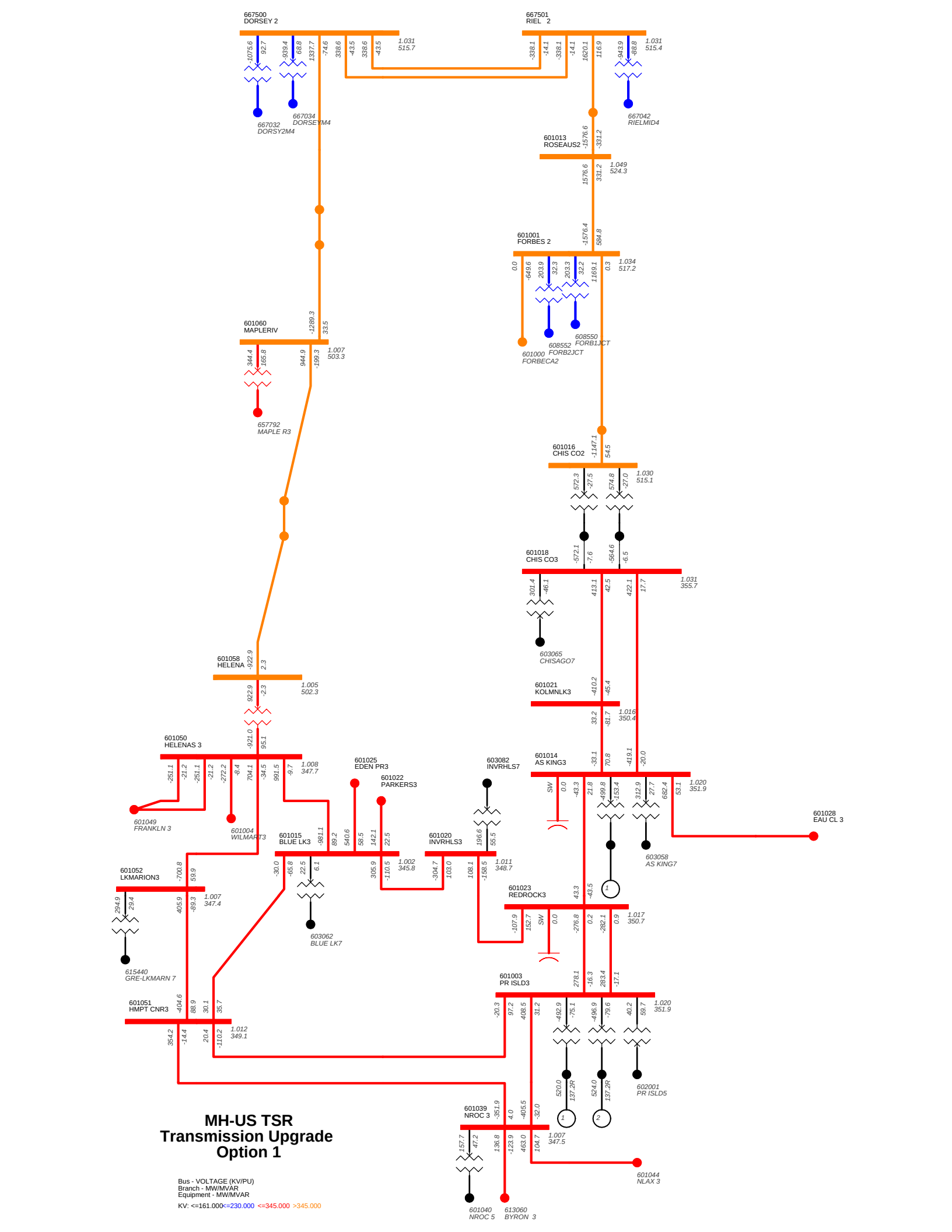
B

Loss Analysis of Transmission Upgrade Options

Table B-1: Loss Analysis Results

Area	Benchmark Case Losses	Option 1 Study Case		Option 2 Study Case		Option 3 Study Case	
		Losses	Difference	Losses	Difference	Losses	Difference
295 WEC	158.5 MW 2661.9 MVAR	164.7 MW 2715.5 MVAR	6.2 MW 53.6 MVAR	165.2 MW 2723.8 MVAR	6.7 MW 61.9 MVAR	165.0 MW 2720.4 MVAR	6.5 MW 58.5 MVAR
600 XEL	412.1 MW 4250.2 MVAR	466.9 MW 4818.1 MVAR	54.8 MW 567.9 MVAR	454.3 MW 4728.6 MVAR	42.2 MW 478.4 MVAR	451.4 MW 4718.1 MVAR	39.3 MW 467.9 MVAR
608 MP	105.0 MW 1338.6 MVAR	110.0 MW 1392.0 MVAR	5.0 MW 53.4 MVAR	105.2 MW 1328.7 MVAR	0.2 MW -9.9 MVAR	111.4 MW 1406.1 MVAR	6.4 MW 67.5 MVAR
613 SMMPA	1.6 MW 16.7 MVAR	2.1 MW 21.0 MVAR	0.5 MW 4.3 MVAR	1.8 MW 18.1 MVAR	0.2 MW 1.4 MVAR	2.0 MW 20.0 MVAR	0.4 MW 3.3 MVAR
615 GRE	94.7 MW 1837.3 MVAR	95.8 MW 1822.1 MVAR	1.1 MW -15.2 MVAR	96.3 MW 1817.1 MVAR	1.6 MW -20.2 MVAR	93.2 MW 1770.6 MVAR	-1.5 MW -66.7 MVAR
620 OTP	111.5 MW 1153.3 MVAR	116.8 MW 1168.1 MVAR	5.3 MW 14.8 MVAR	114.6 MW 1155.5 MVAR	3.1 MW 2.2 MVAR	118.8 MW 1201.9 MVAR	7.3 MW 48.6 MVAR
627 ALTW	99.7 MW 1028.0 MVAR	102.4 MW 1039.5 MVAR	2.7 MW 11.5 MVAR	100.7 MW 1034.2 MVAR	1.0 MW 6.2 MVAR	100.2 MW 1029.5 MVAR	0.5 MW 1.5 MVAR
635 MEC	115.6 MW 1322.9 MVAR	119.3 MW 1346.0 MVAR	3.7 MW 23.1 MVAR	117.5 MW 1336.2 MVAR	1.9 MW 13.3 MVAR	117.1 MW 1331.0 MVAR	1.5 MW 8.1 MVAR
652 WAPA	209.3 MW 2401.9 MVAR	216.8 MW 2488.6 MVAR	7.5 MW 86.7 MVAR	218.3 MW 2514.9 MVAR	9.0 MW 113.0 MVAR	214.9 MW 2470.6 MVAR	5.6 MW 68.7 MVAR
667 MH	336.5 MW 5239.6 MVAR	490.5 MW 8186.5 MVAR	154.0 MW 2946.9 MVAR	490.8 MW 8184.5 MVAR	154.3 MW 2944.9 MVAR	494.5 MW 8199.0 MVAR	158.0 MW 2959.4 MVAR

Area	Benchmark Case Losses	Option 1 Study Case		Option 2 Study Case		Option 3 Study Case	
		Losses	Difference	Losses	Difference	Losses	Difference
680 DPC	76.4 MW 444.0 MVAR	91.3 MW 539.6 MVAR	14.9 MW 95.6 MVAR	82.5 MW 492.6 MVAR	6.1 MW 48.6 MVAR	87.6 MW 521.5 MVAR	11.2 MW 77.5 MVAR
694 ALTE	118.3 MW 1123.9 MVAR	121.5 MW 1154.1 MVAR	3.2 MW 30.2 MVAR	118.4 MW 1131.8 MVAR	0.1 MW 7.9 MVAR	120.6 MW 1148.4 MVAR	2.3 MW 24.5 MVAR
696 WPS	76.9 MW 803.8 MVAR	87.9 MW 872.4 MVAR	11.0 MW 68.6 MVAR	104.4 MW 1051.0 MVAR	27.5 MW 247.2 MVAR	88.3 MW 882.7 MVAR	11.4 MW 78.9 MVAR
697 MGE	14.0 MW 215.5 MVAR	13.3 MW 211.4 MVAR	-0.7 MW -4.1 MVAR	13.2 MW 210.0 MVAR	-0.8 MW -5.5 MVAR	13.2 MW 211.1 MVAR	-0.8 MW -4.4 MVAR
698 UPPC	8.0 MW 27.9 MVAR	8.0 MW 28.0 MVAR	0.0 MW 0.1 MVAR	7.9 MW 27.9 MVAR	-0.1 MW 0.0 MVAR	7.9 MW 28.0 MVAR	-0.1 MW 0.1 MVAR
Network Upgrade Facilities	0.0 MW 0.0 MVAR	76.4 MW 765.8 MVAR	76.4 MW 765.8 MVAR	80.3 MW 805.7 MVAR	80.3 MW 805.7 MVAR	84.0 MW 997.4 MVAR	84.0 MW 997.4 MVAR
TOTALS	1938.2 MW 23866.6 MVAR	2283.7 MW 28569.8 MVAR	345.5 MW 4703.2 MVAR	2271.5 MW 28561.7 MVAR	333.3 MW 4695.1 MVAR	2270.3 MW 28657.5 MVAR	332.1 MW 4790.9 MVAR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FRANKLN 3
601004
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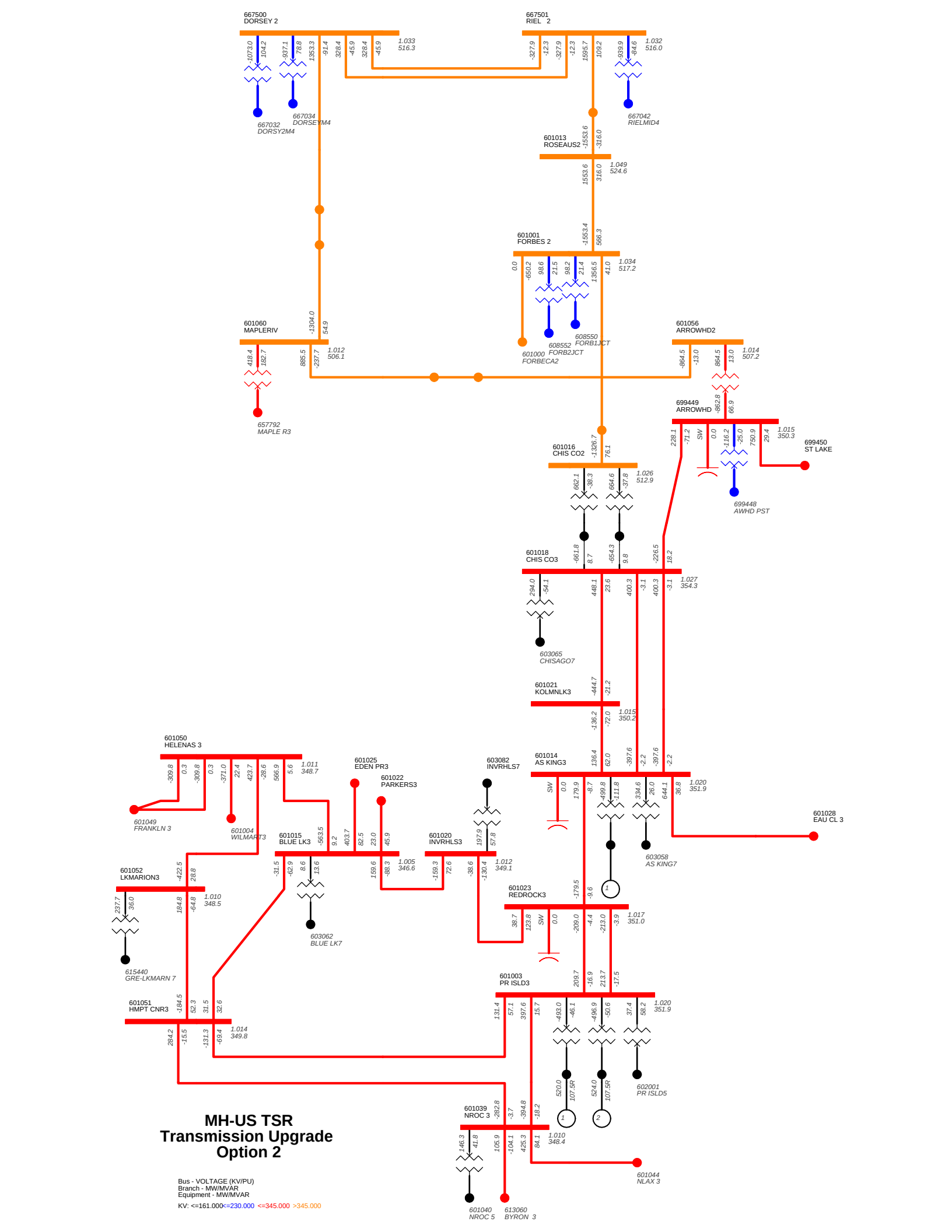
601040
NROC 5
613060
BYRON 3
601044
NLAX 3
MH-US TSR
Transmission Upgrade
Option 1
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000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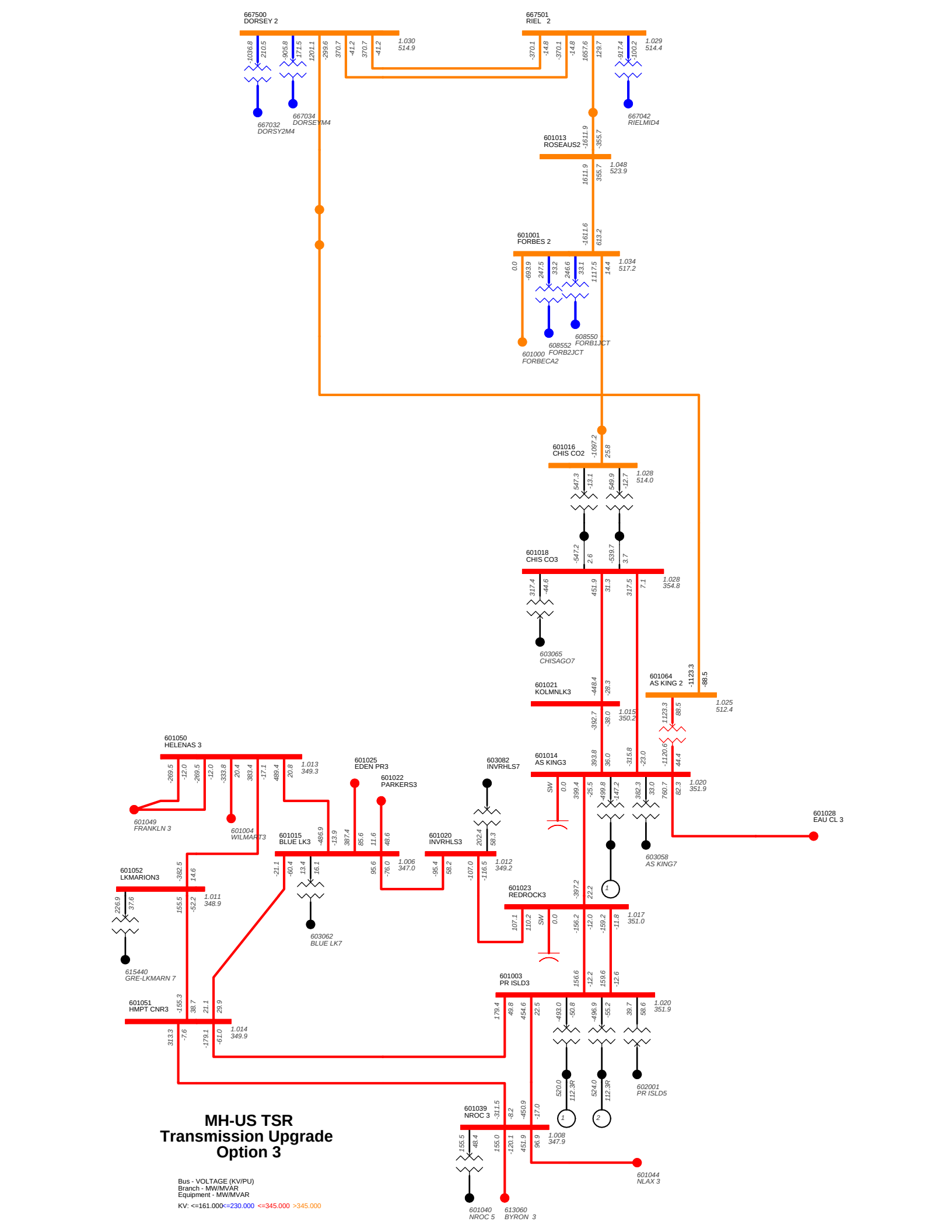
NROC 3
601040
NROC 5
613060
BYRON 3
601044
NLAX 3
MH-US TSR
Transmission Upgrade
Option 2
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000


667500
DORSEY 2
667501
RIEL 2
667032
DORSY2M4
667034
DORSEYM4
667042
RIELMID4
601013
ROSEAUS2
601001
FORBES 2
601000
FORBECA2
608552
FORB2JCT
608550
FORB1JCT
601016
CHIS CO2
601018
CHIS CO3
603065
CHISAGO7
601064
AS KING 2
601021
KOLMNLK3
601014
AS KING3
603058
AS KING7
601028
EAU CL 3
601050
HELENAS 3
601049
FRANKLN 3
601004
WILMART3
601025
EDEN PR3
601022
PARKERS3
601015
BLUE LK3
603062
BLUE LK7
603082
INVRHLS7
601020
INVRHLS3
601052
LKMARION3
615440
GRE-LKMARN 7
601023
REDROCK3
601003
PR ISLD3
601051
HMPT CNR3
602001
PR ISLD5
601039
NROC 3
601040
NROC 5
613060
BYRON 3
601044
NLAX 3
MH-US TSR
Transmission Upgrade
Option 3
Bus - VOLTAGE (KV/PU)
Branch - MW/MVAR
Equipment - MW/MVAR
KV: <=161.000 <=230.000 <=345.000 >345.000

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Appendix

C

Network Analysis Results

Table C-1: Impact of Transmission Upgrade Options on SUPK Benchmark Case
Impacts Exceeding 2% of Monitored Element Rating

** From bus ** ** To bus ** CKT	Rating (MVA)	Benchmark Case Loading (%)	Benchmark Case with Option 1 Loading (%)	Benchmark Case with Option 2 Loading (%)	Benchmark Case with Option 3 Loading (%)
3725:DAVCALQUARCK	152	103.0	107.2	108.2	106.5
6172:SONCOCCOCCCT	168	91.3	114.6	109.9	110.8
6174:SONCCTCOCSON	232	91.1	112.4	110.2	110.8
6186:GENLACGENCOU	260	111.6	126.7	125.0	125.0
603022 SOURIS 7 115 603023 MALLARD7 115 1	113	106.9	116.2	115.0	115.4
603022 SOURIS 7 115 605634 VELVA TAP 115 1	80	128.8			132.1
603023 MALLARD7 115 652452 RUGBY 7 115 1	80	100.1	115.8	114.0	114.6
603028 FRANKLN7 115 605087 FRANKLN8 69.0 1	54	127.8	134.0		
603061 BLK DOG7 115 603204 WILSON TAP7 115 3	239	108.9	111.5		
603152 T-CRNRS7 115 605028 T CORNE8 69.0 1	71.9	125.4	129.3	130.6	129.1
603170 WILLPIP7 115 616922 GRE-APPVLTW7 115 1	195.6	102.4	105.4		
603177 MAYNARD7 115 616004 GRE-KERKHOT7 115 1	85	96.5	100.3		
605012 WILMART8 69.0 617232 GRE-JHNSNTP869.0 1	72.6	134.0	137.2		
605028 T CORNE8 69.0 680531 HULL TAP 69.0 1	25	100.2		106.3	
605102 BELGRAD8 69.0 605119 PAYNES 8 69.0 1	39.6	132.2			139.2
605102 BELGRAD8 69.0 619432 GRE-CROW LK869.0 1	40.7	123.9			130.4
605103 BROOTEN8 69.0 619432 GRE-CROW LK869.0 1	40.7	109.4			115.6
605104 SEDAN 8 69.0 605126 WLMSTAP8 69.0 1	40.7	96.1			102.1
605104 SEDAN 8 69.0 619122 GRE-GLENWD 869.0 1	40.7	95.0			101.2
605160 CNFLSTR8 69.0 616967 GRE-BYLLSBY869.0 1	72	111.1	113.3		
605162 MIESTAP8 69.0 616967 GRE-BYLLSBY869.0 1	72	106.5	108.6		
605166 EAGLELK8 69.0 605569 JAMESTP8 69.0 1	72	117.5	120.7		
605166 EAGLELK8 69.0 617243 GRE-EAGLELK869.0 1	72	124.4	127.6		
605251 LEBNON 8 69.0 605257 FRMNGTN8 69.0 1	52.8	247.9			254.4
605251 LEBNON 8 69.0 616954 GRE-PILOTTP869.0 1	68.1	192.3			197.1
605257 FRMNGTN8 69.0 615441 GRE-LKMARN 869.0 1	72.6	182.9			185.2
605264 HASTING8 69.0 616966 GRE-WHASTNG869.0 1	74.8	109.1	111.5		
605349 WISSOTAG 69.0 605523 LFY TAP8 69.0 1	79.2	145.8			148.2
605351 WISOTBC8 69.0 605523 LFY TAP8 69.0 1	79.2	141.7			144.1
605351 WISOTBC8 69.0 680482 DPC TAP8 69.0 1	72	150.1			152.7
605353 CADOTT 8 69.0 605354 BOYD 8 69.0 1	79.2	130.8			133.3
605353 CADOTT 8 69.0 680482 DPC TAP8 69.0 1	72	150.1			152.8
605354 BOYD 8 69.0 605420 DELMAR 8 69.0 1	79.2	131.2			133.7
605355 STANLEY8 69.0 605420 DELMAR 8 69.0 1	79.2	128.7			131.2
605428 PRENTIC8 69.0 680337 OGEMA 69.0 1	51.7	111.4			115.4
605430 RIB LAK8 69.0 680337 OGEMA 69.0 1	51.7	103.3			107.3
605569 JAMESTP8 69.0 617247 GRE-JMSTWTP869.0 1	45.4	158.7	161.1		
605662 SW_ECL 69.0 605663 SW_ECL 161 1	112	123.2			127.1
608696 TAC HBR6 138 608698 HOYT LK6 138 1	89	123.1		126.4	
608696 TAC HBR6 138 608699 DUNKARD6 138 1	89	124		126.4	
615440 GRE-LKMARN 7 115 616929 GRE-KENRICK7 115 1	201	94.1	100.3		
615440 GRE-LKMARN 7 115 B$0188 115/69 1.00 1	70	215.8	219.3		
615447 GRE-PILOTKB869.0 616956 GRE-DEERWD 869.0 1	51	107.2			109.9
615461 GRE-RUSH CY869.0 617048 GRE-RUSH TP869.0 1	35.9	100.7	104.3		
615478 GRE-SPRNGCK5 161 B$0196 161/69 1.00 1	70	104.4	106.5		
616330 GRE-BUNKER 869.0 616349 GRE-VILGTEN869.0 1	75.8	122.8			126.5
616362 GRE-ISANTTP869.0 617050 GRE-INDSTTP869.0 1	45.5	123.1		127.9	
617220 GRE-PNLPNTP869.0 617238 GRE-PENELOP869.0 1	66.2	142.2	145.7		
617220 GRE-PNLPNTP869.0 617248 GRE-TRAVSWS869.0 1	51.7	182.0	186.6		
617232 GRE-JHNSNTP869.0 617239 GRE-PENELTP869.0 1	92.4	105.3	107.8		
617238 GRE-PENELOP869.0 617239 GRE-PENELTP869.0 1	66.2	146.9	150.5		
617247 GRE-JMSTWTP869.0 618730 GRE-CLVLAND869.0 1	47.8	143.9	146.2		
619900 GRE-ELKRWS1869.0 619904 GRE-WACO 869.0 1	45.5	113.7			116.0
620269 JAMSTWN7 115 620275 NJAMES 7 115 1	106.3	127.2	115.6	118.0	118.4
620273 JAMETAP7 115 620275 NJAMES 7 115 1	106.3	138.8	126.1	128.0	128.3
630139 ADAMS 8 69.0 631122 ADAMS_N5 161 1	74.7	104.1	107.4		106.8
630277 AMOCOIL8 69.0 630319 PEOSTA 8 69.0 1	40	118.9			122.9

** From bus **	** To bus ** CKT	Rating (MVA)	Benchmark Case Loading (%)	Benchmark Case with Option 1 Loading (%)	Benchmark Case with Option 2 Loading (%)	Benchmark Case with Option 3 Loading (%)
630277 AMOCOIL8 69.0	630689 SEIPLRD8 69.0 1	40	123.6			127.7
630281 LORE E 8 69.0	630689 SEIPLRD8 69.0 1	40	139.8			144.0
630419 ECRESTN8 69.0	630446 CRESTN8_ 69.0 1	38	172.4			182.0
630419 ECRESTN8 69.0	652569 CRESTON8 69.0 1	45	169.9			180.8
637841 BELMOND 69.0	637842 BELMNDAL 69.0 1	41	159.2			165.4
637842 BELMNDAL 69.0	637871 KLEMME 8 69.0 1	41	159.2			165.0
652435 FARGO 4 230	B$0803 FA KV1A 1.00 1	100	97.5	110.1	112.2	
652436 FARGO 7 115	B$0803 FA KV1A 1.00 1	100	108.6			113.1
680037 T BRN 69.0	680091 CLDNA SS 69.0 1	25	107.7	111.7		
680037 T BRN 69.0	680110 GENOA 69.0 1	25	121.1	125.1		
680037 T BRN 69.0	680110 GENOA 69.0 1	25	96.6		101.0	
680066 MENOMINE 69.0	680068 T KIELER 69.0 1	25	104.5	110.0	109.1	109.2
680070 LANCASTE 69.0	680079 HURICAN 69.0 1	25	158.2	163.3		163.7
680075 BELLCNTR 69.0	680076 STEUBEN 69.0 1	25	121.2	126.3		125.9
680076 STEUBEN 69.0	680077 T EAST 69.0 1	25	124.7	129.8		129.5
680077 T EAST 69.0	680455 MTHOP TP 69.0 1	25	134.2	139.2		139.2
680079 HURICAN 69.0	680455 MTHOP TP 69.0 1	25	147.7	152.8		153.1
680194 T LOYAL 69.0	680234 LOYAL 69.0 1	17	103.5		111.0	
680233 T SPEN8 69.0	680234 LOYAL 69.0 1	17	126.1		133.4	
680233 T SPEN8 69.0	680531 HULL TAP 69.0 1	25	100.4		106.5	
680306 APLRVR 8 69.0	680312 BUNYAN 69.0 1	47	152.4			158.2
680312 BUNYAN 69.0	680313 T LUC 69.0 1	47	136.1			141.3
680313 T LUC 69.0	680314 SPNCERLK 69.0 1	25	185.1			189.9
680314 SPNCERLK 69.0	680320 BIG SND 69.0 1	25	180.0			184.1
693661 STM E TP 69.0	693662 STM N TP 69.0 1	67.4	102.3	104.5	104.9	105.1
693949 COBB69 69.0	698080 BCH 69 69.0 1	79.8	113.6			115.6
698080 BCH 69 69.0	698081 WAL 69 69.0 1	65.5	113.4			116.2
698160 DAN 69 69.0	698168 LTP 69 69.0 1	46.5	98.4	101.0	100.7	101.1
698216 ACA 69 69.0	698217 C2T 69 69.0 1	65.5	103.6	106.1		106.4
698217 C2T 69 69.0	698219 COS 69 69.0 1	65.5	99.2	101.7		101.8
698668 WMD 69 69.0	698674 WTNM 69 69.0 1	77.9	92.7	102.2	101.6	102.2
698710 CHNDLR 69.0	698711 CORNL TA 69.0 1	34.2	100.7		105.7	
698710 CHNDLR 69.0	699580 CHANDLER 138 1	67.4	105.0		107.1	

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

From bus	To bus	CKT	Owner	Rating (MVA)	Benchmark Case Loading (%)	Option 1 Study Case Loading (%)	Option 1 Study Case DF (%)	Option 2 Study Case Loading (%)	Option 2 Study Case DF (%)	Option 3 Study Case Loading (%)	Option 3 Study Case DF (%)	Contingency
3175:PALXFMMONSPE			MISO	295.0	123.2	125.7	0.5	124.9	0.3	126.1	0.6	C:Contingency of FlowGate 3175
3216:BYNCHEBYNCHE			PJM	1499.0	99.9	101.3	1.4	100.8	0.9	101.1	1.2	C:Contingency of FlowGate 3216
3218:BYRCHEBYRCHE			PJM	1499.0	103.1	104.6	1.5	104.0	0.9	104.4	1.3	C:Contingency of FlowGate 3218
6186:GENLACGENCOU			MISO	260.0	111.6	126.2	2.5	123.4	2.0	122.8	1.9	C:Contingency of FlowGate 6186
602006 SHEYNNE4 230	652435 FARGO 4 230	1	NSP	403.9	107.3					106.6	-0.2	C:620358 BUFFALO3 345 620369 JAMESTN3 345 1
602017 ST LAKE5 161	699450 ST LAKE 345	1	ATC	399.0	81.7			111.6	7.7			C:699450 ST LAKE 345 699676 GARDR PK 345 1
602021 EAU CLA5 161	602030 WHT 14 5 161	1	NSP	300.0	95.7					97.6	0.4	C:B_XEL_KING-EAU_CLA Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 602021 EAU CLA5 161 9
602022 JACKSON5 161	605309 JACKCO 8 69.0	1	NSP	47.0	96.0	104.4	0.3	102.1	0.2	104.5	0.3	Base Case
602023 LACROSS5 161	602025 MONROCO5 161	1	NSP	167.0	117.6	121.0	0.4	113.6	-0.4	120.9	0.4	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
602023 LACROSS5 161	602025 MONROCO5 161	1	NSP	167.0	115.8	119.3	0.4	111.9	-0.4	119.1	0.4	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
602023 LACROSS5 161	602025 MONROCO5 161	1	NSP	167.0	110.5	113.7	0.3	106.7	-0.4	113.6	0.3	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1
602023 LACROSS5 161	602025 MONROCO5 161	1	NSP	167.0	96.1	110.1	1.5			109.0	1.4	C:601044 NLAX 3 345 699829 WMD345 345 1
602023 LACROSS5 161	602025 MONROCO5 161	1	NSP	167.0	105.0	107.5	0.3			107.1	0.2	C:B_XEL_KING-EAU_CLA Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 602021 EAU CLA5 161 9
602023 LACROSS5 161	602025 MONROCO5 161	1	NSP	167.0	100.7	105.0	0.5	98.6	-0.2	105.0	0.5	C:ATC-ARP-OG3 Open 699244 ARP 345 345 699785 ROCKY RN 345 1 Open 699241 POE 138 138 699939 SAL 138 138 1 Open 698948 HOLYWOOD 138 699241 POE 138 138 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1
602023 LACROSS5 161	602025 MONROCO5 161	1	NSP	167.0	101.9	104.4	0.3	102.7	0.1	103.4	0.2	C:699450 ST LAKE 345 699676 GARDR PK 345 1
608666 FONDULAC 115	608676 HIBBARD7 115	1	MP	44.0	33.5			115.4	2.3			C:608667 POTLTCH7 115 608668 CLOQUET7 115 1
608666 FONDULAC 115	608676 HIBBARD7 115	1	MP	44.0	27.5			103.3	2.2			C:608668 CLOQUET7 115 608673 ARROWHD7 115 1
608740 GR RPDS7 115	608781 20L TAP7 115	1	MP	132.0	60.4			102.6	3.6			C:608779 BLANDIN7 115 608781 20L TAP7 115 1
615440 GRE-LKMARN 7 115	616929 GRE-KENRICK7 115	1	GRE	201.0	89.7	105.4	2.0					C:601015 BLUE LK3 345 601050 HELENAS 3 345 1
615440 GRE-LKMARN 7 115	616929 GRE-KENRICK7 115	1	GRE	201.0	89.1	101.8	1.7					C:603131 AIRLAKE7 115 615440 GRE-LKMARN 7 115 1
652514 HURON 4 230	659205 BRDLAND4 230	1	BEPC	400.0	98.5	102.7	1.1	105.8	1.9	102.4	1.0	C:652506 FTTHOMP3 345 659105 LELANDO3 345 1
659120 BRDLAND3 345	659204 BRDLNDTY 345	1	BEPC	400.0	99.9	104.5	1.2	107.5	2.0	104.2	1.1	C:652506 FTTHOMP3 345 659105 LELANDO3 345 1
699240 SAR 138 138	699808 PETENWEL 138	1	ATC	72.2	97.4	115.6	0.9			114.7	0.8	C:ATC-ZN1-2 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1
699240 SAR 138 138	699808 PETENWEL 138	1	ATC	72.2	91.7	109.5	0.8			109.0	0.8	C:ATC-ARP-OG2 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699240 SAR 138 138	699808 PETENWEL 138	1	ATC	72.2	88.0	106.1	0.8			105.3	0.8	C:ATC-ARP-OG1 Open 601014 AS KING3 345 601028 EAU CL 3 345 1 Open 601028 EAU CL 3 345 699244 ARP 345 345 1 Open 698342 COC 69 69.0 699901 TIMBERWOLF 69.0 1 Open 680121 MAUSTON 69.0 698333 HLT 69 69.0 1 Open 680242 LUBLIN 69.0 680505 LAKEHEAD 69.0 1
699619 EAST KRK 138	699620 KEWAUNEE 138	1	ATC	272.6	87.6	101.3	2.4	99.3	2.1	101.0	2.4	C:699359 N APP 1 345 699630 KEWAUNEE 345 1