Dotson Area Load Serving And Generation Outlet Study

Participants:

Alliant Energy
Great River Energy
Xcel Energy

Executive Summary

MISO has identified a number of wind interconnection requests in the region southwest of Mankato in excess of 150 MW in the vicinity of Storden. Along with the request for this wind interconnection, this region is also adding new ethanol plant loads. The City of New Ulm has also requested network transmission service for its load, and the City of Mankato is experiencing a number of load serving issues. The transmission system in this region is predominantly 69 kV and is not capable of providing transmission interconnection capability for the wind generation or reliably serve the new loads.

GRE, Alliant Energy and Xcel Energy conducted a combined load serving and generation outlet study to determine a long term plan for this region that can support the wind generation additions and growing loads. The plan laid out in this study is intended to serve as a high voltage backbone to support the 69 kV transmission system in this region.

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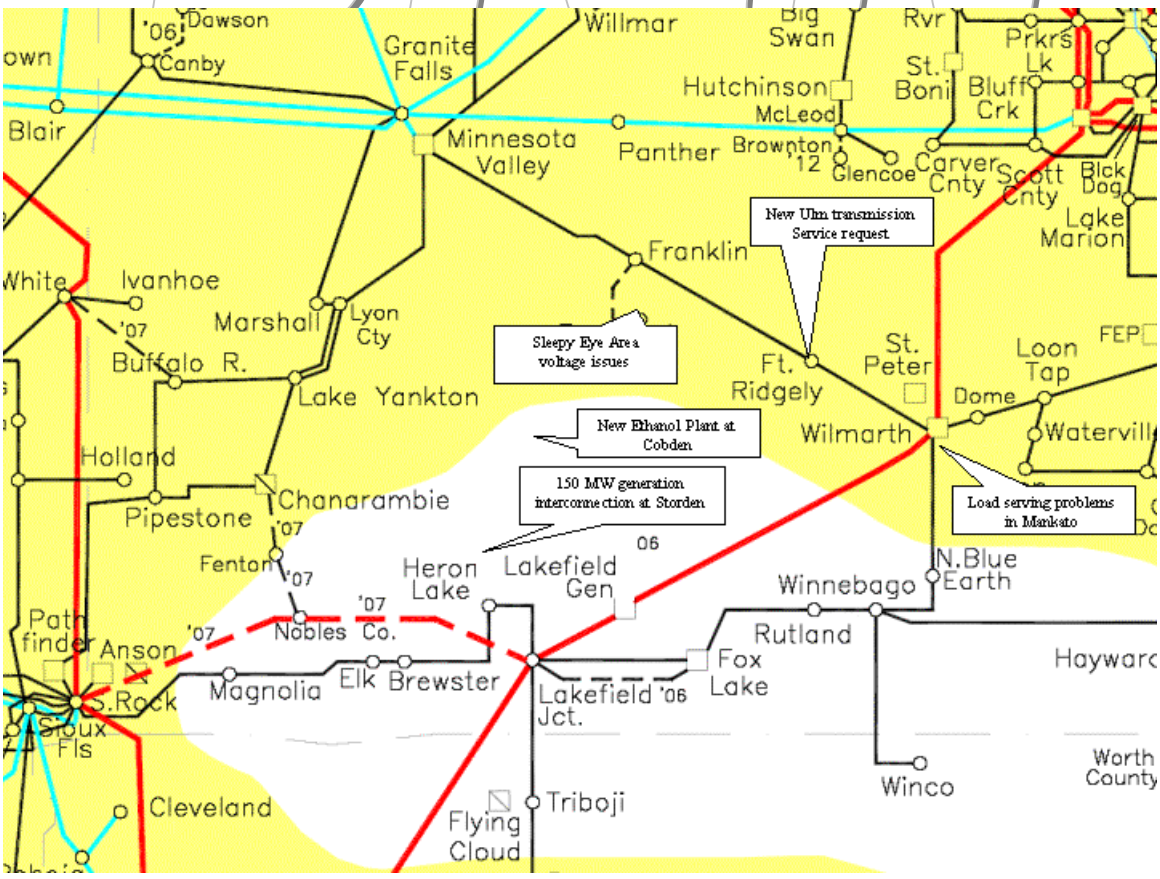
1. Background

The area southwest of the City of Mankato is predominantly served by a weak (long and low capacity) 69 kV system fed from Wilmarth bulk substation and other sources along the southern Minnesota border (Rutland, Heron Lake, and Fox Lake). The load in this area has previously been characterized as slow residential growth. No major new transmission line additions or upgrades have been made in this region in the recent past.

The following new facilities are planned or have been completed recently.

- Watonwan switching station and capacitor bank at Watonwan Jct. (complete)
- Waterbury switching station at Johnsonville tap. (planned)
- Second 69 kV line from Wilder Jc to Windom. (Planned)
- Hungry Hollow switching station. (Planned)
- Milroy—Sheridan 69 kV line (planned)



A number of new ethanol plants have been proposed in this region. This is on the front end of a new developing industry in Minnesota. The 69 kV lines in this region are not capable of serving this new ethanol industry without additional support. Additions for the residential load growth are also required.

In the same study time frame the MISO Group 4 generation interconnection study was completed. The results of this study suggested a second 161 kV line out of Storden[1] is needed to provide interconnection for over 150 MW of wind generation near and to the south of Storden This new outlet line was originally proposed from Storden to Lakefield Junction, however it was found that this circuit (Storden – Lakefield Junction 161 kV) did not provide deliverability of the generation output. The transmission owners determined, through study, that building a second 161 kV outlet line from Storden to the northeast would help provide better deliverability and excellent load serving capabilities. This effort, part of a GRE sponsored vision study performed by Excel Engineering, determined the recommendation for a new 161 kV line from Storden to Ft. Ridgely instead of Lakefield Junction. This study revealed that a new 161 kV line to the north and east through Dotson and then to Ft. Ridgely would facilitate better overall system performance.

In addition to the above, there are other deficiencies in the region including providing the City of New Ulm network transmission service and Mankato area load serving issues.

The City of New Ulm is served from a 69 kV line out of Ft. Ridgely. Recently the City became a full network transmission customer requiring the system to serve all 50 MW of its load. Previously, Xcel Energy provided transmission service for about 15 MW of New Ulm load. The transmission system in this region is not capable of serving this entire load under single contingency condition without upgrades

In the Mankato area the Sibley Park load, located on the west side of Mankato, is a single large load of more than 50 MW served by a 69 kV line from Wilmarth. It was determined that the system serving this load will not be capable of picking up all of this load during summer peak conditions after 2009. Due to lack of space, the Sibley Park substation cannot be converted to 115 kV.

As all the above-mentioned problems came up in the same study time frame, the transmission owners decided to develop a robust and comprehensive plan to address all the issues. This comprehensive study is developed based on the plans developed in the vision study performed by Excel Engineering for a large wind generator near Storden, and extends it to address the additional issues.

[1] The first 161 kV circuit from Storden is created by the conversion of the existing Storden—South Storden—Heron Lake 69 kV circuit to 161 kV. This first circuit, not yet completed, is assumed as a minimum first step to creating interconnection capability at Storden.

2. Conclusion

The proposed 161/115 kV line from Heron Lake to South Storden to Storden to Dotson to New Ulm to Ft. Ridgely provides excellent voltage support for the new ethanol plants and also provides better generation deliverability as compared to a second 161 kV line to Lakefield Junction. This plan also provides a new 115 kV source at New Ulm allowing reliable service to the entire New Ulm load, In addition, this plan will support future transmission expansion to support load growth and possible new ethanol plants between Mankato through St. James.

3. Problems In The Study Region

3.1 Load serving problems

The load serving problems in the study region can be classified into the following sub regions

Dotson area: This study region covers most of Cottonwood, Brown and Redwood Counties in the southwestern region of Minnesota. This region is served through long 69 kV transmission lines from remote sources. This area is characterized by very low residential load growth. Due to the slow load growth, there were no major transmission upgrades made in recent years. Most of the load serving problems in this region are due to the two new ethanol plants expected to be online in 2008/09, however, past studies have indicated that transmission additions will also be necessary in the near future even without the addition of the new ethanol loads. The new ethanol plants are expected to be located at Cobden near Springfield and at Lamberton. It is found that the transmission system in this area is not capable of serving the entire new load under first contingency conditions. Apart from the problems on the 69 kV system, the loss of Split Rock 161 kV source also leads to overloading the 161 kV line from Heron Lake to Lakefield Jct beyond 100%. The detailed list of problems is provided in Table 3.1.

Table 3.1

Year	Contingency	Monitored Element	Rating MVA	Current MVA	% Overload
2011	Heron Lake–Split Rock 161 kV	Heron Lake – Lakefield Jct 161 kV line	112	131.7	117.5
2011	Springfield–Dotson 69 kV	Johnsonville – Wanda 69 kV line	34.8	41	118

Year	Contingency	Bus	Voltage %
2011	Lakefield Jct– Heron Lake	Heron Lake 161 kV	90
2011	Fox Lake – Sherburn 69 kV	Cobden 69 kV	91
2011	Springfield – Dotson 69 kV	Springfield 69 kV	Less than 80%
2011	Springfield – Brookville 69 kV	Springfield	90
2011	Comfrey – Dotson 69 kV	Springfield	89
2011	Comfrey – Mountain Lake	Cobden	88
2011	Mountain Lake – Bat Lake	Cobden	92
2011	Mountain Lake – Mountain Lake	Cobden	86
2011	Windom – Lakeside	Cobden	89.5
2011	Madelia – Hanska	Cobden	91.3

New Ulm and Sleepy Eye: The City of New Ulm load is fed by two 69 kV lines from the Ft. Ridgely bulk substation. Recently, the City of New Ulm placed a request for firm transmission service for the entire load. The total load of the city is more than 50 MW and the transmission system serving the city today is only capable of serving about 15 MW of the city's load under (n-1) conditions. The loss of the Ft. Ridgely transformer will result in a complete voltage collapse in the region.

The City of Sleepy Eye, Morgan and Eden loads are fed from a 69 kV line running from Franklin to Ft. Ridgely. During the loss of Franklin – Eden tap 69 kV line section, the voltages at the Eden to Sleepy Eye loads were found to be 85%. Table 3.2 summarizes the list of load serving problems in this region.

Table 3.2

Year	Contingency	Monitored Element	Rating MVA	Current MVA	% Overload
2011	Ft. Ridgely 115/69 kV TX	No. of 69 kV overloads around New Ulm	-	-	100+
2011	Morgan – Eden Tap	Ft. Ridgely TX	70	85.6	122

Year	Contingency	Bus	Voltage %
2011			
2011	Ft Ridgely 115/69 kV TX	New Ulm region	Voltage Collapse
2011	Franklin – Eden Tap 69 kV	Morgan	85
2011	Morgan – Eden Tap 69 kV	Sleepy Eye	89

Mankato area: This is a large city in the southwestern part of Minnesota in Blue Earth County. The distribution load in this area is mainly served from Eastwood, Sibley Park and Summit Avenue substations. Summit Avenue substation is a 115 kV substation and Eastwood substation is upgraded to 115 kV in 2006. The Sibley Park substation is a single large load (more than 50 MW) served from a 69 kV transmission system in this area and is normally fed from Wilmarth. The alternative source is a weak 69 kV line from Pohl Road tap which is, in turn, fed from Wilmarth.

After 2009 it is expected that the Wilmarth 115/69 kV transformers will overload under system intact conditions during summer peak (without the support from the St. Peter generators). During the loss of the primary source from Wilmarth, Sibley Park is served from Pohl Road tap (Hungry Hollow). During post contingency conditions, Sibley Park load will experience low voltage problems and the 69 kV line from Pohl Road tap to Pohl

will overload (after 2011). The Sibley Park substation cannot be upgraded to 115 kV due to a lack of room in the substation. The area around the substation is highly developed. The details of problems in this area are listed in Table 3.3.

Table 3.3

Year	Contingency	Monitored Element	Rating MVA	Current MVA	% Overload
2011	System Intact	Wilmarth 115/69 kV TXs	70	75	104
2011	Wilmarth – Sibley Park 69 kV	Pohl Road Tap – Pohl tap	68	85	125

Year	Contingency	Bus	Voltage %
2011	Wilmarth – Pohl Tap/ Pohl Road tap 69 kV	69 kV loads from Butternut – St. Clair and Decoria	Less than 90.
2011	Wilmarth – Sibley Park 69 kV	Sibley Park	92.5

3.2 Generation Outlet Problems

One of the main driving forces for new transmission line in the Dotson area is wind generation. As part of the MISO Group-4 generation interconnection studies, a new 161 kV line is required to provide interconnection for a 150 MW Wind farm near Storden. The least cost plan to achieve this interconnection is to build a second 161 kV line from Storden to Lakefield Junction along with converting the existing 69 kV line from Heron Lake to Storden to 161 kV. This plan does not take into account any other issues such as generation outlet, load serving or transmission service requests. Some of the inherent problems with this configuration are (1) additional load on the constrained lines such as the LGS to Wilmarth 345 kV,[1] (2) very low deliverability and (3) no improved load serving ability.

[1] For more information refer to CGS-4 report and the Storden-Dotson-Ft. Ridgely 161 kV Development Feasibility Transmission study.

4. Load Serving Study Analysis

The load serving study region is the region southwest of the City of Mankato. The study region is indicated in diagram 4.1. The load serving study was performed using MAPP 2006 Series 2011 and 2016 summer peak models. The models were updated to reflect the most recent changes to the study region and the loads were raised to their forecasted non-coincident peaks. The plan was laid out to satisfy the following line loading and voltage criteria.

- Minimum bus voltage during system intact condition is 0.95
- Minimum bus voltage for outage of any one transmission element is 0.92
- Maximum line loading during system intact condition is 100%
- Maximum line loading during the outage of any one element is 100% for all the facilities except, 110% for Xcel Energy's transmission lines, 115% for Xcel Energy's transformers

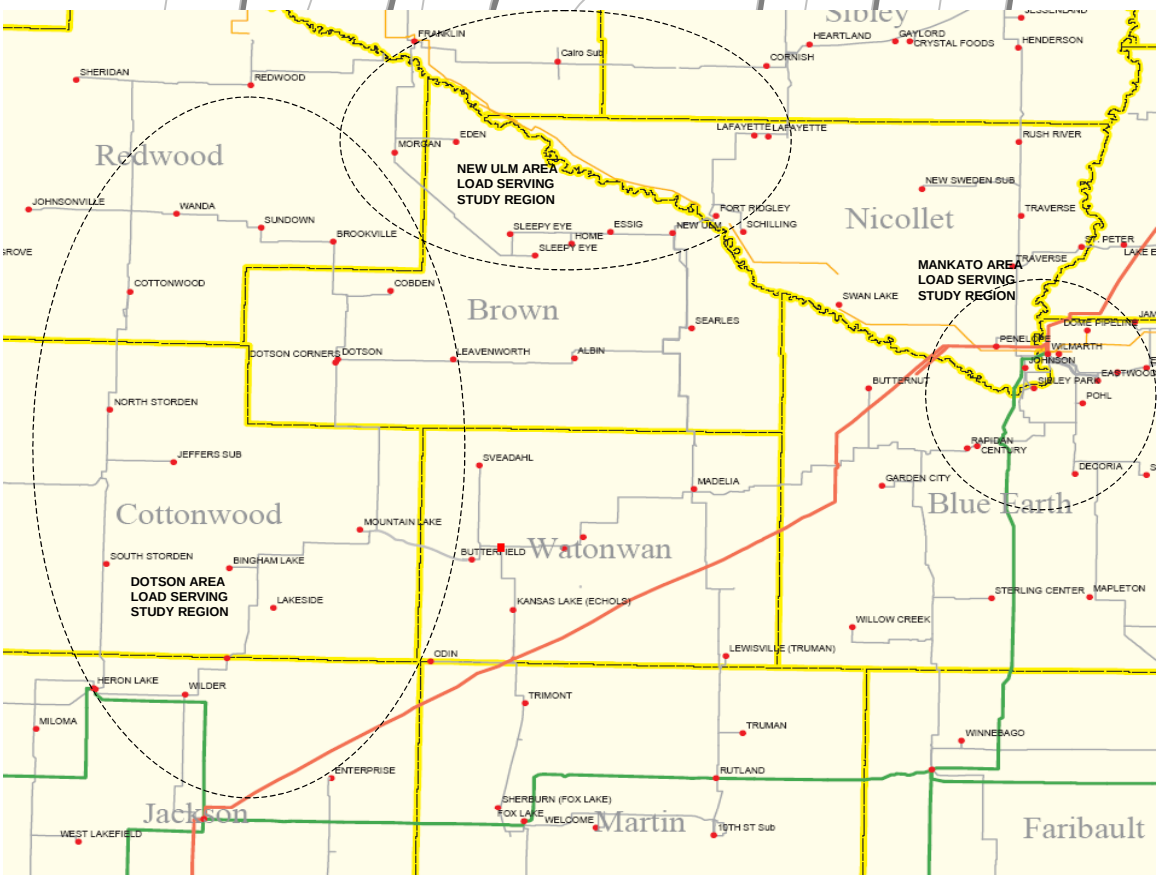


Figure 4.1

For the load serving study, all the local generation is assumed to be off-line. This is a valid assumption as the local generators are expensive to run and they generally remain off-line for most of the year. The new ethanol plants are modeled at Cobden and

Lamberton. The load at these ethanol plants is assumed to be 18 MW at Cobden and 10 MW at Lamberton.

4.1 Detailed analysis by region

Dotson area

The study region for this area is shown in Figure 4.1. As discussed in Section 3.1, there are a number of low voltages issues in the area under first contingency conditions. Even though only two ethanol plants were modeled while doing the analysis, the region is expected to house more of these plants. Some of the potential sites include St. James, increase in capacity of Lakeside Ethanol plant and Butterfield. Since the system in this area is predominantly 69 kV, it is expected that a high voltage line through this area will help provide a long-term solution. Three options were explored to improve the low voltages and help system meet the long-term needs.

Option 1 is to build a Heron Lake – Storden – Dotson – Ft. Ridgely 161 kV line. Even though the 161 kV line from either Dotson to Ft. Ridgely or from Dotson to Storden is sufficient to serve the load, the solution is assumed to be a line from Heron Lake to Ft. Ridgely because the wind generation at Storden requires a second 161 kV outlet. With this option, it is noticed from the 2016 models that the voltages at Heron Lake and Storden drop to 92% during the outage of the Heron Lake – Lakefield Jct 161 kV line. With no intermediate source between Split Rock and Ft. Ridgely, this line would require reactive power support at Dotson to maintain acceptable voltages. For this reason, a 2x30 MVAR capacitor bank is needed at Dotson.

Option 2 is to build a Heron Lake – S Storden – Storden – Dotson – Franklin 161 kV line. A 161 kV line from Franklin to Dotson or a 161 kV line from Heron Lake to Dotson will be sufficient to serve the new ethanol plants, however, similar to the discussion for Option 1, the wind generation outlet at Storden requires two, 161 kV transmission lines, therefore, the line is assumed to be from Heron Lake to Dotson to Franklin. This option also requires 2x30 MVAR capacitors at Dotson.

Option 3 is to build a 161 kV line from Heron Lake to Albin Jct, via Storden and Dotson, and a 115 kV line from Albin Jct to Wilmarth.

Full AC contingency analysis was performed on Alliant, GRE and Xcel Energy control areas for the years 2011 and 2016. The 2016 models included the proposed Brookings Co – Hampton Corner 345 kV line.

During the outage of Heron Lake – Lakefield Jc 161 kV line, the new 161 kV line will have the sources at Split Rock and Ft Ridgely. Due to the length of this line, the voltages can be expected to drop steeply during this outage. The QV curves from 2016 models for the three options considered with a prior outage of Heron Lake – Lakefield Jct 161 kV line are plotted in Figures 4.2 and 4.3

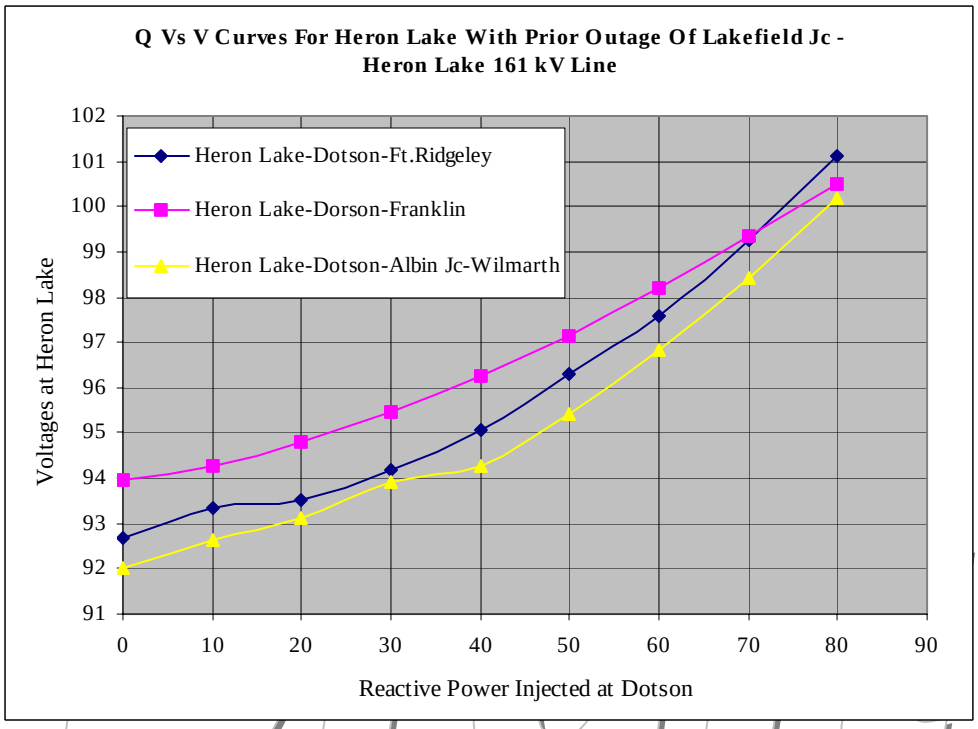


Figure 4.2

Since the Dotson substation is setup to accommodate two 40 MVAR capacitor banks, it is assumed that the reactive power support will be provided from Dotson. The lowest voltages were observed at Heron Lake during the loss of the Heron Lake – Lakefield Jct 161 kV line. From Figure 4.2 it is found that at least 75 to 80 MVARs of reactive power is needed to maintain 1.0 PU voltage at Heron Lake during this condition. However from Figure 4.3 it is found that adding more than 70 MVARs of reactive power would cause the voltages at Dotson to rise above 1.05 PU. Due to this reason 2x30 MVARs of capacitors at Dotson should be adequate to meet the post contingent voltage requirements.

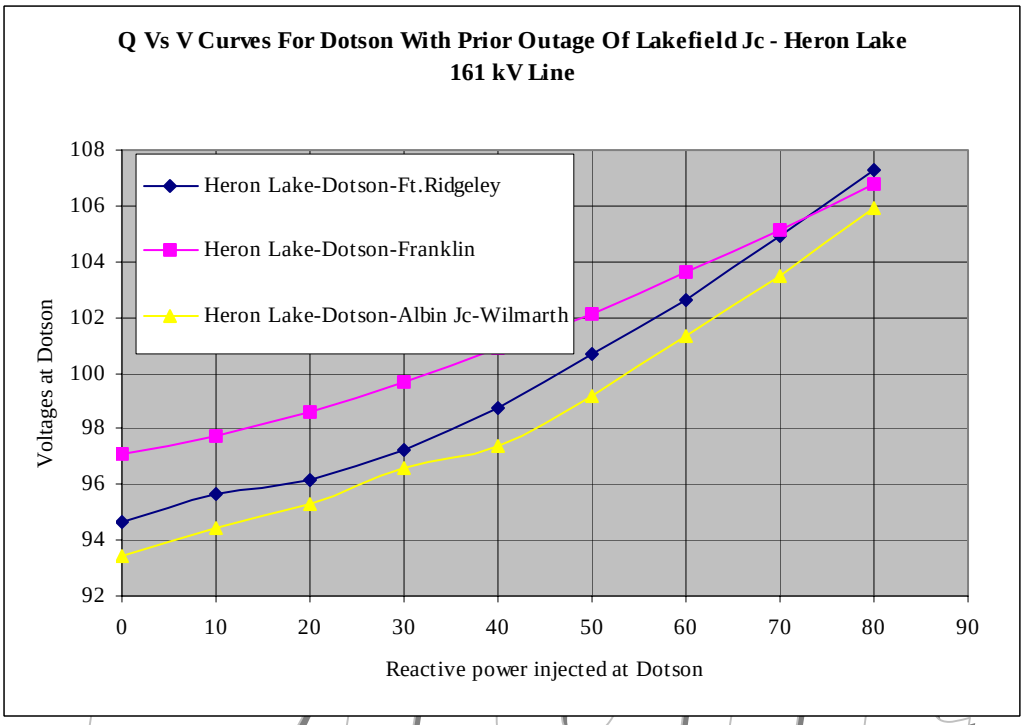


Figure 4.3

New Ulm Area

The study region for New Ulm TSR and Sleepy Eye area load serving issues consist of all the 69 kV lines from Ft Ridgely to Franklin and other 69 kV lines north of Ft. Ridgely. The study region is marked in Figure 4.1. Two concepts were considered for this region.

Option 4 is a new 115 kV line from Ft. Ridgely to Searles Jct and a new 115/69 kV substation at Searles Jct. With this plan, a new 115 kV source will be established south of the City of New Ulm. This helps to improve the voltages at Sleepy Eye during the loss of Franklin – Eden 69 kV line, thereby addressing both the New Ulm TSR as well as Sleepy Eye area problems.

Option 5 is a second Ft. Ridgely 115/69 kV TX and a new 69 kV line from Cobden to Sleepy Eye. Since the loss of the Ft. Ridgely transformer is a single contingency that causes voltage collapse, adding a second transformer at Ft. Ridgely should be adequate to address the New Ulm TSR problems. However the low voltages at Sleepy Eye cannot be addressed with a second transformer at Ft. Ridgely. To fix these voltage problems, a new 69 kV source has to be introduced into this area from Dotson.

A full AC contingency analysis was performed on the above options. For option 4, it was found that the loss of Ft Ridgely transformer causes overload of the Searles Jct – New Ulm 69 kV line. This is due to the fact that the rating of this line is lower than the New Ulm load. Hence, as part of option 4, the line from Searles Jct to New Ulm has to be reconductored to 84 MVA. It is also observed that the voltages at Eden during the loss of Eden tap – Franklin 69 kV line can be expected to drop to 92% after 2018. This problem

can be addressed by installing a 10 MVAR capacitor at Sleepy Eye Junction or Morgan in 2018.

Mankato Area

The study region for Mankato area consists of the 69 kV lines south and west of the Wilmarth substation. The problems in this area are due to large load at Sibley Park substation on the 69 kV system. To fix the problems in this area, two concepts were considered.

Option 6 is a 115 kV circuit around the City of Mankato. This plan provides a new 115/69 kV source at the proposed Hungry Hollow switching station and a new South Bend 161/115/69 kV substation. From a long-term perspective, this plan proves to be a robust solution. The 115 kV loop is obtained by converting the South Bend – Ballard Corner – Hungry Hollow – Pohl 69 kV line to 115 kV. The Pohl substation load will also be converted to 115 kV. The 69 kV line from Pohl to Eastwood is already built to 161 kV specs and only requires to be re-energized at 115 kV. Similarly the 161 kV line from Wilmarth to South Bend requires to be re-energized at 115 kV. This option does not require any new right-of-way and major sections of the loop are already built to 161 kV specifications. Only substation work is required.

Option 7 requires a Eastwood – Hungry Hollow 115 kV line and Wilmarth 115/69kV transformer upgrades to 112 MVA. For this option, it is not possible to operate the existing 69 kV line from Eastwood – Pohl - Hungry Hollow at 115 kV. During the loss of Eastwood – Pohl 115 kV, Pohl load on 115 kV line will be fed from the 69 kV source at Hungry Hollow, there by resulting in low voltages at Pohl. To avoid this problem, the 69 kV service to Pohl load from Wilmarth and Hungry Hollow should be retained. This implies that a new circuit from Eastwood – Hungry Hollow is required either on a new right of way or a double circuit with the existing line.

Although it was found that all the load serving problems associated with the city of Mankato are addressed by options 6 and 7, other problems in the vicinity of Eagle Lake, Jamestown, Cleveland and Lake Emily (northeast of Mankato) do exist and are not addressed by either option. It is understood that the area northeast of Mankato needs to be studied separately to address these problems. The schematic one-line diagrams for options 6 and 7 are presented in Appendix C.

5. Generation Outlet Study

5.1 Model description

The generation outlet study was performed as a continuation of the BRIGO study. The analysis was performed on MAPP 2006 series 2011 and 2016 summer off peak cases. The off-peak models are ideal for performing generation outlet studies with high transfers. Since the load in the off-peak models is modeled at 70% of its peak, generation is generally available in excess, there by making it easy to model high exports from North Dakota to stress the NDEX interface.

The facilities proposed in BRIGO study were included in the 2011 models. These facilities include 2nd Nobles 345/115 kV transformer, 2nd Fenton – Nobles 115 kV line, 2nd Brookings Co – Yankee 115 kV line and 115 kV line from Lake Yankton – Marshall SE. Since the BRIGO facilities are assumed to provide 1200 MW of outlet from SW MN, 1200 MW of wind generation is modeled in the Buffalo Ridge area for the 2011 models. The NDEX was set to 1570 MW in the 2011 Models. The facilities proposed in BRIGO and Brookings Co – Hampton Corner 345 kV line study were also included in the 2016 summer off-peak cases. Since the 345 kV line from Brookings Co to Hampton Corner supports up to 2000 MW of outlet for generation in southwest Minnesota, 2000 MW of generation was modeled in the Buffalo Ridge area. In addition to the 2000 MW of generation in southwest Minnesota, 600 MW of Big Stone 2 generation and the associated transmission facilities were included in the 2016 off-peak cases. The NDEX for 2016 models is set to 2170 MW (including the flow on proposed 345 kV line from Canby to Hazel with Big Stone 2).

The objective of using the 2016 models is to verify the compatibility of the new 161 kV plans in the Dotson, Heron Lake, and New Ulm areas with the planned BRIGO and Brookings Co – Hampton Corner 345 kV facilities. These models were used only to demonstrate that the proposed 161/115 kV line from Heron Lake to Ft. Ridgely does not have any negative impact on the planned transmission facilities.

Throughout the generation outlet study, the following operating procedures were used:

(1) Loss of the Wilmarth – Blue Lake / Helena 345 kV line will result in tripping the Mankato Energy Center.
(2) Loss of the LGS – Fieldon/Wilmarth 345 kV line results in tripping the LGS units.
(3) The Lakefield - Fox Lake 161 kV #1 will trip when overloaded.

5.2 Study Methodology

The plans (options 1, 2 and 3) identified in the Dotson area load serving study (Section 4) were used as basis for generation outlet from Storden. The various options are provided in Figure 5.1.

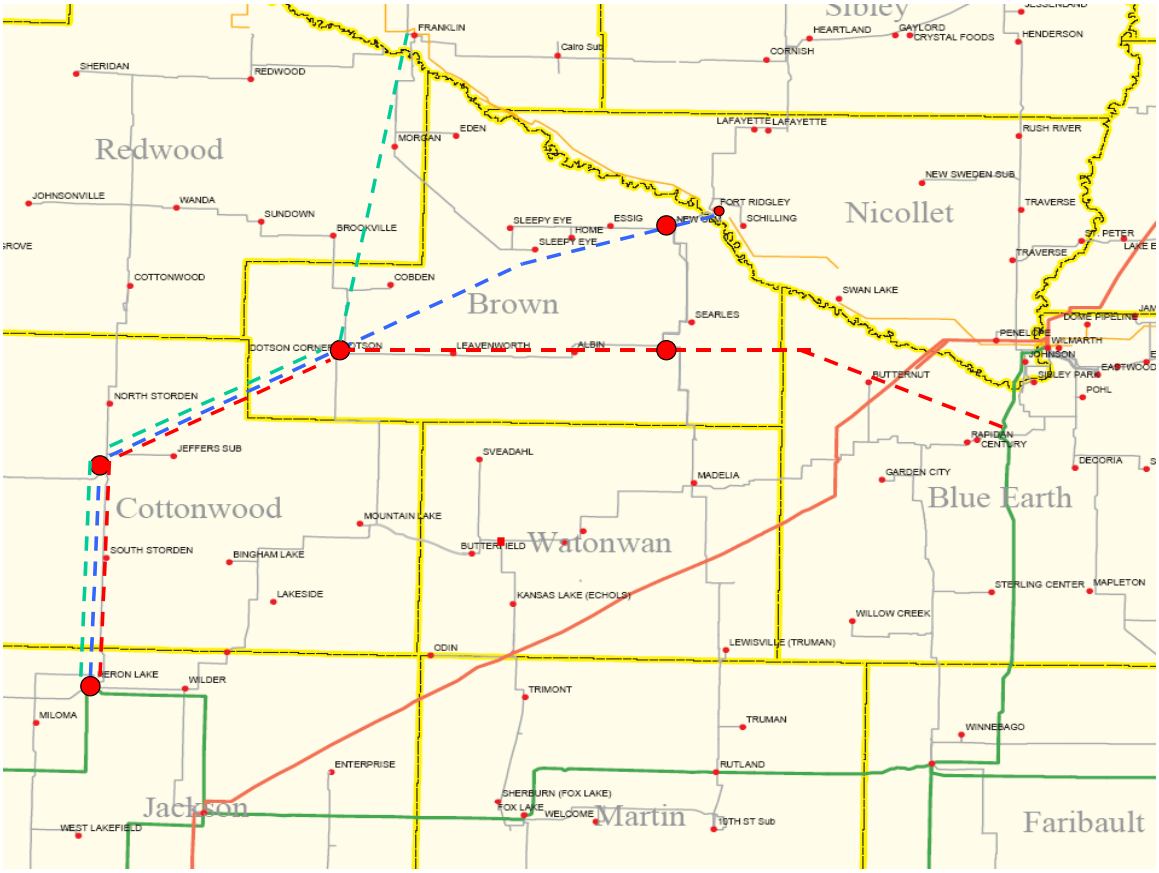


Figure 5.1

By applying each option to the base case, three models were generated that represent the three options considered. In all the cases, new generation is assumed to be at Storden. Transfer limit analysis was performed on these models with Storden generation as a source and Sherco and A.S King generators as sinks. The generation is ramped up at Storden and all the facilities having 2% or higher distribution factors and power flows greater than their emergency ratings are identified as constraints. A similar analysis was done using the 2016 summer off-peak models. Stability analysis was not done as part of this study. For the stability results of Group 4 interconnections with the proposed 161 kV line, refer to "Storden – Dotson – Ft. Ridgely 161 kV Development Feasibility Transmission System Study".

5.3 Transfer Limit analysis

The system was studied using three configurations. The list of constraints found in the 2011 summer off-peak model for each configuration are as follows:

Option 1: This is a 161 kV line from Heron Lake to South Storden to Dotson to Searles Jct and a 115 kV line from Searles Jct to Ft. Ridgely (marked in blue in Fig 5.1). A summary of the results of the transfer limit analysis are presented in Table 5.1

Table 5.1

Contingency	Constraint	%DF	Outlet (1200 +)
Wilmarth–Blue Lake 345 kV	Arlington–Green Island 69 kV	4.7	-255
Wilmarth–Blue Lake 345 kV	Green Island – Carver Co 69 kV	4.7	-237
Wilmarth-Blue Lake345 kV	Winnebago – Hayward 161 kV	8.9	100

Option 2: This is a 161 kV line from Heron Lake to Storden to Dotson to Franklin (marked in Green in Fig 5.1). A summary of the results of the transfer limit analysis are tabulated in Table 5.2

Table 5.2

Contingency	Constraint	%DF	Outlet (1200 +)
Wilmarth-BlueLake345 kV	Arlington – Green Island 69 kV	4.4	-218
Wilmarth-BlueLake345 kV	Green Island – Carver Co 69 kV	4.4	-200
Wilmarth-BlueLake345 kV	Hayward-Winnebago 161 kV	10.5	100

Option 3: This is a 161 kV line from Heron Lake to Storden to Dotson to Albin Jct and a 115 kV line from Albin Jct to Wilmarth (marked in red in Fig 5.1). A summary of the results of the transfer limit analysis for this plan are tabulated in Table 5.3

Table 5.3

Contingency	Constraint	%DF	Outlet (1200 +)
Wilmarth-Blue Lake 345kV	Arlington – Green Island 69kV	3.97	-244.8
Wilmarth-Blue Lake 345kV	Green Island – Carver Co 69 kV	3.92	-235.2
Wilmarth-Blue Lake 345kV	Traverse – Traverse SS 69 kV	3.32	0
Wilmarth-Blue Lake 345kV	Traverse SS – New Sweden 69kV	3.25	0
Wilmarth-Blue Lake 345kV	New Sweden – Rush River 69 kV	3.08	64
Wilmarth-Blue Lake 345kV	Hayward – Winnebago 161 kV	11	117

The detailed list of affected facilities and the outlets obtained from the proposed configurations for 2011 and 2016 models are listed in Appendix D**.** It is concluded from the analysis that the proposed 161 kV line does not have negative impact on the planned Brookings Co – Hampton Corner 345 kV line or the BRIGO facilities. For the 2011 models without the Brookings Co – Hampton Corner 345 kV line, the Storden generation is increased until the line from Winnebago to Hayward overloads for the loss of Wilmarth – Blue Lake 345 kV. It is observed that the Brookings Co – Hampton Corner 345 kV line will mitigate the Winnebago – Hayward 161 kV line overload.

For the 2016 models, the generation at Storden is increased for each configuration until the LGS – Fieldon 345 kV line overloads beyond the emergency rating. The 345 kV line from LGS to Wilmarth is limited by the rating of the series compensator to 1195 MVA (Normal) and 1493 MVA (Emergency). Further, changing the impedance of the line will result in changing the required series compensation level.

A number of other 345 kV and 230 kV line overloads were observed in the 2016 models, however these problems were also identified in the SW MN -> Twin Cities EHV line study. Plans to mitigate these problems are not identified in this study, as they are not a direct consequence of Storden generation interconnection and associated TSR. It is implicit that the study performed on 2016 models is exploratory in nature. The out-year models provide a way to analyze the impact of the planned 345 kV lines from Brookings Co to Hampton Corner. Although the results from the out-year models do indicate possibility for higher outlet levels from Storden, it should be understood that the increase in local load in the southwest Minnesota region would have some effect of reducing the flows on the bulk transmission system out of the area. Along with the effect of load growth, the effect of increased wind generation (beyond 2000 MW) in Buffalo Ridge area is also not considered in 2016 models.

The generation outlet study performed for this area is based on the assumption that all the generation in the area is installed at Storden and does not take the MISO generation interconnection queue or TSRs into account. The results of the study provide the approximate amount of generation outlet that can be achieved from this area with the proposed high voltage facilities.

6. Exploratory Study

All the exploratory studies were performed on the preferred option (1), a 161 kV line from Heron Lake – Dotson - Ft. Ridgely 161/115 kV line on 2016 summer peak and off peak models.

6.1 Effect of additional ethanol plants in the region (Load serving)

As more ethanol plants are expected in the study area, analysis was performed on the 2016 summer peak models to determine the ability of the proposed 161 kV line to meet the expected load growth. New ethanol plants were modeled at Butterfield and St. James (each 15 MW) and the capacity of the Lakeside ethanol plant is doubled to 15 MW. The limitations that arise only due to the addition of these ethanol plants are listed in Table 6.1.

Table 6.1

Year	Contingency	Monitored Element	Rating MVA	Current MVA	% Load
2016	Lakefield Jct 345/161 kV TX#1	Lakefield Jct 345/161 kV TX#2	335	335	100
2016	Lakefield Jct 345/161 kV TX#2	Lakefield Jct 345/161 kV TX#1	335	335	100
2016	Rutland 161/69 kV TX	Fox Lake 161/69 kV	74.7	82	110
2016	Bel Pl – Stone Pt 115 kV	IAF 115/69 kV TX	31.3	31.3	100
2016	Burlington – S Burl 69 kV	New Port – Cairo 69 kV	32	32.1	100
2016	Elk 161/69 kV	Worthington tap – Worthington 69 kV	47	50.6	107.65

Year	Contingency	Bus	% Voltage
2016	Elk 161/69 kV TX	Fulda	65.5
2016	Elk 161/69 kV TX	Bloom	62.7

6.2 Effect of Maple River – Alexandria – St. Cloud 345 kV line (Generation outlet)

In addition to the effect of Brookings Co – Hampton Corner 345 kV line, the impact of Maple River – Alexandria – St. Cloud 345 kV line is also studied using the 2016 summer off-peak models. The results of transfer limit analysis are presented in Table 6.2. It is seen that the outlet from Storden generator increased by 100% compared to the results presented in **Table D.4.** It is expected that the Maple River – Alexandria – St. Cloud 345 kV along with addressing the load serving problems in St. Cloud, Alexandria and Red River Valley regions, also helps reduce the flow on the LGS – Wilmarth 345 kV line. The summary of transfer limit analysis is presented in Table 6.2

Table 6.2

Contingency	Constraint	%DF	Outlet (2000 +)
Franklin – Fairfax 69 kV	Ft. Ridgely – Schilling tap 69 kV	2.82	-91.13
Franklin – Fairfax 69 kV	Schilling Tap – Lafayette 69 kV	2.87	-20
Franklin – Fairfax 69 kV	Lafayette-Lafayette 69 kV	2.78	18.8
Storden – Dotson 161 kV	Johnsonville-Wanda 69 kV	3.31	118.5
Wilmarth – Helena 345 kV	Arlington – Green Island 69 kV	3.00	122.87
Wilmarth – Helena 345 kV	Green Island – Carver Co 69 kV	3.00	140.54
Storden – Dotson 161 kV	Wanda – Sundown 69 kV	3.28	135.9
Storden – Dotson 161 kV	Storden – South Storden 69 kV	79.3	185.8
Storden – Dotson 161 kV	South Storden – Heron Lake	78	187.1
Storden – Dotson 161 kV	Comfrey – Dotson 69 kV	10.96	294.4
Franklin – Fairfax 69 kV	Lafayette – Winthrop 69 kV	2.77	300
Franklin – Helena 345 kV	LGS – Fieldon – Wilmarth 345 kV	30.74	328

6.3 Sensitivity to generation in Buffalo Ridge area (Generation Outlet)

The sensitivity of reduced generation in Buffalo Ridge area is studied by decreasing the generation at Buffalo Ridge area by 100 MW (Total Buffalo Ridge generation at 1900 MW). Transfer limit analysis was performed on this model to determine the maximum generation outlet obtained from Storden. The summary of transfer limit analysis is presented in Table 6.3. It can be concluded that reducing 100 MW of generation in Buffalo Ridge area provides outlet for approximately additional 100 MW at Storden, but it should be noted that the local constraints around the Storden generator should be mitigated to achieve this level of outlet.

Table 6.3

Contingency	Constraint	%DF	Outlet (1900 +)
Franklin-Fairfax 69 kV	Ft. Ridgely – Schilling tap 69 kV	2.91	-80
Franklin – Fairfax 69 kV	Schilling tap – Lafayette 69 kV	2.9	-20
Franklin – Fairfax 69 kV	Lafayette – Lafayette 69 kV	2.8	17.4
Wilmarth – Helena 345 kV	Arlington – Green Island 69 kV	3.1	93.22
Wilmarth – Helena 345 kV	Green Island – Carver Co 69 kV	3.1	109.35
Storden – Dotson 161 kV	Johnsonville tap – Wanda 69 kV	3.27	120.9
Storden – Dotson 161 kV	Wanda – Sundown 69 kV	3.23	138.1
Storden – Dotson 161 kV	Storden – South Storden 161 kV	79.4	185.5
Storden – Dotson 161 kV	South Storden – Heron Lake	78.2	186.9
Franklin – Helena 345 kV, ckt 2	LGS – Wilmarth 345 kV	34.78	291.8

7. Economic Analysis and Summary

7.1 Estimated cost of facilities

The estimates used for comparison of the options are provided by the study participants and are indicative in nature.

Preferred Plan:

Facility	Cost (Millions)$
Lakefield Jc – Heron Lake Upgrade to 2-795 ACSR	10.2
Heron Lake – S Storden – Storden upgrade to 161 kV	6.8
Storden 161/69 kV transformer addition	4
Dotson – Storden 161 kV line	10.76
Dotson – Searles Jc	12.22
Dotson 161/69 kV Sub	5.278
Searles 161/115/69 kV Substation	9.98
Searles Jc – Ft. Ridgeley 115 kV line	4.6
Ft. Ridgley Sub work	0.53
Searles Jc – New Ulm 69 kV line upgrade to 477 ACSR	0.6
Total: $64.97 million	

Preferred plan for Mankato area:

Facility	Cost (Millions)$
Eastwood 115 kV line termination	0.44
Pohl substation conversion to 115 kV	0.54
Pohl tap – Hungry Hollow 115 kV conversion	0.95
Hungry Hollow 115/69 kV substation	2.622
Hungry Hollow – Ballard Corner double ckt 115 kV line	1.8
Ballard Corner – South Bend conversion to 115 kV	0.25
South Bend substation 161/115/69 kV	6.405
Work at Wilmarth	0.28
Total: $13 million	

Alternative 1:

Facility	Cost (Millions)$
Lakefield Jc – Heron Lake Upgrade to 2-795 ACSR	10.2
Heron Lake – S Storden – Storden upgrade to 161 kV	6.8
Storden 161/69 kV transformer addition	4
Dotson – Storden 161 kV line	10.76
Dotson – Franklin 161 kV	14.67
Dotson 161/69 kV sub	5.278
Cobden – Dotson 69 kV line	2.53
Franklin 161/115 kV TX	2.5
69 kV line from Sleepy Eye – Cobden	2.6
Sleepy Eye Jc breaker station	1.985
Ft. Ridgley 2nd TX and breakers	2.75
Total: $61.07	

Alternative plan for Mankato Area:

Facility	Cost (Millions)$
Eastwood 115 kV line termination	0.44
New 115 kV line from Eastwood – Hungry Hollow	2.55
Hungry Hollow 115/69 kV substation	2.622
Hungry Hollow – Ballard Corner double ckt 115 kV line	1.8
Wilmarth 115/69 kV TX upgrades to 112 MVA	5.195
Total: $12.6 million	

Alternative 2 for Dotson area:

Facility	Cost (Millions)$
Lakefield Jc – Heron Lake Upgrade to 2-795 ACSR	10.2
Heron Lake – S Storden – Storden upgrade to 161 kV	6.8
Storden 161/69 kV transformer addition	4
Dotson – Storden 161 kV line	10.76
Dotson 161/69 kV substation	5.278
Cobden – Dotson 69 kV line	2.533
Dotson – Leavenworth – Albin – Albin Jc upgrade to 161 kV	5.244
Leavenworth sub conversion to 161 kV	0.54
Albin Jc sub conversion to 161 kV	0.54
Albin Jc – South Bend 115 kV	10.6
Albin Jc 161/115/69 kV sub	8.9
Ft. Ridgley 2nd TX and breakers	2.75
69 kV line from Sleepy Eye – Cobden	2.6
Sleepy Eye Jc breaker station	1.985
Total: $72.73 million	

7.2 Loss analysis

Table 7.2

Year	Model	Plan	Losses
2011	Off peak	Option 1	12691.2 MW
2011	Off peak	Option 2	12690.9 MW
2011	Off peak	Option 3	12689.8 MW

Table 7.3

Year	Model	Plan	Losses
2011	Peak	Option 1	12756.7 MW
2011	Peak	Option 2	12755.5 MW
2011	Peak	Option 3	12754.2 MW

Tables 7.2 and 7.3 provide the losses for the various options during summer off peak and peak conditions respectively. From these tables, it can be noticed that the difference in losses between any two options is not significant (less than 2.5 MW). Hence no further analysis was done on energy value or capacity value of loss savings.

Dotson and New Ulm areas

Properties	(Preferred) Option 1	(Alternative) Option 2	(Alternative) Option 3
(1) Approximate miles of new line[1]	161 kV – 66 miles 115 kV – 5 miles 69 kV – ~0 miles	161 kV – 71 miles 115 kV – ~0 miles 69 kV – ~12 miles	161 kV – 64 miles 115 kV – 23 miles 69 kV – ~12 miles
(2) Losses[2]	0/0	-0.3/-1.2	-1.4/-2.5
(3) Cost	$ 64.97 million	$ 61.07 million	$ 72.73 million
(4) Generation outlet	100 MW	100 MW	117 MW
(5) Cost / MW of generation outlet	$ 0.65 million	$ 0.61 million	$ 0.62 million
(6) Incremental Load serving capabilities	Based on the 2016 models, the following are the incremental load serving capabilities: Dotson – Approx 92 MW New Ulm – 13 MW Sleepy Eye - 4.4MW, and an additional 6MW after adding a cap at Sleepy Eye Jc.	Dotson – Approx 105 MW New Ulm-14 MW Sleepy Eye - 18.3MW	Dotson – Approx 105 MW New Ulm – 14 MW Sleepy Eye - 18.3MW

Mankato area

Properties	(Preferred) Option 6	(Alternative) Option 7
(1) Approximate miles of new right of way.	~0	5 miles of new 115 kV line.
(2) Cost	$13 million	$ 12.6 million
(3) Ease of adding new Distribution subs	New distribution substations can be easily accommodated along the proposed 115 kV loop.	As this is a radial 115 kV line from Eastwood to Hungry Hollow, new distribution substations cannot be accommodated easily.

[1] Includes conversion from 69 kV to higher voltages.
[2] Normalized with respect to option 1 (off peak / on peak)

(4) Incremental Load serving capabilities	The incremental load serving capabilities of these two options are not limited by the transmission system. Due to the physical constraints of Sibley Park Substation, no new feeders or distribution banks can be added at this location. This might drive the need to build new distribution substation at the City of Mankato. The 115 kV loop around the city is an ideal choice for building new distribution substation in the future for this region. Assuming no physical constraints at the substations, both the plans can add an additional 10 MW of load at Sibley Park. By building new 115 kV distribution substation more than 50 MW of new load can be added in this region.

APPENDIX – A
Detailed List of Facilities

Preferred plan:

- Convert the 69 kV line from Heron Lake to South Storden to Storden to 161 kV.
- Upgrade the service to South Storden load to 161 kV.
- 1x161/69 kV transformer at Storden, at least 56 MVA.
- New 161 kV line from Storden to Dotson corners (795 ACSS).
- 2x161/69 kV transformers at Dotson Corners, at least 56 MVA each.
- New 161 kV line from Dotson Corners to Searles Jc 795 ACSS.
- 2x30 MVAR capacitors at Dotson.
- 1x161/115 kV transformer at Searles Jc, at least 187 MVA.
- 112 MVA 115/69 kV transformer at Searles Jc.
- New 115 kV line from Searles Jc to Ft. Ridgely (2-795 ACSS).
- Upgrade the 69 kV line from Searles Jc to New Ulm to 477 ACSR.
- Upgrade the 161 kV line from Heron Lake to Lakefield Jc to 2-795 ACSR.
- Upgrade the Fox Lake 161/69 kV transformer, #2 to 70 MVA.
- New 69 kV line from Dotson to Cobden (477 ACSR).

Mankato area preferred plan:

- Relocate the 161/115 kV transformer from Wilmarth to a location 12 miles south on the 161 kV line to Blue Earth (South Bend). Operate the 161 kV line from South Bend to Wilmarth at 115 kV.
- 1x115/69 kV TX at South Bend (70 MVA).
- Serve Century from South Bend 69 kV source.
- Convert the existing 69 kV line from South Bend to Hungry Hollow to 115 kV (795 ACSR/ACSS).
- 1x115/69 kV 112 MVATX at Hungry Hollow (70 MVA should suffice if Sibley park substation is converted to 115 kV by 2018).
- Convert the existing 69 kV line from Hungry Hollow to Wilmarth along with Pohl load (or build new 115 kV line from Hungry Hollow to Eastwood).
- Feed the Sibley Park Load normally from Hungry Hollow.

Alternative plan 1:

- Convert the 69 kV line from Heron Lake to South Storden to Storden to 161 kV.
- Upgrade the service to South Storden load to 161 kV.
- 1x161/69 kV transformer at Storden.
- New 161 kV line from Storden to Dotson corners.
- 2x161/69 kV transformers at Dotson Corners.
- New 161 kV line from Dotson Corners to Franklin
- 2x30 MVAR capacitor bank at Dotson.

- 1x161/115 kV TX at Franklin.
- 2nd Ft. Ridgely 115/69 kV TX with LTC (112 MVA).
- Upgrade the Franklin 115/69 kV TXs to 112 MVA.
- New 69 kV line from Dotson to Cobden to Sleepy Eye Jct (477 ACSR).
- 69 kV switching station at Sleepy Eye.
- Upgrade the 161 kV line from Heron Lake to Lakefield Jct to 2-795 ACSR.
- Upgrade the Fox Lake 161/69 kV, #2 transformer to 70 MVA.

Mankato area alternative plan (relatively short term plan):

- Upgrade Wilmarth 115/69 kV TX Nos. 1, 2, and 3 to 112 MVA.
- Build new 115 kV line from Eastwood to Hungry Hollow (795 ACSR/ACSS).
- 1x115/69 kV 112 MVA TX at Hungry Hollow.

Alternative plan 2:

- Convert the 69 kV line from Heron Lake to South Storden to Storden to 161 kV.
- Upgrade the service to South Storden load to 161 kV.
- 1x161/69 kV transformer at Storden (at least 56 MVA).
- New 161 kV line from Storden to Dotson corners (795 ACSS).
- 2x161/69 kV transformers at Dotson Corners (at least 56 MVA each).
- 2x30 MVAR capacitor banks at Dotson.
- Convert the 69 kV line from Dotson to Leavenworth to Albin to Albin Jc to 161 kV.
- Convert Leavenworth and Albin loads to 161 kV.
- 1x161/115 kV TX at Albin Jc, at least 187 MVA.
- 1x115/69 kV TX at Albin Jc (70 MVA)
- New 115 kV line from Albin Jct to South Bend (795 ACSS).
- 2nd Ft. Ridgely 115/69 kV TX with LTC (112 MVA).
- New 69 kV line from Dotson to Cobden to Sleepy Eye Jc (477 ACSR).
- 69 kV switching station at Sleepy Eye.

Mankato area plan (same as preferred plan):

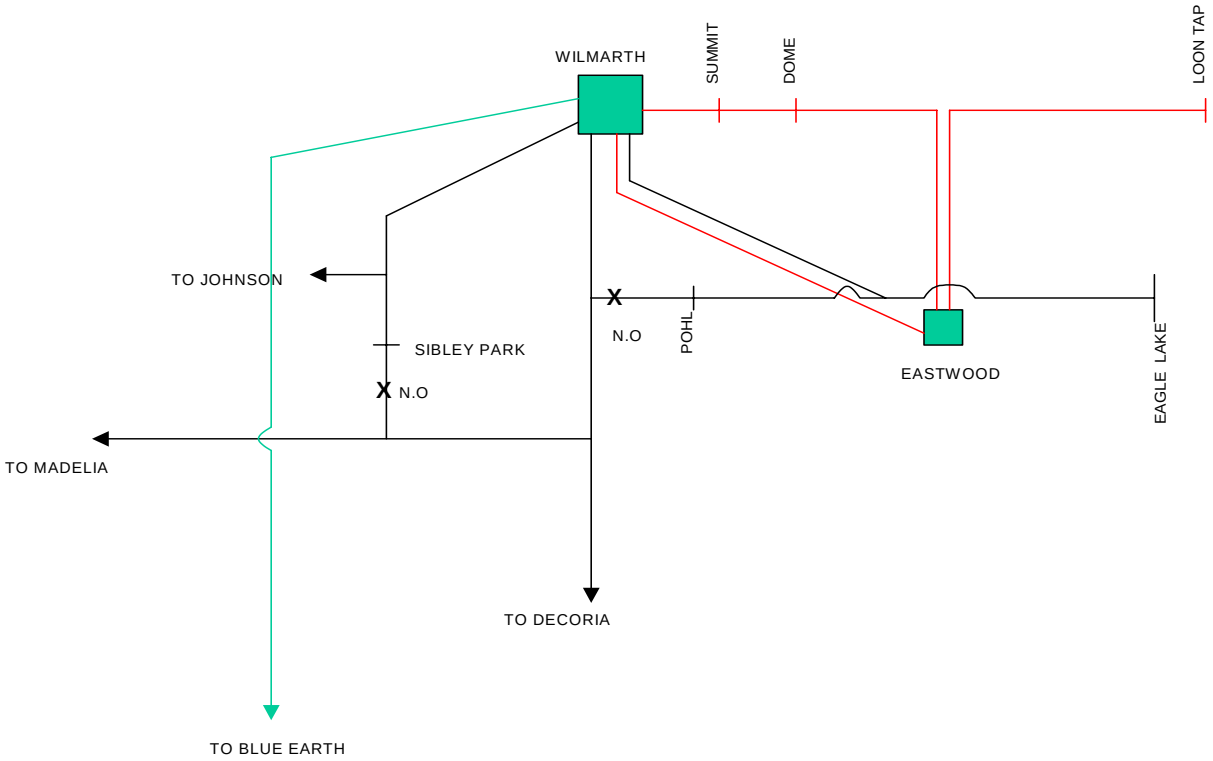
- Relocate the 161/115 kV transformer from Wilmarth to a location 12 miles south on the 161 kV line to Blue Earth (call the location South Bend). Operate the 161 kV line from South Bend to Wilmarth at 115 kV.
- 1x115/69 kV TX at South Bend (112 MVA).
- Serve Century from South Bend 69 kV source.
- Convert the existing 69 kV line from South Bend to Hungry Hollow to 115 kV.
- 1x115/69 kV TX at Hungry Hollow (112 MAV).

- Convert the existing 69 kV line from Hungry Hollow to Wilmarth along with Pohl load (or build new 115 kV line from Hungry Hollow to Eastwood).
- Feed the Sibley Park Load normally from Hungry Hollow.

Appendix – B
Powerflow Maps

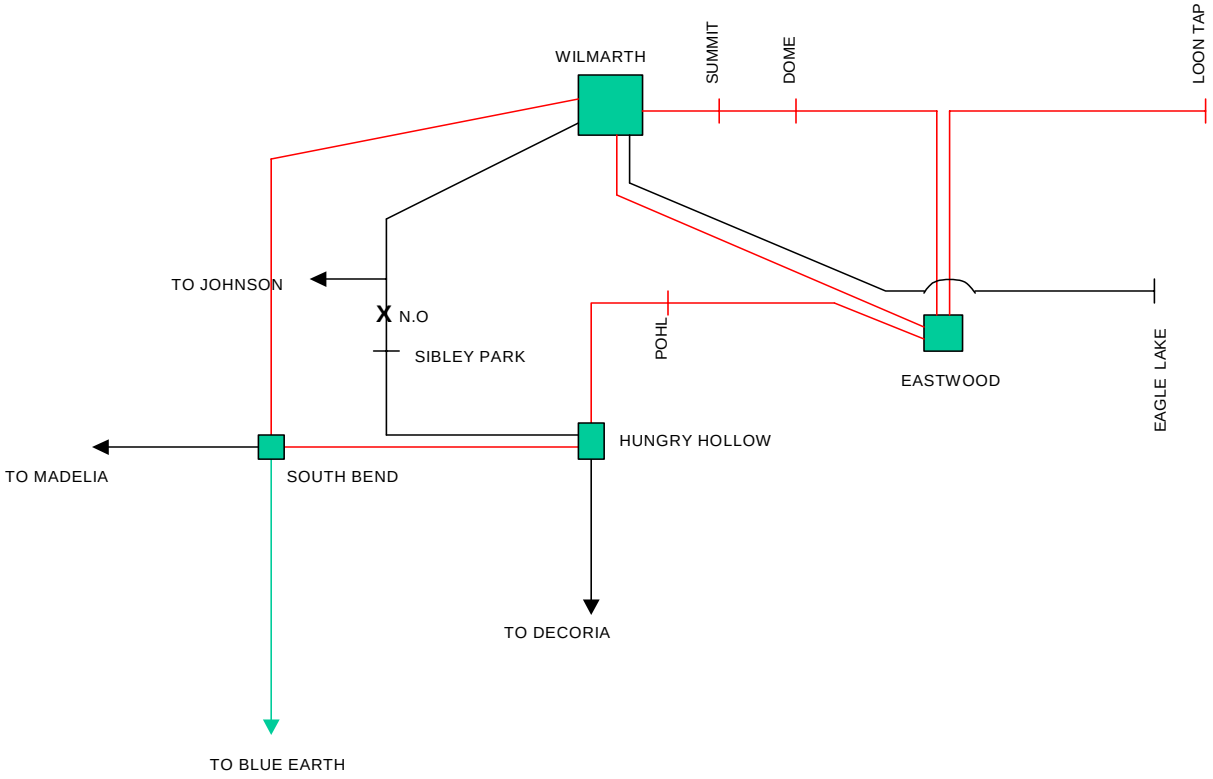
Appendix – C
Geographic and Schematic Maps

EXISTING SYSTEM



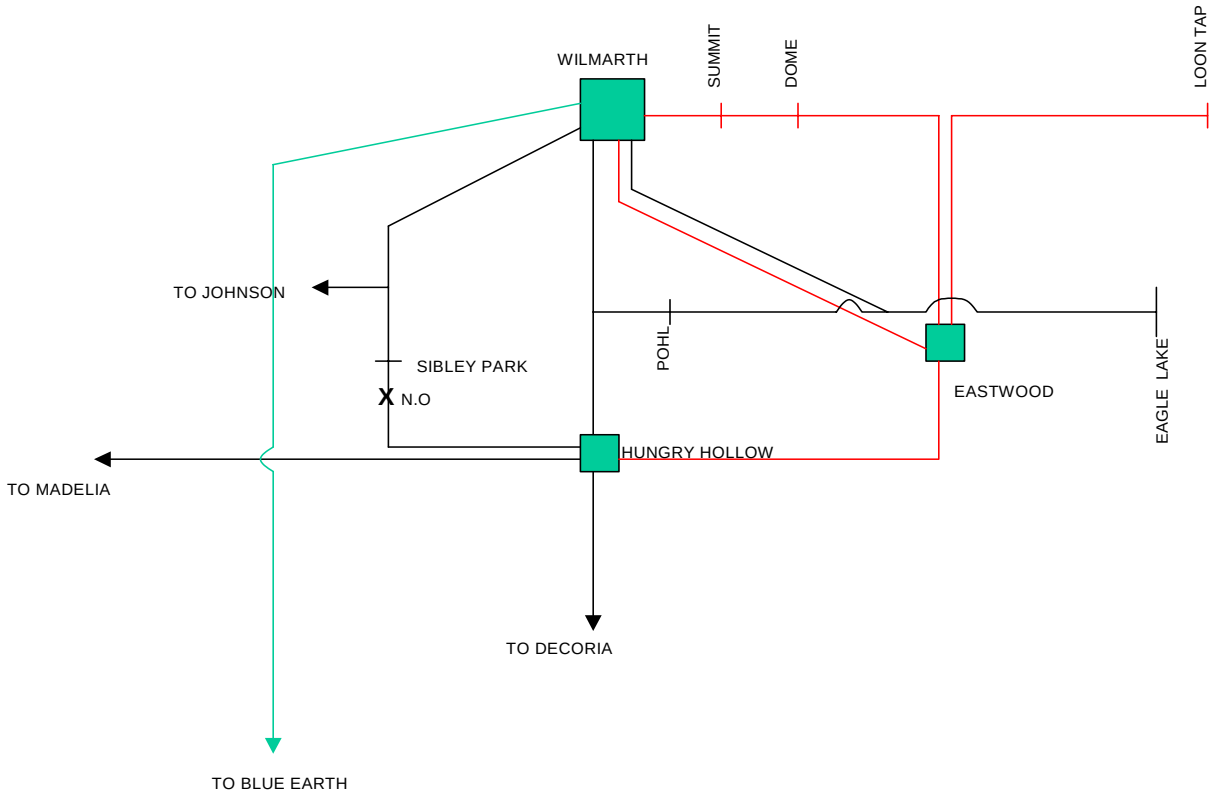
Mankato area

PREFERED PLAN



Mankato area

ALTRENATIVE PLAN



Mankato area

Appendix D
Results of Transfer Limit Analysis

Options 1
Table D.1

2011 SUOP

161 kV line from Heron Lake - Dotson - Searles Jc. 115 kV line from Searles Jc - Ft. Ridgely

Contingency	Limiting element	%DF	MW outlet 1200 +	Comments
Prairie Island - Blue Lake 345 kV Blue Lake - Inver Hills 345 kV Inver Hills - Red Rock 345 kV lines	Edina - Eden Prairie 115 kV line	3.77	-1107	Planned upgrade to 620 MVA
Minn Valley tap - Granite Falls 230 kV line	Minn Valley 230/115 kV TX (115%)	3.5	-42.86	Identified in EHV Study / Upgrade
Wilmarth - Blue Lake 345 kV line (Calpine turned off)	**Arlington - Green Island 69 kV line (110%)**	**4.7**	**-225**	Reconductor
Wilmarth - Blue Lake 345 kV line (Calpine turned off)	**Green Island - Carver Co 69 kV line (110%)**	**4.7**	**-225**	Reconductor
Wilmarth - Blue Lake 345 kV line (Calpine turned off)	**Winnebago - Hayward 161 kV line (100%)**	**8.9**	**100**	**Stop**
Minn Valley tap - Panther 230 kV	Bird Island - Panther 115 kV line (110%)	4.12	143.2	Reconductor
Fairfax - Franklin 69 kV line	Ft. Ridgely - Schilling tap 69 kV (110%)	3.5	102.86	
Fairfax - Franklin 69 kV line	Schilling - Lafayette 69 kV (110 %)	3.3	134	
Storden - Dotson Corners 161 kV line	Storden - South Storden 161 kV line (100%)	78	188	
Storden - Dotson Corners 161 kV line	South Storden – Heron Lake 161 kV line (100%)	77	189	
Franklin - Fairfax 69 kV line	Lafayette (Xcel Energy)- Lafayette (GRE)	3.3	196.9	

Option 2
Table D.2

2011 SUOP

161 kV line from Heron Lake - Dotson - Franklin 161 kV line

Contingency	Limiting element	%DF	MW outlet 1200+	Comments
Prairie Island - Blue Lake 345 kV Blue Lake - Inver Hills 345 kV Inver Hills - Red Rock 345 kV lines	Edina - Eden Prairie 115 kV line	3.69	-1124	Planned upgrade to 620 MVA
Minn Valley tap - Granite Falls 230 kV line	Minn Valley 230/115 kV TX (115%)	4	-49.14	Identified in EHV Study / Upgrade
Wilmarth - Blue Lake 345 kV line (Calpine turned off)	**Arlington - Green Island 69 kV line (110%)**	**4.4**	**-218**	Reconductor
Wilmarth - Blue Lake 345 kV line (Calpine turned off)	**Green Island - Carver Co 69 kV line (110%)**	**4.4**	**-207**	Reconductor
Granite Falls - Willmar 230 kV line	Maynard – Kerkhoven tap 115 kV (110%)	3.1	-370	Identified in EHV Study / Reconductor
Minn Valley Tap - Panther 230 kV line	Franklin 115/69 kV TX (115%)	4.2	-92	Identified in EHV Study / Upgrade
Wilmarth - Blue Lake 345 kV line (Calpine turned off)	**Hayward - Winnebago 161 kV line (100%)**	**10.5**	**100**	**Stop**
Minn Valley tap - Panther 230 kV	Bird Island - Panther 115 kV line	5.4	152.7	
Storden - Dotson Corners 161 kV line	Storden - South Storden 161 kV line (100%)	78	188	
Storden - Dotson Corners 161 kV line	South Storden – Heron Lake 161 kV line (100%)	77	189	

Option 3
Table D.3

2011 SUOP

161 kV line from Heron Lake - Dotson - Albin Jc. 115 kV line from Albin Jc to Wilmarth

Contingency	Limiting element	%DF	MW outlet 1200+	Comments
Prairie Island - Blue Lake 345 kV Blue Lake - Inver Hills 345 kV Inver Hills - Red Rock 345 kV lines	Edina - Eden Prairie 115 kV line	3.85	-1094.5	Planned upgrade to 620 MVA
Willmar - Granite Falls 230 kV line	Minn Valley Tap - Granite Falls 230 kV line (110%)	3.9	0	Identified in EHV Study / Reconductor
Wilmarth - Blue Lake (MEC tripped)	**Arlington - Green Island (110%)**	**3.97**	**-244.8**	Reconductor
Wilmarth - Blue Lake (MEC tripped)	**Green Island - Carver Co (110%)**	**3.92**	**-235.2**	Reconductor
Wilmarth - Blue Lake (MEC tripped)	**Traverse - Traverse 69 kV (110%)**	**3.32**	**0**	Reconductor
Wilmarth - Blue Lake (MEC tripped)	**New Sweden - Traverse 69 kV (110%)**	**3.25**	**0**	Reconductor
Granite Falls - Minn Valley tap 230 kV	Minn Valley tap 230/115 kV TX (115 kV)	5.68	17.6	Identified in EHV Study / Upgrade
Wilmarth - Blue Lake (MEC tripped)	**New Sweden - Rush River 69 kV (110%)**	**3.08**	**64.28**	Reconductor
Wilmarth - Blue Lake (MEC tripped)	**Hayward - Winnebago 161 kV (100%)**	**10.96**	**117.33**	**Stop**
Wilmarth - Blue Lake (MEC tripped)	Lesure Tap - Rush River 69 kV (110%)	3.26	124.53	
Albin Jc - South Bend	Albin Jc - Linden 69 kV (100%)	7.96	148.9	
Albin Jc - South Bend	Linden - Hanska 69 kV (100%)	8	151.6	
Storden - Dotson corners	Storden - South Storden 161 kV (100 %)	75.15	193.2	
Storden - Dotson corners	Storden - Heron Lake 161 kV (100%)	74.29	194.4	

Option 1
Table D.4

2016 SUOP With Brooking Co - Helena - Lake Marion - Hampton Corners 345 kV line
Assumed wind generation in SW MN is 2000 MW
Heron Lake - Dotson - Searles - Ft. Ridgely 161/115 kV line

Contingency	Limiting Element	% DF	Outlet 2000+	Comments
Blue Lake - Helena 345 kV line	Lake Marion - Kenrick 115 kV line (100%)	3.85	-3248	Identified in EHV Study / Reconductor
Blue Lake - Helena 345 kV line	Kenrick - Dakota Heights (100%)	3.94	-3005	Identified in EHV Study / Reconductor
Blue Lake - Helena 345 kV line	Burnsville - Dakota Heights (100%)	3.85	-2429	Identified in EHV Study / Reconductor
Helena - Lake Marion 345 kV	Blue Lake - Helena 345 kV line (110%)	50.29	-693.23	Identified in EHV Study / Reconductor
King - Red Rock 345 kV line	Eden Prairie - Edina 115kV line (110%)	3.34	-252	Planned Upgrade
Franklin - Fairfax 69 kV	**Ft Ridgely - Schilling tap 69 kV (100 %)**	**2.96**	**-106**	Reconductor
Lyon Co - Franklin 345 kV line (2ckt)	Minn Valley tap - Panther 230 kV line (110%)	4.6	-95.4	Identified in EHV Study / Reconductor
Franklin - Fairfax 69 kV	**Schilling tap - Lafayette 69 kV (100%)**	**2.92**	**-47**	Reconductor
Franklin - Fairfax 69 kV	**Lafayette - Lafayette 69 kV (100%)**	**2.5**	**-8.5**	Reconductor
Wilmarth - Helena 345 kV	**Arlington - Green Island 69 kV (110%)**	**3.2**	**65**	Reconductor
Wilmarth - Helena 345 kV	**Green Island - Carver Co 69 kV (110%)**	**3.2**	**80.5**	Reconductor
Storden - Dotson Corners 161 kV	**Johville tap - Wanda 69 kV (100%)**	**3.23**	**108.9**	Reconductor
Storden - Dotson Corners 161 kV	**Wanda - Sundown 69 kV (100%)**	**3.23**	**123.4**	Reconductor
Helena - Franklin 345 kV (2ckt)	Wilmarth - Helena 345 kV (110%)	46.98	154.32	Identified in EHV Study / Reconductor
Franklin - Helena 345 kV line (2ckt)	**LGS - Fieldon 345 kV**	**33.99**	**166.2**	**Identified in the EHV study (Stop)**
Storden - Dotson Corners 161 kV	Storden - South Storden 161 kV	78.82	187.1	
Storden - Dotson Corners 161 kV	South Storden - Heron Lake 161 kV	77.57	188.6	
Lyon Co - Franklin 345 kV	LGS - Wilmarth 345 kV (110%)	29.63	207	
Blue Lake - Helena 345 kV line	Lake Marion 345/115 kv TX (115 %)	6.66	220	EHV Study suggested 448 MVA TX, Consider 672 MVA
Franklin - Fairfax 69 kV	Lafayette - Winthrop (110%)	2.77	263	

Option 2
Table D.5

2016 SUOP With Brooking Co - Helena - Lake Marion - Hampton Corners 345 kV line
Assumed wind generation in SW MN is 2000 MW
Heron Lake - Dotson - Franklin 161 kV line

Contingency	Limiting Element	% DF	Outlet 2000+	Comments
Blue Lake - Helena 345 kV line	Lake Marion - Kenrick 115 kV line (100%)	3.92	-3185	Identified in EHV Study
Blue Lake - Helena 345 kV line	Kenrick - Dakota Heights (100%)	3.83	-3088	Identified in EHV Study
Blue Lake - Helena 345 kV line	Burnsville - Dakota Heights (100%)	3.93	-2374	Identified in EHV Study
Helena - Lake Marion 345 kV	Blue Lake - Helena 345 kV (110%)	51.37	-674.61	Identified in EHV Study
Franklin - Helena 345 kV 2ckt	Franklin 115/69 kV TX	3.1	-444.83	Identified in EHV Study
King - Red Rock 345 kV	Edina - Eden Prairie (110%)	3.41	-244	Planned Upgrade
Lyon Co - Franklin 345 kV 2ckt	Minn Valley Tap - Panther 230 kV (110%)	4.4	-91	Identified in EHV Study
Parkers Lake - Eden Prairie Eden Prairie 345/115 kV TX 10	Eden Prairie 345/115 kV TX 9 (115%)	3.35	-53.73	Identified in EHV Study
Wilmarth - Helena 345 kV	**Arlington - Green Island 69 kV (110%)**	**2.54**	**120.86**	
Wilmarth - Helena 345 kV	**Green Island - Carver Co 69 kV (110%)**	**2.54**	**140.55**	
Helena - Franklin 345 kV (2 ckt)	**LGS - Wilmarth 345 kV line (110%)**	**37.08**	**141.83**	**Identified in EHV Study (Stop)**
Helena - Franklin 345 kV (2 ckt)	Wilmarth - Helena 345 kV line (110%)	42.19	183.42	Identified in EHV Study
Storden - Dotson Corners 161 kV	Storden - South Storden 161 kV (100%)	80	185.3	
Storden - Dotson Corners 161 kV	South Storden - Heron Lake 161 kV (100%)	78.76	186.8	
Blue Lake - Helena 345 kV	Lake Marion 345/115 kV TX (115%)	7.37	203.5	Consider 672 MVA
Blue Lake - Helena 345 kV line	Lake Marion 345/115 kV TX (115 %)	7.11	210.9	EHV Study suggested 448 MVA TX, Consider 672 MVA

Option 3
Table D.6

2016 SUOP With Brooking Co - Helena - Lake Marion - Hampton Corners 345 kV line
Assumed wind generation in SW MN is 2000 MW
Heron Lake - Dotson - Albin Jc - Wilmarth 161/115 kV line

Contingency	Limiting Element	% DF	Outlet 2000+	Comments
Blue Lake - Helena 345 kV line	Lake Marion - Kenrick 115 kV (100%)	4.1	-3062.9	Identified in EHV Study
Blue Lake - Helena 345 kV line	Dakota Heights - Kenrick (100 %)	4.04	-2946.5	Identified in EHV Study
Blue Lake - Helena 345 kV line	Burnsville - Dakota Heights (100%)	4.08	-2303.6	Identified in EHV Study
Helena - Lake Marion 345 kV	Blue Lake - Helena 345 kV (110%)	46.49	-758.78	Identified in EHV Study
AS King - Red Rock 345 kV	Eden Prairie - Edina 115 kV (110%)	3.35	-255.22	Planned upgrade
Lyon Co - Franklin 345 kV 2ckt	Minn Valley Tap - Panther 230 kV (110%)	5.7	-126	Identified in EHV Study
Eden Prairie - Parkers lake 345 kV Eden Prairie 345/115 kV TX 10	Eden Prairie 345/115 kV TX (115%)	3.6	-60.27	Identified in EHV Study
Wilmarth - Helena 345 kV	**Arlington - Green Island 69 kV (110%)**	**2.73**	**154.57**	Reconductor
Albin Jc - South Bend 115 kV	Albin Jc- Linden 69 kV (100 %)	8.7	170	Reconductor
Wilmarth - Helena 345 kV	**Green Island - Carver Co 69 kV (110%)**	**2.74**	**172.26**	Reconductor
Albin Jc - South Bend 115 kV	Hanska - Linden 69 kV (100%)	8.7	179.3	Reconductor
Storden - Dotson Corners 161 kV	Storden - South Storden 161 kV (100%)	77.3	187.3	Reconductor
Storden - Dotson Corners 161 kV	South Storden - Heron Lake 161 kV (100%)	76.38	188.3	Reconductor
Franklin - Helena 345 kV 2ckt	**LGS -(Fieldon) Wilmarth**	**43**	**200**	**Identified in EHV Study (Stop)**
Leavenworth - Dotson Corners 161 kV	Comfrey - Dotson 69 kV (100 %)	12.78	241	
Albin - Leavenworth 161 kV	Mountain Lake - Butterfield 69 kV (100%)	7.3	242	
Blue Lake - Helena 345 kV line	Lake Marion 345/115 kV (115 %)	6.86	242.51	EHV study suggested 448 MVA, consider 672 MVA
South Storden -Storden 161 kV	Mountain Lake - Mountain Lake (100%)	10.95	261	

Exploratory studies:

Option 1
Table D.7

2016 SUOP With Brooking Co - Helena - Lake Marion - Hampton Corners 345 kV line
Assumed wind generation in SW MN is 1900 MW
Heron Lake - Dotson - Searles - Ft. Ridgely 161/115 kV line

Contingency	Limiting Element	% DF	Outlet 2000+	Comments
Blue Lake - Helena 345 kV line	Lake Marion - Kenrick 115 kV line (100%)	4.22	-2694.3	Identified in EHV Study
Blue Lake - Helena 345 kV line	Kenrick - Dakota Heights (100%)	4.23	-2535.2	Identified in EHV study
Blue Lake - Helena 345 kV line	Burnsville - Dakota Heights (100%)	4.12	-2012.6	Identified in EHV study
Helena - Lake Marion 345 kV	Blue Lake - Helena 345 kV line (110%)	50.59	-593.83	Identified in EHV study
Franklin - Fairfax 69 kV	**Ft Ridgely - Schilling tap 69 kV (100 %)**	**2.91**	**-80**	Reconductor
Franklin - Fairfax 69 kV	**Schilling tap – Lafayette 69 kV (100%)**	**2.9**	**-20**	Reconductor
Franklin - Fairfax 69 kV	**Lafayette - Lafayette 69 kV (100%)**	**2.8**	**17.4**	Reconductor
Lyon Co - Franklin 345 kV line (2ckt)	Minn Valley tap - Panther 230 kV line (110%)	5.3	0	Identified in EHV study
Wilmarth - Helena 345 kV	**Arlington - Green Island 69 kV (110%)**	**3.1**	**93.22**	Reconductor
King - Red Rock 345 kV line	Eden Prairie - Edina 115kV line (110%)	3.12	93.58	Planned Upgrade
Wilmarth - Helena 345 kV	**Green Island - Carver Co 69 kV (110%)**	**3.1**	**109.35**	Reconductor
Storden - Dotson Corners 161 kV	**Johnville tap - Wanda 69 kV**	**3.27**	**120.9**	Reconductor
Storden - Dotson Corners 161 kV	**Wanda - Sundown 69 kV**	**3.23**	**138.1**	Reconductor
Storden - Dotson Corners 161 kV	**Storden - South Storden 161 kV**	**79.4**	**185.5**	Reconductor
Storden - Dotson Corners 161 kV	**South Storden - Heron Lake 161 kV**	**78.2**	**186.9**	Reconductor
Franklin - Helena 345 kV (2ckt)	Wilmarth - Helena 345 kV (110%)	45.79	267.5	Identified in EHV Study / Reconductor
Franklin - Helena 345 kV	**LGS - Wilmarth 345 kV (110%)**	**34.78**	**291.83**	**Identified in EHV Study (Stop)**
South Storden – Storden 161 kV	Comfrey - Dotson 69 kV (100%)	11.1	294	Reconductor
South Storden – Storden 161 kV	Storden 161/69 kV (100%)	13.58	295	Indicates need for bigger transformer
Franklin - Fairfax 69 kV	Lafayette - Winthrop 69 kV (110%)	2.65	305.66	Reconductor
Blue Lake - Helena 345 kV line	Lake Marion 345/115 kV TX (115 %)	7.27	439	EHV Study suggested 448 MVA TX, Consider 672 MVA

Option 1
Table D.8

2016 SUOP With Brooking Co - Helena - Lake Marion - Hampton Corners 345 kV line
Assumed wind generation in SW MN is 2000 MW
Heron Lake - Dotson - Searles - Ft. Ridgely 161/115 kV line
Includes Maple River - Alexandria - St. Cloud 345 kV

Contingency	Limiting Element	% DF	Outlet 2000+	Comments
Blue Lake - Helena 345 kV line	Lake Marion - Kenrick 115 kV line (100%)	4.09	-2939.8	Identified in EHV Study
Blue Lake - Helena 345 kV line	Kenrick - Dakota Heights (100%)	4.01	-2835.2	Identified in EHV study
Blue Lake - Helena 345 kV line	Burnsville - Dakota Heights (100%)	3.94	-2255.6	Identified in EHV study
Helena - Lake Marion 345 kV	Blue Lake - Helena 345 kV line (110%)	48.5	-633.2	Identified in EHV study
King - Red Rock 345 kV line	Eden Prairie - Edina 115kV line (100%)	3.31	-215.7	Planned Upgrade
Franklin - Fairfax 69 kV	**Ft Ridgely - Schilling tap 69 kV (100 %)**	**2.82**	**-91.13**	Reconductor
Franklin - Fairfax 69 kV	**Schilling tap - Lafayette 69 kV (100%)**	**2.87**	**-20**	Reconductor
Franklin - Fairfax 69 kV	**Lafayette - Lafayette 69 kV (100%)**	**2.78**	**18.8**	Reconductor
Storden - Dotson Corners 161 kV	**Johville tap - Wanda 69 kV (100%)**	**3.31**	**118.5**	Reconductor
Wilmarth - Helena 345 kV	**Arlington - Green Island 69 kV (110%)**	**3.06**	**122.87**	Reconductor
Storden - Dotson Corners 161 kV	**Wanda - Sundown 69 kV (100%)**	**3.28**	**135.9**	Reconductor
Wilmarth - Helena 345 kV	**Green Island - Carver Co 69 kV (110%)**	**2.96**	**140.54**	Reconductor
Storden - Dotson Corners 161 kV	**Storden - South Storden 161 kV (100%)**	**79.3**	**185.8**	Reconductor
Storden - Dotson Corners 161 kV	**South Storden - Heron Lake 161 kV (100%)**	**78**	**187.1**	Reconductor
Blue Lake - Helena 345 kV line	Lake Marion 345/115 kV TX (115 %)	7.01	236.24	EHV Study suggested 448 MVA TX, Consider 672 MVA
Helena - Franklin 345 kV (2ckt)	Wilmarth - Helena 345 kV (110%)	43.86	286	Identified in EHV Study
South Storden - Storden 161 kV	**Comfrey - Dotson 69 kV (100%)**	**10.96**	**294.4**	Reconductor
Franklin - Fairfax 69 kV	**Lafayette - Winthrop (110%)**	**2.77**	**300**	Reconductor
Franklin - Helena 345 kV line (2ckt)	**LGS - Fieldon - Wilmarth 345 kV**	**30.74**	**328.23**	**Identified in the EHV study (Stop)**
Lyon Co - Franklin 345 kV line (2ckt)	Minn Valley tap - Panther 230 kV line (110%)	3.36	351	Identified in EHV study