APPENDIX I
Benson Area Load Serving Study (2020)

Public

Benson Area Load Serving Study

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Executive Summary

The Benson Power generation in Benson, MN had played a significant role in regulating the reactive power need of the transmission system in the study area. With the retirement of this generation in 2018, loads served from the Benson area transmission system became more distant from the sources. The area sees near-term load serving reliability concerns.

The purpose of this report was to address reliability concerns of the study area transmission system within the requirements of TPL-001-4 standard and local area planning criteria. This report will also address all the requirements of FAC-002 as relevant NERC Transmission Planners and Transmission Owners have coordinated in studying the impacts of interconnecting the preferred option to the transmission system. Stability analysis was deemed not necessary for this study. Short circuit studies will be performed by GRE as part of design phase of the project, though no BES short circuit concerns are expected.

As detailed in this report, seven alternatives were evaluated to address the reliability concerns in the transmission system. P1 and P2 contingency analysis were performed to compare the performance of each option. Based on the P1 and P2 contingency analysis performance, three options were eliminated from further vetting. P4, P5, P6 and P7 contingency analysis, increment load serving capability analysis, and loss analysis were performed with each of the options to identify the best performing option for the study area. A P3 contingency analysis was performed with the most preferred option.

Option 7 that involves installation of a 230/115 kV LTC transformer at the Willmar substation with a 115 kV line to Priam in addition to a 115 kV transmission line from Appleton to Benson (Municipal Substation) with a 25 MVAr capacitor bank at Appleton performed the best among the options evaluated. A variation to this option that converts existing 41.6 kV line and associated distribution substations between Appleton and Benson to 115 kV was evaluated. This option was found to perform like Option 7 in all measures tested, such as addressing reliability concerns in the area, incremental load serving capability and system loss reduction capability. A P3 contingency analysis involving Big Stone generation was performed on option 7 and its variation, and results show no concern in the study area.

Considering the reliability improvement that will be gained with the conversion of existing 41.6 kV line to 115 kV, this study recommends Option 7 with its the variation to address reliability concerns in the study area. This study also recommends GRE/Willmar area specific study to identify transmission solutions that address the identified low voltage and overload concerns in the GRE/Willmar 69 kV system.

Contents

1. Introduction

Benson power generation, retired in 2018, located at the center of the study area used to provide excellent voltage regulation to the transmission system, but its retirement has left the study area with reliability concerns and nullified the transmission system capability to serve new load in the area. The Benson area study encompasses a wide area involving multiple sections of 115 kV, 69 kV and 41.6kV transmission systems that each could be considered for a separate and area specific studies. The following systems are involved in the Benson area study:

1. Walden – Elbow Lake 41.6 kV system
2. Appleton – Benson 41.6 kV system
3. Benson – Douglas County – Paynesville 69 kV system
4. Willmar – Paynesville 69 kV system
5. Morris - Willmar - MN Valley 115 kV transmission system
6. Granite Falls – Willmar – Paynesville 230 kV transmission

The focus of this study is the 115 kV transmission system between Morris, Willmar and MN Valley, and the interconnected 41.6 kV and 69 kV transmission system that either support load serving capability of the 115 kV transmission system or affected by contingencies in the 115 kV system. Reliability concerns in the study area transmission system are discussed in detail, and a system upgrade with the best value solution that addresses TPL-001-4 and local area planning requirements is recommended. As it is not the focus of this study, a separate study that is specific to the underlying 41.6 kV and 69 kV transmission system would be needed to address local area reliability concerns.

This study was performed in collaboration with MRES, OTP and Xcel Energy

2. Planning criteria

GRE local planning criteria also applicable to Willmar Municipal Utilities facilities in GRE and other relevant company criteria, which is summarized below was used to screen reliability concerns in the study area.

Voltage Limits

Voltages outside this range are reported as violations.

- System Intact and Post Contingent voltages as stated by each company (NERC TO and NERC TP) in planning criteria, and implemented in bus voltage limit fields in the power flow case
- Maximum system intact voltage-rise for capacitor bank switching: 3%
- Maximum system contingency voltage-rise for capacitor bank switching: 3%

Thermal Limits

Transmission line loading limits based on Rate A:

- System intact: 100%
- N-1 contingency: 100%

Transformer loading limits, based on continuous rating, are as follows unless otherwise is included in models:

- System intact: 100%
- N-1 contingency 125 %

3. Study procedure

3.1. Load forecasting

Utilities that serve load in the transmission system provided the 2019 summer and winter peak data to determine the study area system peak. While prior studies of this area showed that the transmission system is summer peaking, summer and winter peak load comparison was performed for completeness of this study, and to show the decision making on study model season selection.

The study area system peak included 115 kV, 69 kV and 41.6 kV transmission system connected loads that directly affect the performance of the 115 kV transmission system. The 2019 summer peak total was 260 MW and winter peak total was 223 MW. Each of the utilities serving load in the Benson area transmission system forecasted load for the out-year model. The following are the forecasted total peak load.

- Summer 2028 peak load: 278 MW
- Winter 2028 peak load: 238 MW

The detailed forecasted load data is included in Appendix A

3.2. Study model

The 2028 summer peak and 2028 Winter peak models from MTEP 2018 series were used to show reliability concerns in the transmission system. As the load analysis showed the area is summer peaking, the 2028 summer peak model was chosen for evaluating transmission alternatives. The base model was modified so that future planned load interconnection, such as GRE's Swenoda and Dublin distribution substation, and the retirement of Cashel distribution substation are included. Loads in the base model were also updated with the forecasted peak load of the area. GRE, MRE, OTP, and Xcel Energy reviewed the models prior to the start of the study analysis.

Contingency files from the 2018 MNTACT TPL-001-4 assessment was modified to include changes as a result model modification to add the Swenoda and Dublin distribution substations on the Benson to Kerkhoven Tap 115 kV transmission line. The contingency file was also modified for each option when evaluating the transmission options that are discussed under the transmission alternative section in this study report.

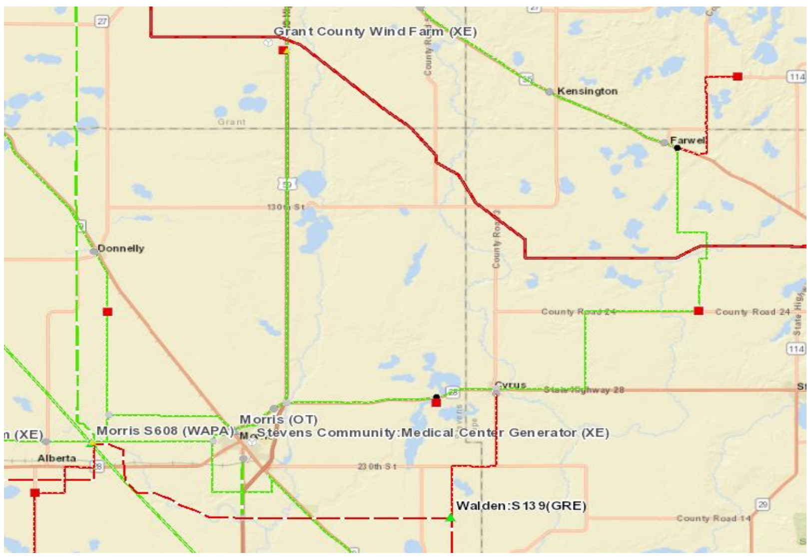
4. Reliability concerns in the area

System intact and contingency analysis were performed on the study models. As the study area is wide, and some areas have local transmission reliability concerns that are not directly related to the 115 kV transmission system between Morris, Willmar and MN Valley, the transmission system in and around the study area was grouped in to five different areas for ease of discussing observed transmission concerns and possible mitigations. Reliability concerns to 41.6 kV and 69 kV systems that are connected to the study area transmission system are discussed below. Possible mitigations to the reliability concerns of the underlying 41.6 kV and 69 kV systems are also discussed and taken into consideration when evaluating transmission alternatives to the study area. It is believed that the recommended solutions that address the local 41.6kV and 69 kV transmission system reliability concerns would indirectly strengthen the performance of the 115 kV transmission system.

In general, steady state analysis show P1 and P2 concerns in the study area. Post the Benson Power generation retirement, the transmission system of the study area doesn't have the capability to serve load under category P6 contingencies. High voltage problems are not a concern to the study area, and thermal concerns are limited to local 41.6 kV and 69 kV transmission systems. Steady state analysis results on the base case are included in Appendix B of this report.

4.1. Walden to Elbow Lake 41.6 kV system

This 41.6 kV transmission system primarily serves Great River Energy (GRE) and Otter Tail Power (OTP) substations. This 41.6 kV system that is served from the Walden 115/41.6 kV transmission system is included in the study as this system stays connected to the 115 kV transmission system during contingencies, such as Morris to Morris OTP 115 kV line outage. While a separate specific Walden to Elbow Lake 41.6 kV transmission system study may be required to fix reliability concerns (if any) due to 41.6 kV contingencies, this study only recommends fixes that is related 115 kV contingencies.



Walden – Elbow Lake 41.6 kV system

This study found low voltage and overload problems in the 41.6 kV system that is served from the Walden 115/41.6 kV system. The low voltage problems are both at system intact and during contingencies in the 115 kV system. System intact low voltage problems at Holmes City, Farwell and Kensington were observed in both 2028 summer and winter peak models as shown in the following slider diagrams. System intact low voltage problems are more pronounced in the winter case than summer case in this area.

[NONPUBLIC DATA BEGINS HERE...]

[redacted]

This study considered two options to address both system intact and contingency low voltage problem in this area:

Option 1: Operate the Cyrus to NE Morris 41.6 kV line normally closed

Option 2: Install a 4 MVAr STATCOM at Holmes city and fix 115 kV low voltage problems

Option 1: While this option addresses the system intact low voltage concerns and improves the voltage profile of the 41.6 kV and 115 kV systems, it doesn't completely solve the low voltage problems that result from the Morris to Morris OTP 115 kV line outage. With this option, there would also need to be an upgrade to the current protection system both at the Morris and Walden substations. For this option to address the low voltage problems in the 41.6 kV system, a 4 MVAr STATCOM (Option 2) would need to be installed at Holmes city. The following slider diagram screenshots show the performance of this option.

[redacted]

The closure of the 41.6 kV line needs to be further investigated from an SPP tariff standpoint as closure of the line creates alternative route for power to flow to the 41.6 kV system that is served from the Walden 115/41.6 kV source. In addition, potential relay coordination/reach concerns should be investigated with the closure of the 41.6 kV line.

Option 2: This option solves system intact low voltage problems, but by itself doesn't solve the low voltage problems for the loss of the Morris to Morris OTP 115 kV line as shown in the diagrams below.

Noting that this option is part of Option 1 that address voltage issues in the 41.6 kV system, doesn't introduce concerns with the protection system, and could be combined with the solution that will be proposed to address 115 kV system reliability concerns to improve voltage in this area, this study recommends Option 2 to address reliability concerns in the 41.6 kV system. Unlike Option 1, this option doesn't add exposure to the loads. This solution will be combined with the options that will be proposed to address 115 kV system reliability concerns, and its performance will be reviewed with contingency analysis of each option. In the case where this option with a proposed solution to the 115 kV system is insufficient to address low voltage concern in the area, a capacitor bank could be included with the STATCOM. A capacitor bank solution without the STATCOM wasn't considered due to voltage rise concerns, but a 5 MVAr cap bank whose voltage rise is controlled by the STATCOM could be considered in the future to further improve voltage profile of the 41.6 kV system.

[redacted]

[...NONPUBLIC DATA ENDS HERE]

The following are observations that would need to be further discussed and must be addressed for the system to reliability serve existing load in the system or new loads that may connect to the 41.6 kV system.

1. Walden 115/41.6 kV transformer – this is a 25 MVA transformer that is limited to 11.5 MVA by a relay load limit. This transformer overloads the most for the loss of the Elbow Lake 115/41.6 kV transformer, or Elbow Lake to Barret 41.6 kV line outage. Incremental load growth would also be limited by the transformer rating. This study recommends resetting the relay load limit or replacing the relay so that the transformer load serving capability is fully utilized.
2. Walden to Cyrus Junction 41.6 kV line - this is a 4/0 A conductor with a rating in the range of 27 MVA. This line is limited to 17.2 MVA by a relay at Walden. This rating can be the limiting element to serving a new load in the 41.6 kV system. This study recommends replacing or resetting of the relay at Walden so that the full rating of the conductor is available for improved load serving capability.

The following summarizes recommended system improvements to the 41.6 kV system that is served from the Walden 115/41.6 kV source:

1. Install a 4 MVAr STATCOM at Holmes City
2. Reset or replace relay so that full rating of the Walden 115/41.6 kV transformer can be used
3. Reset or replace relay for a full rating on the Walden to Cyrus Jct 41.6 kV line

4.2. Appleton to Benson 41.6 kV System

This 41.6 kV transmission system primarily serves GRE member and OTP owned distribution substations. The 41.6 kV system that is fed from the Benson 115/41.6 kV source is in the scope of the Benson area study. While it is not part of the study scope, low voltage concerns at substations that are sourced from the Appleton 115/41.6 kV source were studied for the reason that the fix for this system could enhance load serving capability of the Benson area 115 kV system, the main focus of this Benson area study.

Appleton – Benson 41.6 kV system

Contingency analysis on the summer peak model showed that the loss of the Appleton 115/41.6 kV transformer causes low voltage problems at Appleton, Shible Lake, Millan, Holloway and Moyer as shown in the slider diagram below. Voltage and overload violations were not observed in the winter peak model. Among the options considered to address the low voltage problems in the summer peak case are installation of distribution capacitor banks at Millan and Holloway, a 4 MVAr STATCOM at Moyer, and conversion of the Appleton 41.6 kV fed load to 115 kV service.

Conversion of the Appleton distribution substation would address the local area low voltage problem, but this conversion doesn't benefit the Benson area 115 kV transmission system. Therefore, it wasn't considered further. Installation of a major reactive support to this transmission system, such as a STATCOM, could be pushed out for several years by installation of distribution capacitor banks at Millan and Holloway, but a stronger voltage profile that make the system ready to serve spot loads (1 to 2 MW range) could be realized with the installation of a 4 MVAr STATCOM. Therefore, the option to install a 4 MVAr STATCOM was chosen for the following reasons:

1. It addresses the low voltage problem for the loss of the Appleton 115/41.6 kV transformer
2. The STATCOM could provide reactive support to the Benson area 115 kV system
3. Maintains a strong voltage profile in the 41.6 kV system regardless of possible future conversion of the Appleton 41.6 kV/distribution substation from 41.6 kV to 115 kV service

[NONPUBLIC DATA BEGINS HERE...]

4. Assumes the Appleton – Benson 41.6 kV system will continue to serve loads, such as Shible Lake, Milan, Holloway and Moyer. Conversion of these distribution substation from 41.6 kV to 115 kV service eliminates the need for the STATCOM.

[redacted]

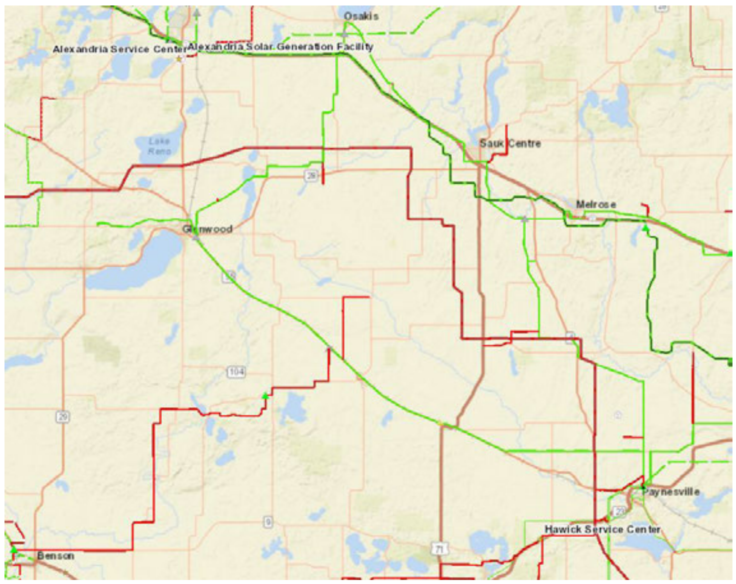
The following slider diagram shows the voltage improvement that the 4 MVAr STATCOM can provide to the 41.6 kV system for the loss of the Appleton 115/41.6 kV transformer.

[redacted]

Additional voltage improvement will be seen when a solution to fix the 115 kV transmission reliability concerns is implemented.

4.3. Benson – Douglas County – Paynesville 69 kV system

This 69 kV transmission system serves mainly GRE members and Xcel Energy owned distribution substations. This transmission system is included in the Benson area study because prior studies showed a need for system improvements in the 69 kV system and strengthening the 69 kV system would directly benefit the Benson area 115 kV system. The Benson 115/69 kV LTC transformer is set to keep the 69 kV side voltage above 1 per unit. In doing so, the LTC bucks the 115 kV side voltage at Benson. Keeping the LTC near the middle tap position and realizing a stronger 69 kV voltage profile by fixing existing reliability issues in the 69 kV system benefits the 115 kV transmission network.



Benson – Douglas County – Paynesville 69 kV system

Contingency analysis using the summer peak model show low voltage and overload problems that require fixes in the short-term. Near marginal voltage was observed in the winter peak analysis. The most critical contingency for the 69 kV transmission system [redacted]

In addition, the loss of the Paynesville to Belgrade 69 kV line causes overload problem on the Douglas County to Westport 69 kV line.

[redacted]

The following two options were considered to fix the low voltage and overload problems in the 69 kV system and have margin available to serve native load growth or new loads in the system:

1. Rebuild of the Paynesville – Grove Lake breaker station 69 kV line and Douglas County to Westport 69 kV line with 477 ACSR or better conductor.
2. Construction of a 115 kV transmission line from Alexandria to Lowry and establish a 115/69kV source near Lowry

The first option recommends rebuilding old and high impedance transmission lines between Paynesville and Grove Lake, and Douglas County and Westport. The Paynesville to Grove Lake 69 kV transmission line consists of 10.2-mile 2/0A, 10.7-mile 3/6 Cu and 5.5-mile 4/0A conductors. The Douglas County to Westport 69 kV transmission line consists of 9.5 mile of 2/0A conductor. Voltage drop across these conductors is significant. This option recommends a rebuild of these sections of lines with 477 ACSR or better conductor. It also recommends considering 115 kV standard construction to prepare for 115 kV conversion possibilities in the future.

The Paynesville to Grove Lake breaker station and the Douglas County to Westport 69 kV line rebuild options address both the low voltage and overload concerns that could be seen in the system during contingencies at system summer peak conditions. This option, in addition to addressing possible age and condition type concerns on the transmission lines, provides about 10 MW incremental load serving capability as shown in the table below. Additional reinforcement can be considered to increase the incremental load serving capability. Among the improvements could be installation of capacitor banks in the system or bringing in a new source to the area.

[redacted]

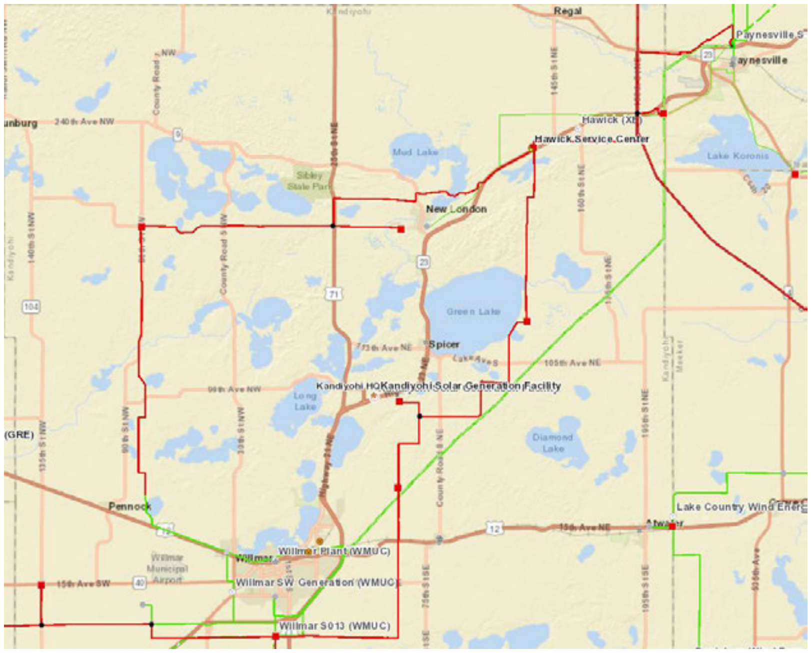
The second option also solves the overload and low voltage problems in 69 kV system, and provides similar incremental load serving capability.

[redacted]

Due to age and high impedance nature of the existing 69 kV transmission lines that are discussed under the first option, this study recommends the line rebuild project first and possibly consider the second option for future system improvement when the capacity of the first option is used up.

4.4. Willmar – Paynesville 69 kV system

This transmission system serves GRE member and Willmar Municipal Utility owned 69 kV/ distribution substations. The Priam 115/69 kV substation, which is directly connected to the Benson area 115 kV transmission system and the Willmar 230/69 kV substation are primary sources to the 69 kV system. Paynesville 115/69 kV substation and sources connected to Litchfield 69 kV system assist the primary sources during contingencies.



Willmar – Paynesville 69 kV system

Contingency analysis showed overload concerns on the Willmar SW to Willmar SWTP and Willmar to Willmar South 69 kV lines. The conductors current carrying capabilities on these lines are limited by terminal equipment, such as switches and jumpers.

1. Willmar – Wilmar Water Treatment Tap - Willmar Southwest 69 kV line: this line is limited to 71.7 MVA. The 600A switch at the Water Treatment Tap limits the conductor current carrying capability. This switch is planned to be replaced with a 1200A three-way switch as part of the Priam 115/69 kV substation buildout project. It is recommended that WMU review this section of the transmission line, identify other limiters (if any) to the conductor current carrying capabilities and set a mitigation plan.

[redacted]

2. Willmar to Willmar South 69 kV line: This transmission line is limited to 47.8 MVA capability due to a jumper. It is recommended that WMU review this transmission line and replace the limiting element so that the transmission line has the full conductor rating.

[redacted]

Willmar 230/69/12.5 kV transformer – Once a 79 MVA terminal limitation is addressed, this is an 84 MVA transformer and with an emergency rating of 125% for 30 minutes. For the loss of the Priam 115/69 kV transformer, the Willmar 230/69 kV transformer overloads 124% of 84 MVA prior to a switching event that would bring the overload significantly lower.

Priam 115/69 kV transformer – This is a 112 MVA rated transformer and has a (125%) emergency rating capability for 30 minutes. This transformer is loaded to 102% for the loss of the Willmar 230/69/12.5 kV transformer. This overload can be mitigated by implementing a switching procedure to bring in the Paynesville and Litchfield area sources to assist load serving in the Willmar area.

After replacing switches and jumpers to remove the limiters to line and transformer current carrying capabilities, the Willmar 230/69/12.5 kV transformer capacity will be the limiter to incremental load serving capability of the Willmar area transmission system from P1 and P2 contingency standpoint. Based on the study model used for this study (2028 summer peak), the transformer will have to be replaced with a larger MVA transformer to allow load growth in the system beyond the 2028 timeframe or an alternative that addresses the transformer overload would need be considered.

This study recommends a separate GRE/Willmar 69 kV system specific study to determine the following:

1. Address transformer overload or other concerns (if any) in the GRE/Willmar 69 kV system
2. Switching procedure that can be implemented during contingencies to bring transformer loading within criteria

A study for this area is in the works.

4.5. Morris - Willmar - MN Valley 115 kV transmission system

The Morris – Willmar – MN Valley 115 kV transmission system is the focus of the Benson area study. The transmission system serves several loads directly, and it is the backbone of the transmission system that are discussed above. This system serves Morris OTP, Hancock, Benson Municipal Utilities, Victor Hanson, Swenoda, and Dublin 115 kV connected distribution substations. It also serves 41.6 kV transmission systems at Walden, Benson and Kerkhoven, and 69 kV transmission system that are connected at Benson, Priam and Maynard.

As the study area transmission system is summer peaking, the summer peak model was chosen to perform detailed analysis and evaluate transmission alternatives. P1 and P2 contingency analysis were performed on the base case and base case with transmission alternatives. Based on P1 and P2 contingency analysis results, some transmission alternatives were chosen for further vetting with P4, P5, P6 and P7 contingency analysis. Finally, a P3 contingency involving the only nearest base load generation in the study area, Big Stone, was performed on the best performing alternative.

5. Base case reliability concerns

5.1. Low voltage concerns:

P1 and P2 contingency analysis on the study models showed several low voltages concerns in the transmission system (refer to Appendix B).[redacted]. These contingencies cause low voltage problem at all 115 kV and 41.6 kV buses that are served from the Morris to MN Valley 115 kV system. Voltages as low as 86.6% on the 115 kV system, 79.7% on the 41.6 kV system and 88% in the 69 kV system was observed in contingency analysis results on the base case models.

5.2. High voltage concerns

The analysis didn't show any high voltage concerns in the study area.

5.3. Thermal concerns

The analysis showed overload concern in the 69 kV system between MN Valley and Maynard for the loss of MN Valley to Maynard 115 kV system. This overload is due to through flow condition from MN Valley through the MN Valley to Maynard 69 kV system on to the study area 115 kV system.

Study results show the transmission system can't serve existing load within the planning criteria. In addition, there is no margin in the transmission system to serve any additional load that may come to connect in the study area. Post the retirement of the Benson Power generation, the transmission system can no longer serve load under a P6 category contingency in the study area. Several alternatives were studied to address reliability concerns and make margin available to reliably serve future load interconnection in the study area.

6. Transmission alternatives

The following transmission alternatives were considered to address the reliability problems and realize margins to serve growing or new loads in the system.

Option 1: Appleton – Benson 115 kV transmission line

Option 2: Willmar 230/115 kV transformer (LTC equipped) with 115 kV connection to Priam.

Option 3: Alexandria – Benson 115 kV transmission line

Option 4: Willmar 230/115 kV transformer (LTC equipped) with Willmar to Benson 115 kV line

Option 5: MN Valley to Benson 115 kV transmission line

Option 6: Six Mile Grove 230/115 kV substation with in/out transmission line to the Benson – Swenoda 115 kV line

Option 7: Combination of Option 1 and Option 2 - Appleton to Benson 115 kV system with Willmar 230/115 kV transformer (LTC) equipped and 115 kV connection to Priam, and a 25 MVAr cap bank at Appleton.

6.1. Option description and one-line diagrams

6.1.1. Option 1: Appleton – Benson 115 kV transmission line

This option reconfigures existing Appleton 115/41.6 kV substation 115 kV bus to a ring bus design and constructs about 23 miles of 115 kV transmission line from Appleton to a tap point on the Benson Muni to GRE Benson substation 115 kV transmission line.

[redacted]

6.1.2. Option 2: Willmar 230/115 kV transformer (LTC equipped)

This option modifies the existing 230 kV straight bus at Willmar to a ring bus and installs a 230/115 kV transformer that is equipped with LTC at the existing Willmar substation and a 115 kV line (using an existing unused 115 kV line segment) from Willmar to Priam.

[redacted]

6.1.3. Option 3: Alexandria – Benson 115 kV transmission line

This options constructs about 45 miles of 115 kV transmission line from MRES's Alexandria substation to the Benson area, specifically to a tap point on the GRE Benson to Benson Muni 115 kV line.

[redacted]

6.1.4. Option 4: Willmar 230/115 kV LTC transformer with Willmar to Benson 115 kV line

This option, in addition to Option 2, constructs about 40 miles of 115 kV transmission line from Willmar to the Benson area, specifically to the GRE Benson to Benson Muni 115 kV line.

[redacted]

6.1.5. Option 5: MN Valley to Benson 115 kV transmission line

This option constructs about 43 to 47 miles of 115 kV transmission line from MN Valley to the GRE Benson to Benson Muni 115 kV line in the Benson area.

[redacted]

6.1.6. Option 6: Six Mile Grove 230/115 kV substation

This option connects to the WAPA's 230 kV transmission line that runs between Granite Falls and Morris to establish a 230/115 kV substation. It also involves construction of about 3.5 mile double circuit 115 kV line from the substation to the Benson – Swenoda 115 kV line.

[redacted]

[...NONPUBLIC DATA ENDS HERE]

6.2. Assumptions

The following system improvement assumptions are taken into consideration when comparing all the option on incremental load serving capability and addressing reliability concerns in the study area.

1. 4 MVAr STATCOM at Holmes City
2. Walden 115/41.6 kV transformer at full rating (limiters mitigated)
3. Walden to Cyrus Junction 41.6 kV line at full conductor rating (limiters mitigated)
4. Paynesville – Grove Lake 69 kV line rebuild with 477 ACSR conductor
5. Douglas County to Westport 69 kV line rebuild with 477 ACSR conductor
6. Jumper and switch replacements in the WMU system

The above system improvements need to be made in the short-term to avoid any low voltage or overload concerns during contingencies at system peak load conditions.

7. Transmission alternatives - study results

7.1. P1 and P2 analysis results

P1 and P2 contingency analysis were performed in all the options considered. The contingency analysis results are included for reference in Appendix C.

7.1.1. Low voltage concerns

The analysis showed Option 2, Option 4, Option 6, Option 7 address NERC category P1 and P2 concerns including bus to bus contingencies. Option 1, Option 3, and Option 5 performs very similar where each option addresses all P1 and P2 contingency low voltage concerns except a category P2 contingency of internal beaker fault on breaker 5N60 at MN Valley, P23:115:XEL:5N60 MNV. Option 5 performs the worst for P23:115:XEL:5N60 MNV, where the low voltage problems are more pronounced in this option than Option 1 or Option 3.

7.1.2. High voltage concerns

The analysis didn't show any high voltage concerns in the study area.

7.1.3. Thermal concerns

The analysis showed all the options performing similar from thermal loading standpoint. The Willmar to Willmar South 69 kV line and Willmar Southwest to Willmar Southwest Tap 69 kV line flagged as overloads with all options. Similarly, the Willmar 230/69 kV transformer overload just under the 125% (105 MVA) assumed emergency limit with all the options tested. The MN Valley to Granite Falls 69 kV line overload showed up with all options except with Option 7 for the loss of MN Valley to Maynard 115 kV line.

7.2. Option minimization

Prior to performing additional analysis, some of the options have been eliminated based on P1 and P2 contingency analysis results.

Option 1 was kept for further vetting as this option and Option 2 could be combined to solve P23 concerns that Option 1 alone couldn't. The amount of transmission that need to be constructed with this combination (Option 1 and Option 2) is much less than what needs to be built under Option 4. The combination of these two options have been named as Option 7.

Option 2 was kept for further vetting as it addresses all P1 and P2 concerns including P23:115:XEL:5N60 MNV. This option was further vetted from P3, P4, P5, P6 and P7 contingency performance standpoint.

Option 3 was not vetted further as its performance is very similar to Option 1, but it would require construction of about twice as much transmission line than that of Option 1. Note that this option was studied from the standpoint of potential opportunity to provide system improvement to the 69 kV transmission system. As discussed under the Benson – Douglas County – Paynesville 69 kV transmission system analysis, a 115 kV line to the Lowry area was not preferred to address 69 kV transmission line concerns. If a 115 kV line is needed in the Lowry area in the future, it could be built from Alexandria or Benson area, and future looping from Lowry to Benson or Alexandria could reinforce reliability of the Benson area 115 kV transmission system.

Option 4 was kept for further vetting from NERC category P3, P4, P5, P6 and P7 contingency performance standpoints.

Option 5 was eliminated from further vetting as it is the least performing option with high constructability concerns. It also involves a long 115 kV transmission line to connect MN Valley to Benson.

Option 6 was eliminated from further vetting. Although it would be the cheapest to construct and the best performing option from NERC category P1 and P2 contingency standpoint, this option requires interconnection with WAPA's 230 kV transmission line. High estimated tariff/transmission service cost to interconnect with the SPP system makes this option uneconomical in the long run.

Option 7 was kept for further vetting at it includes both options 1 and 2.

7.3. P4, P5 and P7 Contingency Analysis

Results from NERC category P4, P5, and P7 contingency analysis on options 1, 2,4 and 7 are included in Appendix D. The analysis didn't show any voltage violations with all the options in the study area. Thermal concerns were seen with Option 1 where the Wilmar 230/69 kV transformer and Willmar – Willmar South 69 kV lines are overloaded for a P5 contingency. No thermal concerns were seen with options 2,4 and 7.

7.4. P6 Analysis

Category P6 contingency analysis was performed with the above five options. Results from this analysis area are included in Appendix E of this report.

[NONPUBLIC DATA BEGINS HERE..]

7.4.1. Low voltage concerns:

Option 1

The analysis showed several low voltage problems in the 115 kV, 69 kV and 41.6 kV systems with this option. [redacted] The prior outage must be followed by system adjustment for the model to solve as a result of voltage collapse condition in the Willmar 69 kV system. System adjustments for these contingencies includes the following:

- Close Spicer – Green Lake 69 kV line
- Close Svea – Litchfield Tap 69 kV line
- Close Willmar Southwest Tap to Willmar 69 kV line
- Open Maynard 115/69 kV transformer

These system adjustments would avoid voltage collapse condition, but low voltage problems would still be seen at:

MAYNARD7 (bus # 603177) – 89.18%
WMU-PRIAM 7 (bus # 619982) – 88.51%
KERKHOVENTP7 (bus # 603267) – 89.7%
GRE-KERKHO 7 (bus # 616005) – 91.66%
DEGRAFF (bus # 7463) – 90.21%
MURDOCK (bus # 7464) – 90.81%

KERK TP (bus # 7465) – 91.86%
GRE-KERKHO 9 (bus # 616073) – 91.93%
KILDARE (bus # 616080) – 90.26%

The analysis also showed that the following contingencies cause low voltage problems in the Willmar/GRE 69 kV system.

- Loss of the Priam 115/69 kV transformer + P12:230:GRE:WMR-GF (fault on Granite Falls – Willmar 230 kV line)
- Loss of Willmar – Granite Falls 230 kV line + P12:115:GRE:BEN-WMU (fault on Benson – Maynard – Priam 115 kV line)

Option 2
The analysis showed several low voltage problems in the 115 kV and 69 kV transmission system with this option. [redacted]

[redacted] P6 category contingencies, the following contingencies results are not listed in the results tables as the case didn't solve due to voltage collapse conditions. [redacted]

[...NONPUBLIC DATA ENDS HERE]

Option 4
The analysis showed better performance over Option 2 in that this option address the severe low voltage condition that would be seen between Morris and Kerkhoven due to the contingencies listed under Option 2 above.
The analysis also showed similar low voltage concerns in the 115 kV system between Morris and Canby and in the GRE/Willmar 69 kV system as discussed under Option 2 above.

Option 7
The analysis showed significantly improved performance addressing load serving constraints due to NERC P6 category contingencies discussed above. This option addresses low voltage problem in the 115 kV system in the study area. The option was also found to address reliability concerns

in the Morris to Canby 115 kV transmission system. This option performs like Option 2 and Option 4 in addressing low voltage concerns in the GRE/Willmar 69 kV transmission system.

7.4.2. High Voltage concerns:

The analysis didn't any show high voltage concerns in the study area with any of the options studied.

7.4.3. Thermal concerns:

Option 1
Contingency analysis showed overload concerns on the MN Valley to Maynard 69 kV system with the prior outage of the MN Valley to Maynard 115 kV line outage. This overload is caused by through flow conditions and could be mitigated by opening Maynard 115/69 kV transformer. Willmar 230/69 KV transformer overload was seen with a prior outage of Priam 115/69 kV transformer. The analysis also showed transmission line overload in the GRE/Willmar 69 kV system, such as Willmar to Willmar South and Willmar SW (Bus # 619986) to Willmar SW tap (bus#619988) 69 kV lines. Overloads in the Willmar/GRE 69 kV system involve a prior outage of the Priam 115/69 kV transformer, Willmar 230/69 transformer or loss of the Granite Falls to Willmar 230 kV line.

Option 2
The analysis showed similar thermal concerns as discussed under Option 1. In addition to the thermal concerns discussed under Option 1, the Dawson Tap to Louisburg Tap 115 kV line and Canby to Granite Falls 115 kV line flagged as overloaded transmission lines for a Johnson Junction to Morris + P13:115-230:OTP:BIGSTON4:T1 (fault on Big Stone transformer) contingency. These overloads are driven by low voltage conditions that could be addressed with system adjustment following the prior outage . The system adjustment is to close the normally open line between Dome and Fairmont, bus # 655511 and 620227, respectively.

Option 4
The analysis showed similar thermal concerns as discussed under Option 1.

Option 7
The analysis showed similar thermal concerns as discussed under Option 1.

7.5. P6 Analysis conclusion

Option 7 brings a significant improvement to the study area from P6 load serving standpoint. It outperforms Option 1 in the GRE/Willmar 69 kV system as it provides better voltage regulation to the 115 kV system and reduces the risk of low voltage problems due to contingencies such as loss of Maynard to Kerkhoven 115 kV line followed by a fault on the Granite Falls to Willmar 230 kV line. This option also outperforms Option 2 and Option 4 as it also solves low voltage problems in the Morris – Canby 115 kV transmission system.
Like all the options tested, this option doesn't entirely address P6 concerns in the GRE/Willmar 69 kV system. A second transformer at Priam and additional 115 kV line build out in the GRE/Willmar area

might be needed to address remaining P6 concerns in the GRE/Willmar 69 kV system. It is a recommendation this study for GRE/Willmar area specific study, which is currently underway, to look for possible solutions to the remaining P6 concerns in the area.

With Option 7 being the best performing alternative, a P3 contingency analysis with this option was performed to test for any reliability concerns in the study area. This contingency analysis involved the lone base load generation that is close to the study area, Big Stone generator. The analysis showed no voltage or thermal concern in the study area.

8. Incremental load serving capability results

Incremental load analysis was performed to test the capabilities of each option to serve future loads in the study area. The incremental load analysis assumed all the recommended system improvements for the 41.6 kV and 69 kV transmission system (discussed above) are in place. The incremental load analysis results are based on system intact and bus to bus contingencies. The following area subsystem loads are incremented in the analysis.

Bus #	SUB NAME	Bus #	SUB NAME
7443	KENSING	**7459**	DANVERS
7442	FARWELL	**616077**	MOYER
619162	HOLMES CITY	**7460**	SEED CO
619167	WHITE BEAR	**7461**	CLONTAR
7441	CYRUS	**7462**	HANCOCK
619169	FRAMNAS	**620218**	MORRIS OTP
7465	KERKHOVEN	**616006**	HANCOCK
7464	MURDOCK	**615365**	VICTOR HANSON
616080	KILDAR	**658098**	BENSON MUNI
7463	DEGRAFF	**616008**	SWENODA
616076	DOME	**616009**	DUBLIN

Subsystem load for incremental load analysis

[NONPUBLIC DATA BEGINS HERE...]

8.1. Option 1: Appleton – Benson 115 kV system

As discussed under P1 and P2 contingency analysis results, there is a P23 contingency low voltage problem that this option doesn't solve or address. Load shed may need to be implemented if this option is chosen without any additional reinforcement to address the [redacted]

Based on bus to bus contingencies, this option can serve about 22 MW load on top of the 2028 summer peak load level. The following table show the full list of incremental load serving capabilities.

[redacted]

[redacted]

After 22 MW incremental load, the Kerkhoven transformer outage causes low voltage problem at OTP's Kerkhoven distribution substation. This can be mitigated with installation of a 4 MVAr STATCOM at Kildar. After the installation of the 4 MVAr STATCOM at Kildar, the next limit is at 28 MW incremental load where low voltage problem will be seen in 41.6 kV system during contingencies. [redacted]

[redacted]

[redacted]

The alternative to adding STATCOMS at Moyer and Kildar is conversion of large loads from 41.6 kV service to 115 kV service. OTP's Appleton and Kerkhoven substation loads are the largest that are close to the 115 kV transmission lines. Conversion of these loads doesn't improve the incremental load serving capability as the low voltage problem shifts from Kerkhoven to Walden area 41.6 kV system at about 22 MW incremental load as shown in the table below. STATCOMs are preferred because of the reactive support that it provides to the Benson area 115 kV system.

[redacted]

A second STATCOM at Holmes City would increase the incremental load serving capability to 44MW. The limiter to the incremental load serving capability becomes low voltage in the 41.6 kV system near Kerkhoven. The alternatives to adding a second STATCOM at Holmes city are to install an LTC transformer at Walden, establishing a new 115/41.6 kV source near Holmes City, or a 5 MVAr capacitor bank that would be controlled by Holmes City STATCOM.

[redacted]

Option 1: Incremental load serving summary:

Stages	Project	Incremental load (MW)	Limiter
1	STATCOMs at Holmes and Moyer	22	Low voltage at Kerkhoven Tap
2	STATCOMS at Holmes, Moyer and Kildar	28	Low voltage in the Walden 41.6kV system
3	Install a second STATCOM at Holmes City	44	Low voltage in the Kerkhoven 41.6kV system

8.2. Option 2: Willmar 230/115 kV LTC transformer w/ 115 kV line to Priam

Incremental load analysis show that the 41.6 kV system that is served from the Walden 115/41.6 kV substation experiences low voltage problem after 12 MW incremental load growth for the loss of Morris to Morris OTP 115 kV line. This contingency also causes overload concern on the Kerkhoven to Kerkhoven Tap 115 kV transmission line after 12 MW incremental load growth. The following table is the incremental load serving capability output.

[redacted]

A second STATCOM at Holmes City addresses the voltage problems after the 12 MW incremental load level. The Kerkhoven to Kerkhoven Tap 115 kV line is a 266 ACSR conductor, which is rated at 89 MVA. This section of the line would need to be rebuilt for additional incremental load serving capability. A rebuild of the Kerkhoven to Kerkhoven tap 115 kV line with 795 ACSS conductor along with installation of a second STATCOM at Holmes City increases the incremental load serving capability to 22 MW as shown in the table below.

[redacted]

Low voltage problem for the loss of the Kerkhoven 115/41.6 kV transformer becomes the limiter. Installing a STATCOM at Kildar substation increases the incremental load serving capability from 22 MW to 32 MW. Low voltage in the Walden 41.6 kV system becomes the limiter to the incremental load serving capability.

[redacted]

Option 2: Incremental load serving summary

Stages	Project	Increment Load (MW)	Limiter
1	STATCOMs at Holmes City and Moyer	12	Low voltage in the Walden 41.6kV system Overload on Kerkhoven Tap to Kerkhoven 115 kV line
2	STATCOMS at Holmes, Moyer and Kildar	22	Low voltage in the Kerkhoven 41.6 kV system
3	Install a second STATCOM at Holmes City	32	Low voltage in the Walden 41.6kV system

Option 3: This option was eliminated from additional analysis

8.3. Option 4: Willmar 230/115 kV LTC transformer and Willmar to Benson 115 kV line

Incremental load analysis with this option showed that low voltage problems in the 41.6 kV system that is served from Kerkhoven 115/41.6 kV source limit the incremental load serving capability to 24 MW.

[redacted]

[redacted]

Option 5: This option was eliminated from additional analysis

Option 6: This option was eliminated from additional analysis

8.4. Option 7: Combination of Option 1 and Option 2

This option combines Option 1 and Option 2 to address P1 and P2 concerns that Option 1 alone can't address and get a better incremental load serving capability. While Option 2 addresses P1 and P2 concerns, it doesn't provide enough incremental load serving capability. In addition, after 12 MW incremental load, the Kerkhoven to Kerkhoven Tap 115 kV line would need to be rebuilt. Combining the two options result in better incremental load serving capability, better P1 and P2 performance, avoid the rebuild of Kerkhoven to Kerkhoven Tap 115 kV line and provide a better reliability performance from NERC category P6 contingency standpoint.

Incremental load analysis showed that the transmission system can serve about 24 MW incremental load with this option prior to experiencing low voltage problems. The following table shows the incremental load serving capability.

[redacted]

Installation of a 4 MVAr STATCOM at Kildar increases the incremental load serving capability to 32MW. The Morris to Morris OTP 115 kV line outage causes low voltage problem in the 41.6 kV system after 32 MW incremental load growth.

[redacted]

This incremental load serving capability can further be improved in the future by installing a second 4MVAr capacitor bank at Holmes City. This installation increases the incremental load serving capability to 48 MW. The Kerkhoven 115/41.6 kV transformer overloads for the loss of the Benson 115/41.6 kV transformer after 48 MW incremental load.

[redacted]

[redacted]

[...NONPUBLIC DATA ENDS HERE]

Option 7: Incremental load serving summary

Stages	Project	Increment load (MW)	Limiter
1	STATCOMs at Holmes and Moyer	24	Low voltage in the Kerkhoven 41.6kV system
2	STATCOMs at Holmes, Moyer and Kildar	32	Low voltage in the Walden 41.6kV system
3	Install a second STATCOM at Holmes	48	Kerkhoven 115/41.6 kV transformer overload

A test on incremental load serving capability of Option 7 with a capacitor bank at Appleton bus was performed. Voltage rise analysis using MISO18_2020_SLL0__TA model show a 27 MVAr capacitor bank can be switched in based on a system intact and contingency voltage rise criteria of 3% and 5%, respectively. Refer to Appendix I for capacitor bank voltage raise analysis output.
If installation of a capacitor bank at Appleton is chosen, switching impacts to the Victor Hanson ethanol plant should be studied. A sync close /zero crossing breaker for capacitor bank switching could be used to minimize transient impacts.

The following summarizes the incremental load serving capability of Option 7 with a 25 MVAr capacitor bank installed at the Appleton 115 kV bus.

Stages	Project	Increment load (MW)	Limiter
1	STATCOMs at Holmes and Moyer	30	Low voltage in the Kerkhoven 41.6kV system
2	STATCOMs at Holmes, Moyer and Kildar	39	Low voltage in the Walden 41.6kV system
3	Install a second STATCOM at Holmes	48	Kerkhoven 115/41.6 kV transformer overload

8.5. Incremental load serving capability summary

Incremental load serving capabilities of each option were improved by installing STATCOMs where low voltage is the limiter. Only Option 2 require rebuilding of the Kerkhoven to Kerkhoven 115 kV line on stage #2. The following table summarizes the incremental load serving capabilities of each option:

Options	Stage #1 (MW)	Stage #2 (MW)	Stage #3 (MW)
Option 1	22	28	44
Option 2	12	22	32
Option 4	24	42	48
Option 7	24	32	48
Option 7 with Appleton capacitor	30	39	48

9. Loss Analysis

Loss analysis was performed to document the performance of each option from system loss reduction standpoint. The summer peak study model was used for this analysis. The base case (no upgrades) was considered as a benchmark for loss comparison.

LBA	Losses (MW)				
	Base Case	Option 1	Option 2	Option 4	Option 7
OTP	87	86.4	86.1	85.7	85.9
GRE	96.1	96.1	95.9	96.1	95.9
XCEL	248.5	245.6	245.5	246.1	244.8
All	431.5	428	427.5	427.9	426.7

Loss analysis show all options result in a significant loss saving over the base case. Most of the loss savings are shared by OTP and Xcel Energy. Relatively no change to the loss in the GRE LBA was observed. Option 7 performs the best among all the options tested. It would result in about 4.8 MW loss reduction over the base case.

10. Cost Estimate

Project cost estimation for each option was done to provide a high-level indicative cost estimate of each option. The following table consist of a high level planning cost estimate based on 2018 prices. The estimates will be significantly impacted by several factor, such as increase or decrease on the amount of transmission line to be built, overtaking existing transmission lines, possible underbuilding of existing lines, retirement of existing transmission lines, substation land availability and cost…etc. Final engineering cost estimate may differ from the estimates that are listed in the table.

Option	**Cost Estimate**
Option1: Appleton – Benson 115 kV line	$15.2 M
Option2: Willmar 230/115 kV substation	$12.1M
Option4: Willmar 230/115 kV substation + Willmar – Benson 115 kV line	$30.5M
Option7: Willmar 230/115 kV substation + Appleton – Benson 115 kV line + Capacitor	$27.8M

11. Variation – Option 7

Instead of building a new 115 kV line on a new route for the Appleton – Benson 115kV line, a variation that converts existing 41.6 kV transmission line to 115 kV was considered in this study. This variation of Option 7 includes converting the existing Appleton – Benson 41.6 kV line to 115 kV, converting substation that used be served from the 41.6 kV system, such as Shible Lake, Holloway, Moyer and Danvers for 115 kV service and routing the Benson – Swenoda 115 kV line to Benson Muni substation. The following one-line diagram show this proposed variation. Note that the exact configuration at Appleton will be determined in the future based on further optimization serving local distribution system load, and possible substation breaker configuration based on exact needs not yet determined. This will be subject to additional study work prior to reconfiguration of Appleton actually taking place before the Appleton – Benson 115 kV line goes in-service. This may include the capacitor bank

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connected via a dedicated breaker position.

[redacted]

[...NONPUBLIC DATA ENDS HERE]

11.1. P1 and P2 Contingency Analysis

Contingency analysis was performed to test the performance this variation. Full contingency analysis results are included in **Appendix G** of this report.

11.1.1. Low voltage concerns

The analysis didn't show any low voltage concerns in the study area.

11.1.2. High voltage concerns

The analysis didn't show any high voltage concerns in the study area.

11.1.3. Thermal concerns

The analysis showed overload concerns in the GRE/Willmar 69 kV system. The Willmar to Willmar South 69 kV line, Willmar Southwest to Willmar Southwest Tap 69 kV line and Willmar 230/69 kV transformer overload for multiple P1, P2 and bus to bus contingencies in GRE/Willmar 69 kV transmission system. A separate GRE/Willmar area specific study that is currently underway would provide solutions for these overload concerns.

11.2. P4, P5 and P7 contingencies

The analysis didn't show any low voltage, high voltage or thermal concerns with this option in the study area.

11.3. P6 Contingency Analysis

The P6 contingency analysis results are included in the Appendix F of this report.

11.3.1. Low voltage concerns

The analysis show low voltage concerns in the Willmar/GRE 69 kV system for the loss of Priam 115/69/12.8 transformer followed by a fault on Granite Falls to Willmar 230 kV line. The low voltage problem due to this P6 contingency could be alleviated with system adjustment following the prior outage. The system adjustment could include transferring load to the Paynesville 115/69 kV system or closing the Spicer - Green Lake and Willmar – Willmar SW 69 kV normally open lines. Mitigations to this and other Willmar/GRE 69 kV system related reliability concerns will be addressed with the Willmar/GRE area specific study.

11.3.2. High voltage concerns

The analysis didn't show any high voltage concerns in the study area.

11.3.3. Thermal concerns

The analysis showed overload concerns in the GRE/Willmar 69 kV system. The Willmar to Willmar South 69 kV line, Willmar Southwest to Willmar Southwest Tap 69 kV line and Willmar 230/69 kV transformer overload for multiple P6 contingencies that involve a prior outage of the Priam 115/69 kV transformer. The Willmar 230/69 kV transformer overload could be addressed with system adjustment following the loss of the Priam 115/69 kV transformer. The GRE/Willmar area specific study that is currently underway would provide solutions for these overload concerns.

The analysis also showed overload concern in the 69 kV system in the MN Valley – Maynard 69 kV system with a prior outage of MN Valley to Maynard 115 kV line. The overload concern in this system is caused by through flow condition and could be mitigated with a system adjustment that involves opening the Maynard 115/69 kV transformer.

11.4. Incremental load analysis with Option 7- variation

Incremental load serving analysis was preformed to compare the performance of this variation to the Option 7 discussed above. As the table below shows, this variation to Option 7 performs like the Option 7 (without 41.6 kV system conversion to 115 kV) discussed above.

Stages	Project	Option 7-Variation	Option 7	Limiter
1	STATCOM at Holmes City	28	30	Low voltage in the Benson - Kerkhoven 41.6kV system
2	STATCOMs at Holmes City and Kildar	43	39	Low voltage in the Walden - Elbow Lake 41.6kV system
3	Install a second STATCOM at Holmes City	53	48	Kerkhoven 115/41.6 kV transformer overload

11.5. Loss analysis with Option 7 – variation

Loss analysis was performed to see any loss reduction performance that may be gained with the proposed variation to Option 7. As the following table show, this option performs like Option 7(without 41.6 kV line conversion to 115kV)

LBA		Loss (MW)	
	Base Case	Option 7	Option 7 - variation
OTP	87	85.9	85.8
GRE	96.1	95.9	95.9
XCEL	248.5	244.8	244.8
All	431.5	426.7	426.5

Willmar 230/115 kV transformer size -187 MVA
Willmar transformer size determination was done based on expected maximum flows on the Willmar 230/115 kV transformer. The study model, 2028 summer peak case, and the 2022_SH90_TA_Pass3-DPP2016-Aug_West were used to determine system intact and post continent maximum flow of the transformer. A transfer bias was created with the shoulder peak model by turning off Sherco units which resulted in over 300 MVA flow on the Granite Falls – Willmar 230 kV line. The following table shows the maximum flow on the Willmar 230/115 kV transformer.

Model	MAV flows		
	System Intact	N-1 Max Flow	P6 Max Flow
2028 SUMMER	42.17	75.41	105.2
2022 SH90	43.12	98.18	134.6

With the assumptions that the transformer is most efficient when it is loaded 25%-35% range of its top rating, and possible new loads in the system that may drive more flow on the transformer, it was determine that a 187 MVA transformer would be the most efficient at Willmar.

Additional comments for FAC-002 compliance

This is a coordination study that involved transmission planners and transmission owners of the study area, namely Great River Energy, Missouri River Energy Services, Otter Tail Power, Willmar Municipal Utilities, and Xcel Energy. The study analysis thus far address most of the FAC-002 requirements, the following additional requirements have not been performed based on engineering judgment.

- Stability Analysis – Dynamic stability analysis was not performed as part of this study based on engineering judgment. The options considered don't introduce a new generator and change the dynamic performance of existing units in the transmission system.
- Short Circuit Analysis – short circuit analysis was not performed as part of this study. A short circuit study will be part of equipment specification process during the implementation of the preferred option. Any equipment that may be affected with the installation of the preferred option will be addressed as part the design and project implementation process.
- Sub-synchronous resonance analysis – this type of analysis was not performed as part of this study based on engineering judgment. This study will neither engage in high power transfer nor involve generation dispatching that will impact frequency of the transmission system or turbines on generators. Therefore, SSR would not be a concern and was not studied.

12. Conclusion:

Option 7 with the variation that upgrades the Appleton to Benson 41.6 kV line to 115 kV provides the best reliability improvement to the study area, Morris– Willmar – Mn Valley 115 kV system in addition to addressing reliability concerns in the Morris – Canby 115 kV system. In addition to addressing existing category P1 and P2 low voltage concerns in the study area, it brings a much-needed load serving reliability improvement for NERC category P6 contingency in study area that is none existent in the current system configuration. This option brings loss reduction in the transmission system and is the best option from incremental load serving standpoint. Loads served from Appleton, Shible Lake, Milan, Holloway and Moyer distribution substation will see considerable reliability improvement as a result of the upgrades to receive 115 kV service.

[NONPUBLIC DATA BEGINS HERE...]

While Option 1 and Option 2 don't cost as much as Option 7 (with variation) , both options don't address NERC category P6 concerns in the study area. In addition to P6 concerns, Option 1 doesn't address low voltage concerns in the study area due to [redacted] The total cost of Option 2 will increase significantly as the Kerkhoven Junction to Kerkhoven Tap 115 kV line will need to be rebuilt after a 12 MW incremental load in the study area.

[...NONPUBLIC DATA ENDS HERE]

Option 4 is the most expensive project in comparison. While it addresses reliability concerns in the study area, it doesn't provide the additional reliability improvement that Option 7 provides to the Morris – Canby 115 kV transmission system.

The cost of Option 7 (with variation) could increase with the conversion of the distribution substation along the 115 kV route from 41.6 kV to 115 kV service. The distribution service upgrade is not a requirement to address reliability concerns in the study area; therefore, the incremental cost wasn't considered against option 7. It rather was considered as an opportunity that this option provides for existing 41.6 kV system fed load in the area to receive a better reliable service from a 115 kV transmission system.

It is the recommendation of this study that Option 7 (with its variation that upgrades existing 41.6 kV line to 115 kV) is constructed to address reliability concerns in the study area transmission system and Morris to Canby 115 kV system. This option is also recommended to make capacity available in the study area transmission system to serve additional load that may connect to the study area transmission system in the future. As discussed above, it is also a recommendation of this study that the Willmar area specific study to find a solution that addresses P1, P2 and P6 concerns to the GRE/Willmar system, which are not addressed by Option 7(with variation).

Appendix A: Load data

Summer peak study model load data

69 kV System Peak Load			**2019 Summer**		**2028 Summer**		**Data Source:**
Bus #	Name		MW	MVAr	MW	MVAr	
605004	LOWRY	XCEL	4.30	0.87	4.52	0.92	MNTACT 2018 models
605102	BELGRADE	XCEL	2.14	0.43	2.25	0.46	MNTACT 2018 models
605103	BROOTEN	XCEL	5.99	1.22	6.30	1.28	MNTACT 2018 models
605104	SEDAN	XCEL	0.31	0.06	0.30	0.06	MNTACT 2018 models
605105	GLENWOOD	XCEL	13.79	2.80	14.52	2.95	MNTACT 2018 models
605106	VILLARD	XCEL	1.40	0.28	1.37	0.28	MNTACT 2018 models
605107	WESTPORT	XCEL	0.32	0.07	0.32	0.06	MNTACT 2018 models
616025	LAKE JOHANNA	GRE	3.93	0.80	4.34	0.88	GRE Member Owner Forecast
616061	SWIFT FALLS	GRE	1.39	0.28	1.54	0.31	GRE Member Owner Forecast
616062	GILCHRIST	GRE	1.43	0.29	1.58	0.32	GRE Member Owner Forecast
619120	OMMEN	GRE	2.18	0.44	2.41	0.49	GRE Member Owner Forecast
619121	LEVEN	GRE	3.24	0.66	3.58	0.73	GRE Member Owner Forecast
619122	GLENWOOD	GRE	2.96	0.60	3.27	0.66	GRE Member Owner Forecast
619430	BANGON	GRE	2.98	0.61	3.26	0.66	COOP COIN PEAK -2016
619432	CROW LAKE	GRE	5.46	1.11	5.97	1.21	COOP COIN PEAK -2016
Walden 115/41.6 kV							
Bus #	Name		MW	MVAr	MW	MVAr	
7441	CYRUS	OTP	0.52	0.15	0.57	0.17	PROVIDED BY OTP

7442	FARWELL	OTP	0.14	0.03	0.15	0.03	PROVIDED BY OTP
7443	KENSING	OTP	0.87	0.14	0.95	0.15	PROVIDED BY OTP
619162	HOLMES CITY	GRE	2.52	0.51	2.79	0.57	GRE Member Owner Forecast
619167	WHITE BEAR	GRE	1.69	0.34	1.86	0.38	GRE Member Owner Forecast
619169	FRAMNAS	GRE	2.32	0.47	2.56	0.52	GRE Member Owner Forecast
Benson 115/41.6 kV							
Bus #	Name		MW	MVAr	MW	MVAr	
616079	CASHEL	GRE	1.56	0.32	0.00	0.00	GRE Member Owner Forecast
616076	DOME	GRE	1.72	0.35	1.90	0.39	GRE Member Owner Forecast
616077	MOYER	GRE	3.24	0.66	3.95	0.80	GRE Member Owner Forecast
7461	CLONTARF	OTP	0.32	0.07	0.35	0.08	PROVIDED BY OTP
7459	DANVERS	OTP	0.28	0.07	0.31	0.08	PROVIDED BY OTP
7462	HANCOCK	OTP	1.20	0.24	1.31	0.26	PROVIDED BY OTP
7460	SEED CO	OTP	0.00	0.00	0.00	0.00	PROVIDED BY OTP
Kerkhoven 115/41.6 kV							
Bus #	Name		MW	MVAr	MW	MVAr	
7463	DEGRAFF	OTP	0.38	0.09	0.41	0.10	PROVIDED BY OTP
7464	MURDOCK	OTP	0.98	0.26	1.08	0.29	PROVIDED BY OTP
7465	KERKHOVEN	OTP	3.53	0.71	3.86	0.78	PROVIDED BY OTP
616080	KILDARE	GRE	2.66	0.54	1.44	0.29	GRE Member Owner Forecast
115 kV System Peak Load							
Bus #	Name		MW	MVAr	MW	MVAr	

615365	BENSON	GRE	12.86	2.61	16.32	3.31	GRE Member Owner Forecast
616006	HANCOCK	GRE	9.26	1.88	11.29	2.29	GRE Member Owner Forecast
616008	SWENODA	GRE	2.00	0.41	2.21	0.45	GRE Member Owner Forecast
620218	MORRIS OTP	OTP	7.52	1.73	8.20	1.89	MNTACT 2018 models
658098	BENSON MUNI	MRES	7.29	1.66	8.00	1.82	PROVIDED BY MRES
616009	DUBLIN	GRE	2.56	0.52	2.83	0.57	GRE Member Owner Forecast
Willmar Area 69 kV System Peak Load							
Bus #	**Name**		**MW**	**MVAr**	**MW**	**MVAr**	
617910	PENNOCK	GRE	4.09	0.83	4.52	0.92	GRE Member Owner Forecast
619991	WT PLANT	MRES	0.76	0.00	0.77	0.00	PROVIDED BY MRES
619986	WILLMAR SW	MRES	10.96	4.77	11.08	4.82	PROVIDED BY MRES
619985	WMU PLANT SUB	MRES	28.32	6.96	28.62	7.03	PROVIDED BY MRES
619990	WILLMAR EAST	MRES	8.58	2.57	8.67	2.60	PROVIDED BY MRES
619987	WILLMAR SOUTH	MRES	13.83	2.86	13.97	2.89	PROVIDED BY MRES
617912	SUNBURG	GRE	4.81	0.98	5.31	1.08	GRE Member Owner Forecast
617916	PRAIRIE WOODS	GRE	3.69	0.75	4.07	0.83	GRE Member Owner Forecast
617924	SPICER	GRE	4.31	0.87	4.76	0.97	GRE Member Owner Forecast
617914	KANDYOHI	GRE	4.09	0.83	4.52	0.92	GRE Member Owner Forecast
619977	WILLMAR	GRE	2.91	0.59	3.22	0.65	GRE Member Owner Forecast
617915	SVEA	GRE	3.56	0.72	3.93	0.80	GRE Member Owner Forecast
617918	GREEN LAKE	GRE	2.15	0.44	2.38	0.48	GRE Member Owner Forecast

617913	HAWICK	GRE	5.09	1.03	5.62	1.14	GRE Member Owner Forecast
618528	LAKE KORONIS	GRE	1.78	0.36	2.07	0.42	GRE Member Owner Forecast
Maynard 115/69 kV connected peak loads							
605053	CITY OF GRANITE FALLS	XCEL	7.62	1.55	8.02	1.63	MNTACT 2018 models
605006	MAYNARD	XCEL	2.14	0.43	2.25	0.46	MNTACT 2018 models
605007	CLARA CITY	XCEL	8.66	1.76	9.12	1.85	MNTACT 2018 models
605051	FIESTA CITY	XCEL	10.36	2.10	10.91	2.22	MNTACT 2018 models
Appleton and Elbow Lake Loads 41.6 kV connected loads							
619171	ROSEVILLE	GRE	2.06	0.42	2.28	0.46	GRE Member Owner Forecast
616083	SHIBLE CPA	GRE	3.07	0.62	3.39	0.69	GRE Member Owner Forecast
658115	APPLETN9	OTP	4.58	1.60	5.01	1.75	PROVIDED BY OTP
7457	MILAN	OTP	1.10	0.17	1.20	0.19	PROVIDED BY OTP
7458	HOLLOWAY	OTP	1.16	0.49	1.27	0.54	PROVIDED BY OTP
7446	BARRET	OTP	1.46	0.39	1.59	0.43	PROVIDED BY OTP
7444	HOFFMAN JCT	OTP	0.03	0.01	0.03	0.01	PROVIDED BY OTP
7445	HOFFMAN	OTP	1.64	0.37	1.79	0.41	PROVIDED BY OTP
7446	BARRET 41.600	OTP	1.46	0.39	1.59	0.43	PROVIDED BY OTP
7444	HOFF JT 41.600	OTP	0.03	0.01	0.03	0.01	PROVIDED BY OTP
7445	HOFFMN 41.600	OTP	1.64	0.37	1.79	0.41	PROVIDED BY OTP

Winter peak study model load data

69 kV System Peak Load			2019 Winter		2028 Winter		Data Source:
Bus #	Name		MW	MVAr	MW	MVAr	
605004	LOWRY	XCEL	3.68	0.75	3.87	0.79	MNTACT 2018 models
605102	BELGRADE	XCEL	2.03	0.41	2.14	0.43	MNTACT 2018 models
605103	BROOTEN	XCEL	5.12	1.04	5.40	1.10	MNTACT 2018 models
605104	SEDAN	XCEL	0.27	0.05	0.26	0.05	MNTACT 2018 models
605105	GLENWOOD	XCEL	11.80	2.40	12.43	2.52	MNTACT 2018 models
605106	VILLARD	XCEL	1.20	0.24	1.17	0.24	MNTACT 2018 models
605107	WESTPORT	XCEL	0.28	0.06	0.27	0.06	MNTACT 2018 models
616025	LAKE JOHANNA	GRE	0.85	0.17	0.94	0.19	GRE Member Owner Forecast
616061	SWIFT FALLS	GRE	1.90	0.39	2.10	0.43	GRE Member Owner Forecast
616062	GILCHRIST	GRE	1.55	0.31	1.71	0.35	GRE Member Owner Forecast
619120	OMMEN	GRE	1.58	0.32	1.75	0.35	GRE Member Owner Forecast
619121	LEVEN	GRE	2.62	0.53	2.89	0.59	GRE Member Owner Forecast
619122	GLENWOOD - GRE	GRE	2.48	0.50	2.74	0.56	GRE Member Owner Forecast
619430	BANGON	GRE	2.00	0.41	2.19	0.44	COOP COIN PEAK -2014
619432	CROW LAKE	GRE	1.91	0.39	2.09	0.42	COOP COIN PEAK -2014
Walden 115/41.6 kV							
Bus #	Name		MW	MVAr	MW	MVAr	
7441	CYRUS	OTP	0.47	0.14	0.52	0.15	PROVIDED BY OTP
7442	FARWELL	OTP	0.13	0.03	0.14	0.03	PROVIDED BY OTP
7443	KENSING	OTP	0.80	0.13	0.87	0.14	PROVIDED BY OTP

619162	HOLMES CITY	GRE	3.58	0.73	3.96	0.80	GRE Member Owner Forecast
619167	WHITE BEAR	GRE	3.56	0.72	3.93	0.80	GRE Member Owner Forecast
619169	FRAMNAS	GRE	1.99	0.40	2.19	0.45	GRE Member Owner Forecast
Benson 115/41.6 kV							
Bus #	Name		MW	MVAr	MW	MVAr	
616079	CASHEL	GRE	1.87	0.38	0.00	0.00	GRE Member Owner Forecast
616076	DOME	GRE	1.63	0.33	1.80	0.37	GRE Member Owner Forecast
616077	MOYER	GRE	2.05	0.42	2.50	0.51	GRE Member Owner Forecast
7461	CLONTARF	OTP	0.30	0.06	0.32	0.07	PROVIDED BY OTP
7459	DANVERS	OTP	0.26	0.07	0.28	0.07	PROVIDED BY OTP
7462	HANCOCK	OTP	1.10	0.22	1.20	0.24	PROVIDED BY OTP
7460	SEED CO	OTP	0.00	0.00	0.00	0.00	PROVIDED BY OTP
Kerkhoven 115/41.6 kV							
Bus #	Name		MW	MVAr	MW	MVAr	
7463	DEGRAFF	OTP	0.35	0.08	0.38	0.09	PROVIDED BY OTP
7464	MURDOCK	OTP	0.90	0.24	0.98	0.26	PROVIDED BY OTP
7465	KERKHOVEN	OTP	3.84	0.28	4.20	0.31	PROVIDED BY OTP
616080	KILDARE	GRE	2.87	0.58	1.67	0.34	GRE Member Owner Forecast
115 kV System Peak Load							
Bus #	Name		MW	MVAr	MW	MVAr	
615365	BENSON	GRE	11.99	2.44	15.07	3.06	GRE Member Owner Forecast

616006	HANCOCK	GRE	4.97	1.01	6.06	1.23	GRE Member Owner Forecast
616008	SWENODA	GRE	2.00	0.41	2.21	0.45	GRE Member Owner Forecast
620218	MORRIS OTP	OTP	7.18	0.59	7.70	0.64	MNTACT 2018 models
658098	BENSON MUNI	MRES	6.82	0.10	7.48	0.11	PROVIDED BY MRES (Power factor ?)
616009	DUBLIN	GRE	2.87	0.58	3.17	0.64	GRE Member Owner Forecast
Willmar Area 69 kV System Peak Load							
Bus #	**Name**		**MW**	**MVAr**	**MW**	**MVAr**	
617910	PENNOCK	GRE	3.32	0.67	3.67	0.74	GRE Member Owner Forecast
619991	WT PLANT	MRES	0.85	0.00	0.86	0.00	PROVIDED BY MRES
619986	WILLMAR SW	MRES	8.60	1.40	8.69	1.43	PROVIDED BY MRES
619985	WMU PLANT SUB	MRES	19.18	3.80	19.38	3.82	PROVIDED BY MRES
619990	WILLMAR EAST	MRES	7.27	1.30	7.35	1.34	PROVIDED BY MRES
619987	WILLMAR SOUTH	MRES	9.92	-1.10	10.03	-1.15	PROVIDED BY MRES
617912	SUNBURG	GRE	5.48	1.11	6.05	1.23	GRE Member Owner Forecast
617916	PRAIRIE WOODS	GRE	4.66	0.95	5.14	1.04	GRE Member Owner Forecast
617924	SPICER	GRE	5.23	1.06	5.77	1.17	GRE Member Owner Forecast
617914	KANDYOHI	GRE	4.47	0.91	4.94	1.00	GRE Member Owner Forecast
619977	WILLMAR	GRE	3.12	0.63	3.45	0.70	GRE Member Owner Forecast
617915	SVEA	GRE	3.23	0.66	3.57	0.72	GRE Member Owner Forecast
617918	GREEN LAKE	GRE	2.02	0.41	2.23	0.45	GRE Member Owner Forecast

617913	HAWICK	GRE	4.66	0.95	5.15	1.05	GRE Member Owner Forecast
618528	LAKE KORONIS	GRE	3.01	0.61	3.49	0.71	GRE Member Owner Forecast
Maynard 115/69 kV connected peak loads							
605053	CITY OF GRANITE FALLS	XCEL	6.859	1.393	7.216	1.465	MNTACT 2018 models
605006	MAYNARD	XCEL	1.827	0.371	1.924	0.391	MNTACT 2018 models
605007	CLARA CITY	XCEL	7.415	1.506	7.81	1.586	MNTACT 2018 models
605051	FIESTA CITY	XCEL	8.87	1.801	9.341	1.897	MNTACT 2018 models
Appleton and Elbow Lake Loads 41.6 kV connected loads							
619171	ROSEVILLE	GRE	2.45	0.50	2.70	0.55	GRE Member Owner Forecast
616083	SHIBLE CPA	GRE	0.79	0.16	0.87	0.18	GRE Member Owner Forecast
658115	APPLETN9 41.600	OTP	4.19	1.46	4.59	1.60	PROVIDED BY OTP
7457	MILAN	OTP	1.01	0.16	1.10	0.17	PROVIDED BY OTP
7458	HOLLOWAY	OTP	1.07	0.45	1.17	0.49	PROVIDED BY OTP
7446	BARRET	OTP	1.33	0.36	1.46	0.39	PROVIDED BY OTP
7444	HOFFMAN JCT	OTP	0.03	0.01	0.03	0.01	PROVIDED BY OTP
7445	HOFFMAN	OTP	1.48	0.34	1.62	0.37	PROVIDED BY OTP

ALL REMAINING APPENDICES HAVE BEEN EXCISED FROM THIS DOCUMENT DUE TO THE CONFIDENTIAL NATURE OF THE CONTENT