Final Report –

Southwest Twin Cities – Granite Falls Transmission Upgrade Study

&

Minnesota RES Update Study

Companion Report for the

Southwest Twin Cities – Granite Falls Transmission Upgrade Study Technical Report

and the

Minnesota RES Update Study Technical Report

Prepared by:
The Minnesota Transmission Owners

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Core Study Team

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Great River Energy, Xcel Energy and Otter Tail Power provided leadership for the studies. The Minnesota Transmission Owners-member utility transmission planning engineers provided valuable input to the study process.

Minnesota Transmission Owners (MTO)*

Basin Electric Power Cooperative
(also representing East River Electric Power Cooperative and L&O Power Cooperative)
Central Minnesota Municipal Power Agency
Dairyland Power Cooperative
Great River Energy
Heartland Consumers Power District
Interstate Power and Light
Minnesota Municipal Power Agency
Minnesota Power
Minnkota Power Cooperative
Missouri River Energy Services
(also representing Hutchinson Utilities Commission and Marshall Municipal Utilities)
Northern States Power Company, a Minnesota Corporation (" Xcel Energy")
Otter Tail Power Company
Rochester Public Utilities
Southern Minnesota Municipal Power Agency
Willmar Municipal Utilities

- The Minnesota Transmission Owners are utilities that own or operate high voltage transmission lines within Minnesota. When originally formed, this group was made up of those utilities subject to 2001 legislation requiring transmission owners to file a biennial transmission report. Additional utilities have joined the MTO to collaborate on more recent transmission studies.

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I. Executive Summary

Background

A robust transmission system needs to be in place to support the effective growth in consumers' energy needs, including renewable energy development. This transmission system must be developed in order to satisfy all relevant legal requirements as well as all consumer needs.

One important legal requirement arises out of the Next Generation Energy Act of 2007 Renewable Energy Standard (RES) requiring 25 percent of the energy consumed by the state's utility customers to come from renewable sources by 2025. Xcel Energy has been directed to supply 30 percent of customers' electricity needs with renewable resources by 2020. In Minnesota, high potential wind resources used for energy production are located far from the load centers where the majority of energy is consumed.

The Southwest Twin Cities – Granite Falls Transmission Upgrade Study (also called the Corridor Study) and the Minnesota RES Update Study are part of an extensive effort undertaken by the Minnesota Transmission Owners (MTO) to assess the transmission system in the upper Midwest for improvements necessary to develop a robust and reliable transmission system that (i) allows the development of generation projects that satisfy all relevant legal requirements, including the Renewable Energy Standard legislation milestones, (ii) continue to enable reliable, low cost energy for our region, and (iii) continue developing a robust and reliable transmission system that meets customers' needs. While the collection of MTO sponsored studies has this common high-level goal, each study has a unique focus with different assumptions, different potential projects, and different outcomes. Therefore, results of one study are not necessarily comparable with that of another without taking note of varying assumptions, analytical processes and other study differences. The wealth of study work can be reviewed to identify trends.

This document is a companion report for the Southwest Twin Cities – Granite Falls Transmission Study Technical Report and the Minnesota RES Update Study Technical Report. The technical reports and their appendices can be found at http://www.minnelectrans.com. This companion report is a summary of each technical report presented together to provide context for the studies' findings given the complementary nature of the study process and analysis. The full significance of each study's results can be understood more clearly when presented together.

Purpose

The objective of the Southwest Twin Cities – Granite Falls Transmission Upgrade Study (also called the Corridor Study) was to confirm that upgrading the existing

230 kV corridor removes a key limiter to increasing generation delivery between western and southwestern Minnesota (as well as points further west) and the load centers in Minnesota. The Corridor Study was also tasked with determining the optimal transmission endpoint configurations for the recommended project. One additional study goal was to determine the generation deliverability gained by the proposed upgrade.

The objective of the Minnesota RES Update Study (also referred as the RES Study) was to investigate and recommend future transmission alternatives to increase generation delivery beyond that enabled by the proposed Corridor project. The RES Update was necessary in order to refine and finalize the endpoints and to verify the results and recommendations of the Corridor Study. The RES Study team identified future limiting facilities on the transmission system with emphasis on several popular generation development zones. The RES Update Study team also conducted a key analysis to determine the operational impact of increasing wind generation in the region on the transmission system.

Process

The Corridor Study and RES Update Study were conducted in tandem and reported together because of their complementary goals, similar timeframes, and common analytical processes. It is important to note that these studies focus on transmission planning, the costs of transmission projects and the level of generation that might be enabled by various transmission upgrades. Based on the Midwest ISO interconnection queue and general interest, the studies assume that a large percentage of the generation that will develop in the study region will be wind-energy generation. The specific wind and non-wind generation projects that develop in the region will be highly dependent upon a variety of factors, including the requirements of Open Access Transmission Tariffs (OATTs) such as the Midwest ISO's tariff. However, for purposes of these studies it is assumed that wind-energy generation is the primary source of generation developed. These studies focused primarily on the transmission solutions necessary to enable generation development, including wind-energy generation, in the study area.

Corridor Study Findings

<u>Upgrade Existing Minnesota Valley – Blue Lake 230 kV Line</u>

The Corridor Study analyzed upgrading the existing 230 kV transmission line between Granite Falls and southwest metro to a double-circuit 345 kV configuration (the "Corridor Upgrade"). One key finding of the Corridor study is that upgrading the existing transmission corridor from Granite Falls, Minnesota to the southwest Twin Cities will provide significant new transmission capacity from southwestern and western Minnesota in the 2016 timeframe. Based on

generator interest and the Midwest ISO's current tariff requirements, this additional transmission capacity should result in a robust and reliable transmission system that will allow the development of generation projects to satisfy the 2016 RES milestones established by the State of Minnesota. This Corridor Upgrade works well to facilitate serving Minnesota load with generation located west of Marshall in southwest Minnesota, as well as to the north and into the eastern Dakotas.

Corridor Upgrade Provides Reliability Benefits

The Corridor Upgrade also serves to increase the overall reliability of the transmission system. As the bulk transmission system is called upon to deliver increasing amounts of generation remote from load centers, a robust, reliable, and redundant transmission system will be necessary to minimize generation curtailment (and, thus, variability in generation levels) during transmission system contingencies. Specifically, the Corridor Upgrade's interconnection to the Twin Cities – Brookings line on the western end will allow the Brookings line and the Corridor Upgrade to back one another up very effectively. On the eastern end, the Corridor Upgrade provides a new direct connection to the double-circuit 345 kV loop around the Twin Cities. Combined with the connection to the Helena – Blue Lake 345 kV line and the Helena – Lake Marion – Hampton Corner 345 kV line that is part of the Twin Cities – Brookings project, the Corridor Upgrade will provide for the increased transmission system redundancy necessary to ensure continued reliable electrical service as renewable energy penetration increases.

Corridor Endpoints Established

The transmission system upgrade endpoints were clarified through study findings and verified by the RES Update study results. The two end points of the Corridor Upgrade are the Hazel Creek Substation near Granite Falls, Minnesota to the west and the Blue Lake Substation in Shakopee, Minnesota to the east. The Hazel Creek substation is a proposed substation that is being built in conjunction with the BRIGO facilities and is planned to be used by the Twin Cities – Brookings 345 kV transmission project (assuming all regulatory approvals are obtained).

Corridor Upgrade Supporting Projects

The Corridor study team also assessed the necessary supporting projects to enable full realization of the upgrade benefits. The study results determined the approximate range of capacity or energy carrying capability likely created through installation of the corridor upgrade and supporting project. This assessment is expressed as a range since many outside influences can affect the actual results.

Corridor Study Associated Observations

- Transmission Grid in Western Wisconsin – One observation is that the transmission grid in western Wisconsin, along with interface loading levels along the Minnesota-Wisconsin border, limits the transmission system's ability to deliver more generation from Minnesota and points further west.
- Generation Siting – Another observation is that the actual amount of generation delivery capability gained by the Corridor upgrade will be determined by the actual location of future generation development. To the extent that actual generation development differs from that which was studied, the actual outlet capacity achieved by this system addition may either increase or decrease. The study team selected likely generation development sites based on the best resources available, such as the Midwest ISO generation interconnection queue and utility resource planners in order to provide a reasonable range of results.
- Big Stone II Status – The study team dealt with the ambiguity of whether the Big Stone II project will be built by doing the majority of the analysis without the Big Stone II generation and transmission facilities in place. The key outcome of this analysis showed that it is not necessary to have the Corridor Upgrade project extend west to Big Stone substation to meet the 2016 RES milestone regardless of the status of the Big Stone II generation or transmission facilities. In consideration of the more than 1000 MW of wind generation interconnection requests in the vicinity of Big Stone Substation, system alternative analysis was completed with the proposed 345 kV line extended to Big Stone Substation. The presence or absence of the Big Stone II generation and/or transmission facilities did not materially impact the Corridor Study's conclusions or the benefits of the Corridor Upgrade to serving Minnesota generation or in meeting the 2016 RES milestone.
- Supporting Facilities for Corridor Upgrade –
  - One outcome of studying a Midwest ISO market sink scenario is that the system requires additional facilities to deliver power east from La Crosse, Wisconsin to the rest of the Midwest ISO footprint during low load and high wind periods in the Minnesota and Dakota areas. The Corridor Upgrade facility would then achieve its full potential in the Midwest ISO market dispatch.
  - The Twin Cities metro sink scenario analysis showed that in order to sink as much as 2000 MW of generation from the west to the Twin Cities, many metro area electric generation units must be shut down to allow the imported generation to remain online. To enable this new generation to be sunk in the Twin Cities metro and maintain reliable operation requires a significant list of metro area transmission system upgrades.
- Tipping Point in Transmission System – Following the addition of the Corridor upgrade (and associated underlying system upgrades required with a Twin Cities Metro sink scenario) any future transmission or

generation capacity additions will require a facility from La Crosse to the Madison, Wisconsin area. In other words, without a line to the east of La Crosse the system will reach a tipping point, where additional transmission and generation capacity additions cannot be accommodated due to the need to keep Twin Cities generation online for steady state and dynamic system stability.

RES Update Study Key Findings

Operational Limits with Increased Wind Penetration

The key finding of the RES Update Study is the realization of an operational limit on the amount of wind penetration that can be accepted into the transmission grid in the upper Midwest. Both steady state and dynamic stability analysis point to these operational issues. The RES Update Study verified that installing additional variable or intermittent generation sources (beyond what was assumed in the Corridor Study) would require the larger fossil fuel generators near the Twin Cities to begin backing down. It is also possible that these limits could be observed during very low load periods, requiring the curtailment of wind generation in order to maintain operable output of larger generators.

This impacts system reliability and system operations. This is significant because the fossil fuel plants typically cannot respond to significant changes in load or variable generation sources such as wind. When taken offline, minimum restart times for fossil fuel plants are typically two to three days and not having the units available to deal with fluctuations in wind generation could jeopardize the reliability of transmission service in the upper Midwest.

These findings underscore the need for additional transmission infrastructure to keep the overall system stable as wind penetration increases. In other words, ensuring reliable operation of the overall electric system at increasing levels of renewable generation will require additional transmission facilities.

In addition to the steady state issues identified above, concerns about approaching the region's operational limit for wind penetration were confirmed by the results of the dynamic stability assessment. A larger-scale stability analysis that included substantial levels of wind penetration (7300 MW of wind generation) revealed significant dynamic stability issues for the loss of regional transmission lines.

The results of the RES Update Study show that caution must be exercised as wind penetration in the upper Midwest surpasses the levels contemplated by the Corridor Upgrade. While there have been numerous steady-state studies performed analyzing increasing levels of wind penetration, the stability assessment described here is noteworthy because the study team believes it is

the most extensive publicly-available system stability study to include these levels of wind generation.

RES Update Study Identification of Constraints and Sensitivities

Another key finding of the RES Update Study is that future generation development will be constrained beyond the levels contemplated by the BRIGO[1] facilities, the CapX2020 Group I facilities[2], and the Corridor Upgrade. Without improvements to the transmission system, additional generation will be unable to flow to the areas where the energy is needed.

For example,

- prior to the Corridor Upgrade: the Buffalo Ridge area, an area of significant wind development interest in southwestern Minnesota, will be constrained to approximately 1900 MW; generation in southeastern Minnesota will be capped at about 900 MW; and the North Dakota Export will be limited to 2080 MW prior to installation of the CapX2020 Group I facilities.[3]
- after the Corridor Upgrade: the Buffalo Ridge area would increase to nearly 3,900 MW; generation in southeastern Minnesota will be capped at about 900 MW; and generation in North Dakota also receives an indirect benefit from the Corridor Upgrade.

Despite the increase in generation capacity from the Buffalo Ridge area, interest in developing additional generation projects in North Dakota and southeastern Minnesota will remain strong. The RES Update Study lays out the projects that will most beneficially increase those areas and provides support for the Corridor Study and its generation outlet findings.

Sensitivity Analysis Results

The RES Study not only identified the different transmission system upgrades necessary to increase generation outlet, it also investigated the impact these improvements have on each other in each zone. This sensitivity analysis provided useful data for the study recommendations.

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[1] The BRIGO (Buffalo Ridge Incremental Generation Outlet Study) focused on increasing wind outlet capacity of the transmission system in the Buffalo Ridge area.

[2] CapX2020 is a joint initiative of 11 transmission-owning utilities in Minnesota and the surrounding region to expand the electric transmission grid to ensure reliable and affordable service. Capx2020 projects will be built in phases designed to meet the increasing demand for electricity and support renewable expansion. The Group 1 projects includes the Bemidji – Grand Rapids 230 kV line and the following 345 kV lines: Twin Cities – Brookings, Twin Cities – Fargo, and Twin Cities – La Crosse.

[3] The impact of the CapX2020 Group I facilities on North Dakota Export is still being determined. For purposes of this analysis, the North Dakota Export level was established prior to placing the CapX2020 Group I facilities in the model.

In the North Dakota zone, the upgrade of the Corridor facilities provides a significant benefit to North Dakota-based generation, however, other transmission facilities are necessary to unlock generation potential within North Dakota.

In the southwest zone, transmission improvements provide noteworthy results in terms of generation capacity improvement. The largest benefit for this zone occurs with installation of the La Crosse – Madison 345 kV line which crosses Wisconsin from La Crosse to the Madison area.

This sensitivity test showed that the greatest benefit comes from installation of the Corridor Upgrade and the La Crosse – Madison 345 kV line. The need for the La Crosse – Madison 345 kV line is not caused by the Corridor Upgrade, as benefit to installing the line is seen even in cases in which the Corridor Upgrade is not included. The La Crosse – Madison line is driven by the need to strengthen ties to increase regional reliability under both steady-state and dynamic stability conditions. The line also happens to provide a significant generation delivery benefit.

Installing the Corridor Upgrade and the La Crosse – Madison lines together results in approximately 3600 MW of generation delivery capability above that included in the base case in the model. This is an additional 1600 MW above and beyond the 2000 MW provided by the Corridor Upgrade. This 3600 MW includes locations specified by the Corridor study as well as locations throughout southeastern Minnesota and northeastern Iowa.

Additional sensitivity analysis was performed that investigated simultaneously increasing generation in all the zones being considered. This analysis showed that facilities in and around Sioux Falls, South Dakota will require mitigation prior to significant additional generation delivery from anywhere west of the Buffalo Ridge area.

Overall sensitivity analysis findings highlighted some high potential projects that have impacts to multiple zones and may merit resolution sooner.

- The first is the installation of the La Crosse – Madison 345 kV line which provides significant benefit in all cases.
- The facilities in and around Sioux Falls, South Dakota at the Split Rock substation will also require upgrades. Most of these improvements are necessary due to terminal equipment limitations and would be relatively inexpensive to complete.

Conclusions

The Corridor Study and RES Upgrade Study provide complementary conclusions that direct future transmission expansion planning to enable a robust and reliable transmission system as generation is added in the region.

Upgrading Existing Minnesota Valley – Blue Lake 230 kV Line

Both the Corridor Study and the RES Update Study separately confirmed the need for the existing Minnesota Valley – Blue Lake 230 kV line to be upgraded to double-circuit 345 kV. If significant new generation resources are to be developed in locations west of the Twin Cities, from the Buffalo Ridge into North Dakota, upgrade of the Minnesota Valley – Blue Lake 230 kV line to double-circuit 345 kV is necessary. Completion of this upgrade and necessary underlying system projects will result in an increase in generation delivery on the order of 2000 MW.

Wisconsin Transmission Limits

In addition to this upgrade, a new high-voltage transmission facility is necessary between La Crosse and eastern Wisconsin to ensure reliable operation and enable full dispatch of new generation resources. The Corridor and RES Update Studies assumed a termination in the Madison area. Southern Minnesota currently only has one high voltage tie between Minnesota and eastern Wisconsin (the King – Eau Claire – Arpin 345 kV line). Together with the Corridor upgrade, addition of this facility adds as much as 1600 MW of additional capacity to the system - a total of 3600 MW of new generation delivery capability. The need for a new line to the east is consistent with the findings of the Minnesota Wind Integration Study, the study upon which the Minnesota legislature relied when drafting the RES legislation.

Twin Cities Generation Sink Scenario

Another contributing factor is the Twin Cities generation sink scenario studied in the Corridor Study. Importing approximately 2000 MW of generation into the Twin Cities without additional outlet capacity to the east, as was done in the Corridor Study, required significant Twin Cities generation resources to be turned off. This result is significant because any increase beyond 2000 MW will require generation at Sherburne County to be shut down. With its restart time measured in days, this would make Sherburne County unable to respond to fluctuations in energy demand and wind generation. This scenario is not recommended due to a decrease in reliability that would result.

Stability Assessment Results

An indicative stability assessment was also performed. This assessment confirmed that significant new reactive capability will be necessary as variable and intermittent generation sources increase. This is due in large part to generation being located a significant distance from load centers. At the same time, some larger generators are being turned down to make room for the new generators.

In general, the message these results portray is that wind penetration beyond the levels studied in the Corridor Upgrade must be pursued with the utmost caution. As the stabilizing influence of larger generators is reduced or those units are replaced by smaller generators with variable output that are more susceptible to voltage swings, additional bulk transmission lines will be needed in order to effectively absorb the impacts of regional faults and generator outages. As this stability study demonstrates, a lack of sufficient transmission resources will expose the upper Midwest region to degraded reliability and the potential for relatively innocuous transmission contingencies to cascade into large-scale regional concerns.

II. Introduction

This report is a synopsis of two important studies – the Southwest Twin Cities – Granite Falls Transmission Upgrade Study (also called the Corridor Study) and the Minnesota Renewable Energy Standard (RES) Update Study (also referred to as the RES Update Study). The Corridor Study sought to assess the additional generation delivery support provided by the transmission system after upgrading the existing 230 kV transmission line from Granite Falls to the Southwest Twin Cities. The RES Update Study takes the outcomes of the Corridor Study and analyzes additional transmission system improvements that will be necessary in order to maintain system reliability, enable reliable, low-cost energy for customers in our region, and for Minnesota utilities to comply with the RES requirements. These studies were undertaken by Minnesota Transmission Owners (MTO).

Fundamentally, additional transmission capacity is needed to bring additional power generated at various points throughout the system to the areas in Minnesota and beyond where the power will be utilized. In light of generator interest (expressed through the Midwest ISO interconnection queue) it is reasonable to assume that a significant portion of the generation enabled by adding additional transmission capacity will be available for renewable sources of generation, in addition to the important system benefits provided by these improvements. The Corridor and RES Update Studies were conducted in tandem and reported together because of their complementary goals, similar timeframes, and common analytical processes.

Transmission planning studies tend to fall into two broad categories: vision studies and Certificate of Need studies. Vision studies take a high level, indicative look at the transmission needs; a Certificate of Need study is a more detailed analysis of the transmission system and is required by regulators to move forward to the next steps of constructing a transmission system. The study work supporting the southwest Twin Cities – Granite Falls upgrade is considered to be Certificate of Need-level work. This study work is the result of both the Corridor Study and the RES Update Study. While the RES Update Study by itself is considered to be a vision-level study, its analysis and results were key inputs in determining the outcome and recommended endpoints of the Corridor Study.

In addition to the effort documented here, an additional study, the Capacity Verification Study (CVS Study) is being pursued separately by the MTO. This high-level analysis is being performed to synthesize the various transmission studies being performed throughout the region and determine the approximate generation delivery capability created by various combinations of the projects being studied. The CVS Study also performs some analysis regarding cost of transmission upgrades based on amount of delivery enabled and considers the cost of underlying system upgrades.

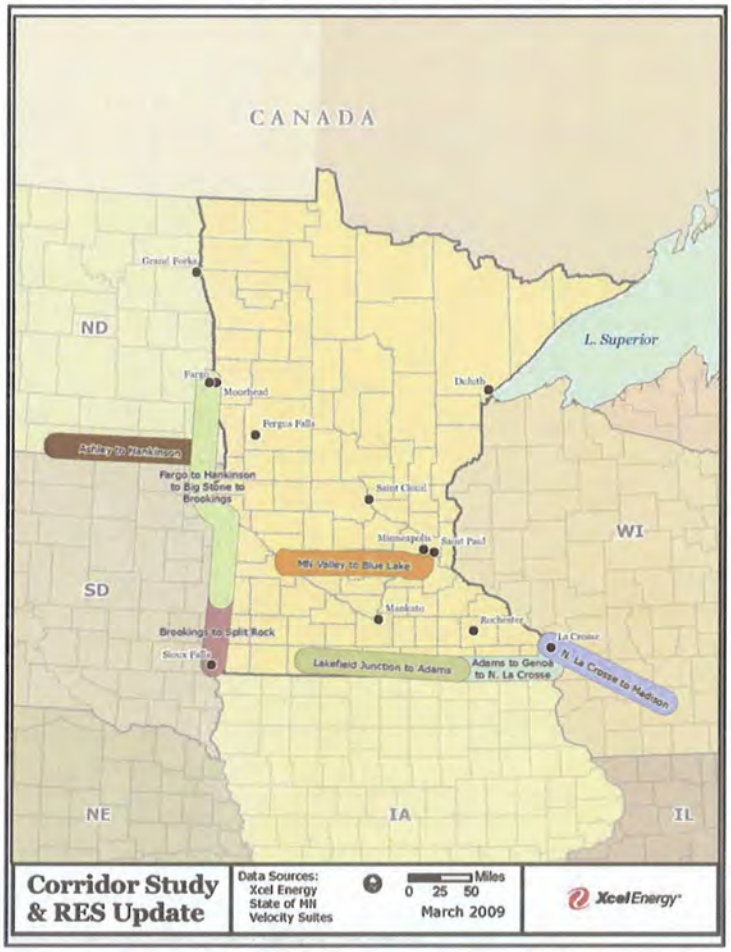
The Corridor Study, RES Update Study, and CVS Study, among other study efforts, are proceeding simultaneously to examine the transmission system impacts as new generation comes online. Since each study has a unique focus, the study teams have examined the cumulative transmission system under different assumptions, with different potential projects, and with different purposes for the various studies. The studies do not precisely mirror one another with regard to generation outlet, limiting facilities, or possible solutions, and this is typical of transmission planning work. As assumptions change among various studies, the results will also change. The most important things to watch for when examining the wealth of study work being completed are trends that develop in the data. For example, when multiple studies with varying assumptions suggest significant outlet can be created with a particular project (or set of projects), this presents a reliable indication that completing the project will result in outlet capability within these general ranges.

This report is organized with information about the Corridor and RES Update Studies' mutual background and scope, and a section describing the initial modeling and assumptions common to both studies. Then, each study team conducted their own analysis to address the scope and goals of their respective studies. The analysis and key findings sections of the report explain the separate efforts and conclusions for each study. The final section describes the common key findings and next steps. This report is accompanied by two more detailed technical reports specifically documenting the assumptions, study methodologies, and results of the Corridor and RES Update Studies.

The Corridor Study's focus is west-central Minnesota where the RES Update Study looks beyond west-central Minnesota. The Corridor Study considers additional transmission capacity through 2016 to achieve a robust and reliable transmission system in light of regional utilities' requirements to develop generation projects to satisfy generation additions through 2016 and the RES Update Study explores transmission improvements needed to provide a robust and reliable transmission system beyond 2016 through 2020. The RES Update Study builds upon the results of the Corridor Study so there is a natural progression of planning concepts and analysis. The Minnesota RES Update Study builds upon the results of the Corridor Study by investigating the best way to integrate the significant interest in generation development in and around Minnesota into the regional transmission system.

The RES Update Study was necessary in order to refine and finalize the endpoints and to verify the results and recommendations of the Corridor Study. In addition, the RES Update Study provided additional insight into the amount of generation delivery that was achievable when the Corridor Upgrade is combined with other project developments. Figure 1 shows the location of the Corridor Upgrade along with the location of the projects considered in conjunction with the RES Update Study.

Figure 1 - Map of Corridor Upgrade and RES Update Projects



The Corridor Study and RES Update Study were conducted in tandem and reported together because of their complementary goals, similar timeframes, and common analytical processes. It is important to note that these studies focus on transmission planning, the costs of transmission projects and the level of generation that might be enabled by various transmission upgrades. Based on the Midwest ISO interconnection queue and general interest, the studies assume that a large percentage of the generation that will develop in the study region will be wind-energy generation. The specific wind and non-wind generation projects that develop in the region will be highly dependent upon a variety of factors, including the requirements of Open Access Transmission Tariffs (OATTs) such as the Midwest ISO's tariff. However, for purposes of these studies it is assumed that wind-energy generation is the primary source of generation developed. These studies focused on the transmission solutions necessary to enable

generation development, including wind-energy generation, in the study area.[4] These studies focused on the transmission solutions and did not focus on the overall consumer costs.

Where these studies investigated production cost (PROMOD[5]) impacts, this was a high-level indicative performance. Production cost represents the instantaneous cost to actually produce sufficient energy to meet the load in a region. It does not take into account the value of power purchase contracts in its analysis.

The final component of consumer cost is the generation integration cost. This issue arises because of the variable or intermittent nature of certain types of generation, such as wind-energy generation. This is the cost incurred in order to operate the grid reliably with significant levels of wind integrated into the grid. These costs can include, but are not limited to, the power purchase cost of wind energy, cost of existing generation assets that operate less than originally anticipated in the market, and the cost of maintaining higher levels of spinning reserves in order to absorb rapid fluctuations in levels of wind generation.

This study focuses only on the first of these three factors and does not attempt to examine the other two factors with specificity. To assess the total cost to consumers of any project, additional analysis is required. The issue of importance for the RES Update Study work is ensuring a robust and reliable transmission system exists sufficient for all purposes, including allowing Minnesota utilities to satisfy the RES milestones while maintaining a reliable, operable power system.

A. Background

A robust transmission system needs to be in place to support generation development. The effective growth of renewable energy development is also highly dependent upon the presence of a robust and reliable transmission system. In Minnesota, high potential wind resources used for energy production are located far from the load centers where the majority of energy is consumed.

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[4] Note that the actual cost to consumers of new generation is represented by the total of three very distinct factors: transmission cost, production cost, and integration cost. The RES study took a high-level partial look at production cost of wind generation but further analysis is necessary to determine the actual production cost impact. That study did not attempt to address the integration cost. This is the cost incurred to operate the grid reliably with significant levels of wind integrated into the grid. To understand the total cost implication of implementing transmission development assuming specific wind integration plans, additional analysis is required.

[5] PROMOD is a production modeling analysis program that mimics the Midwest ISO's real-time generation market. It can be used to model how a new transmission (or generation) project functions in the market environment. For more information about PROMOD and how it was incorporated in this study work, see Chapter V, Section B.

The distance from likely generation sources to Minnesota's load centers also contributes to the need for a robust and reliable transmission system.

Going back a decade or more, the transmission studies to enable wind delivery were focused on the Buffalo Ridge area in southwest Minnesota where many wind generation projects were planned and have been built. The first significant transmission project focused on enabling wind generation development was a series of smaller transmission system improvement projects (the 425 Project) that provided system support for the development of 425 MW of wind generation capacity in the Buffalo Ridge.

The next major transmission project was designed to increase generation outlet from the Buffalo Ridge to 825 MW (the 825 Project). It included several smaller transmission projects and one 345 kV line in southwest Minnesota from Split Rock near Sioux Falls, South Dakota to Lakefield, Minnesota. The 825 MW Project provided system support for increasing the wind generation capacity in the Buffalo Ridge to approximately 825 MW.

Then, the BRIGO (Buffalo Ridge Incremental Generation Outlet) Project planned three new 115 kV lines in the Buffalo Ridge area and some 345 kV substation work. The BRIGO series of improvements raised the Buffalo Ridge generation output to roughly 1200 MW.

The most recent Buffalo Ridge area project is the Brookings County, South Dakota to Hampton, Minnesota 345 kV line. This line is one of the CapX2020 Group I[6] lines and is currently being permitted. It is planned to run east and west through southern Minnesota and will increase generation capacity to approximately 1900 MW.

Through these projects, a general trend has been observed that the more the transmission grid is improved, the more incremental output each project makes available for generation delivery capability. Each addition to the transmission system tends to add much more capacity as an incremental part of the greater transmission system. While the CapX2020 Group 1 project adds capacity, the Corridor Upgrade is projected to provide a significant step increase in overall system transfer capability. This study work shows that the Corridor Upgrade improvements work with the existing transmission grid to leverage and maximize beneficial impacts of the investments already made in CapX2020.

The need for the Corridor Study was triggered by the findings in the Brookings study work for the Brookings County to Hampton 345 kV transmission line project (Brookings Project) as well as numerous Midwest ISO generation interconnection

[6]CapX2020 is a joint initiative of 11 transmission-owning utilities in Minnesota and the surrounding region to expand the electric transmission grid to ensure reliable and affordable service. Capx2020 projects will be built in phases designed to meet the increasing demand for electricity and support renewable expansion.

studies. The Brookings Study[7] revealed that the 230 kV transmission line from Granite Falls, Minnesota to the southwest corner of the Twin Cities is one of the facilities that limited generation delivery for the Brookings transmission line to approximately 1900 MW.

The Brookings Study showed that the 230 kV corridor cannot be taken out of service without key segments of the proposed Brookings – Twin Cities line being in- service. Removing the 230 kV line without these segments in service will result in significant curtailment of Buffalo Ridge wind generation. This means that if the Corridor Upgrade is ultimately approved for construction prior to completion of the Brookings Project, significant curtailed wind generation from Buffalo Ridge will result. It is beyond the scope of the Corridor Study to analyze the amount of such costs or the parties primarily responsible for those costs. However, it is expected that this issue will need to be addressed as it could impact the timing and cost of the Corridor Upgrade.

The Corridor Upgrade is the next project necessary to deliver more regional generation from western Minnesota, eastern North Dakota and eastern South Dakota to serve load in Minnesota through numerous Midwest Independent Transmission System Operator (Midwest ISO)[8] led interconnection and deliverability studies.

Several factors have contributed to a shift in information needed from the RES Update Study. The original purpose of the RES Update Study was to look at the need for transmission system upgrades beyond those recommended by the Corridor Study to ensure a robust and reliable transmission system is in place to facilitate load serving entities' efforts to meet the legislated 2016 Renewable Energy Standard milestones in Minnesota. Using the results of the RES gap analysis[9] conducted by the Minnesota utilities, preliminary calculations indicated approximately 1,000 MW of generation delivery capability would be needed beyond that which would be provided by the Corridor Upgrade. This was based on a preliminary assumption that the Corridor Upgrade would yield approximately 1,000 MW of generation delivery capability. This gap analysis is adjusted over time as energy demand forecasts and energy production forecasts are defined. As the Corridor study progressed, the study results indicated greater-than-

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[7] The Brookings Study (or EHV Study as it was originally titled) is the technical study analyzing the CapX 2020 Groups 1 345 kV line from Brookings, SD to Hampton Corner substation in the southern Twin Cities.

[8] Midwest ISO is a not-for-profit member-based organization of electric transmission owners, covering a 15 state region from the Dakotas to Pennsylvania. Midwest ISO administers and manages the transmission of electricity within its region.

[9] The original Gap Analysis was conducted by the MTO for inclusion in the 2007 RES Report and calculated the amount of wind energy (in MW) that would be necessary to meet each RES milestone statewide and for each company. The RES Report was required by the 2007 Next Generation Energy act and was filed in conjunction with the 2007 Biennial Transmission Projects Report. A full version of the report can be found on the web at http://www.minnelectrans.com.

expected deliverability from the Corridor Upgrade than the initial projections of 1,000 MW.

In addition, reductions in load growth due to conservation efforts and economic impacts result in load growth forecasts that suggest a slight reduction in the amount of renewable generation that may be necessary.

The third reason the RES Update Study scope has shifted is the fact that existing wind generation in the study area is performing better than expected with higher capacity factors than originally estimated. In the original Gap Analysis, a lack of definitive wind turbine capacity factor information led transmission engineers to conservatively estimate the average capacity factor at 30%. Several years of actual information have now placed the average wind turbine capacity factor at a level closer to 40%. The capacity factor is one way to measure the productivity of a wind turbine or any other power production facility. It compares the plant's actual production over a given period of time with the amount of power the plant would have produced if it had run at full capacity for the same amount of time. In other words, an increase in capacity factor from 30% to almost 40% means fewer turbines are necessary to satisfy the Minnesota RES requirements.[10]

Taking into account these three factors, the results of the Corridor Study suggest that its installation combined with the CapX2020 Group I projects will provide sufficient transmission support to create a robust and reliable transmission system that will allow utilities to develop generation projects sufficient to satisfy their 2016 RES milestone.

B. Summary of Each Study's Scope

Corridor Study Scope

The scope of the Corridor Study involves confirming the upgrade of the existing Minnesota Valley – Blue Lake 230 kV line as the key limiter to increasing generation delivery from western Minnesota and North and South Dakota. The study also included determining the most efficient use of the existing Minnesota Valley – Blue Lake 230 kV transmission corridor, and identifying generation deliverability gained. This upgrade will be available to support new generation in western and southwestern Minnesota and should assist utilities in achieving their RES milestones while maintaining a reliable transmission network.

The Corridor Study team examined various voltage configuration possibilities, including a double-circuit 345 kV and single-circuit 500 kV and 765 kV systems. For each configuration, the team considered the potential loading capability and the present underlying facilities in place in order to determine the best application

[10] Consistent with generation development interest in the upper Midwest, and the fact that Xcel Energy's 2020 RES milestone specifically requires 25% wind generation, it is generally assumed that a majority of the generation necessary for RES compliance will come from wind turbines.

for this situation. The 345 kV double circuit configuration was concluded to be a better choice than 500 kV as it has been shown that one 500 kV circuit provides similar capability and electrical performance as double-circuit 345 kV. Also, 345 kV is a native voltage in this area. In other words, transmission utilities commonly work on and operate 345 kV transmission systems and regularly order and keep inventory of the equipment necessary to operate these systems. After preliminary analysis, the 765 kV voltage option was also ruled out because, at this time, the underlying system along this corridor is not in place to support 765 kV.[11]

RES Update Study Scope

Based on the Corridor Study findings and the trends mentioned above, the RES Update Study's scope evolved to investigate and recommend future transmission alternatives to increase generation delivery beyond that enabled by the Corridor project. The RES Update Study team identified future limiting facilities on the transmission system with emphasis on several popular generation development zones and recommended solutions to alleviate transmission system constraints and increase generation outlet from each zone. The team also pinpointed limiting facilities common to multiple zones, especially those that may merit resolution now.

The RES Update Study team also performed a stability assessment that considered the impact of the new facilities proposed in both the Corridor and RES Update Studies. This assessment is discussed in Chapter VI, Section A and identified important system stability concerns that must be addressed as additional generation (particularly wind) is integrated into the transmission system. Based upon results of the transmission analysis, transmission system improvement projects are recommended that are common to a number of development scenarios and provide optimal flexibility with regard to future deployment of new generation resources.

The zonal generation approach has been complemented with "wide area" sensitivity studies that provide a comprehensive examination of many potential generation development scenarios. This means the results of the RES Update Study will be able to inform future transmission development decisions regardless of how future generation projects are deployed.

[11] This is also important when considering potential impacts of the various recent proposals depicting potential 765 kV overlays through the region. If these were to materialize, a robust underlying 345 kV system would be required and this corridor upgrade would be an integral part of that system. It is the opinion of the study team that regardless of any 765 kV future in the region this upgrade is the best next step for the transmission system.

C. Uncertainties

Uncertainties affecting the results of the Corridor Study and RES Update Study include the following:

- CapX2020 Group I project upsizing – If the Brookings County – Hampton Corner 345 kV CapX2020 project is upsized to double circuit 345 kV, more delivery capability from southwest Minnesota will be possible. In addition, if the second Twin Cities – Fargo 345 kV circuit is added, additional capability from North Dakota will be possible without significantly impacting flow on the Corridor Upgrade.
- Uncertainty of generation location – The study team used the best information available at the time of the study. This study used one set of generation location assumptions and provided a possible range of delivery capability and locations. However, as actual generation is sited in varying locations, this range may be subject to change.
- Generation Interconnection Process – This study work is neither intended to replace the interconnection process of the Midwest ISO or any other regional transmission organization nor is it intended to provide a guarantee of interconnection should a generation project seek to interconnect in a particular location. Specific generators, even those seeking to interconnect in locations at which generation was assumed in this study, will still be required to move through the interconnection process.
- Transmission Cost – Cost estimates for the project were completed using 2007 dollars. Prevailing market conditions could change these estimates due to cost of materials, competitive bidding for crews, and other expenses.
- Generation for delivery outside Minnesota – For the purposes of these studies, all generation sited is assumed to assist in meeting the RES milestones. However, utilities from outside the state and region are not precluded from purchasing some of the generation enabled by these facilities. This would reduce the amount of generation capacity able to be counted for Minnesota's RES milestones.

Recognizing these uncertainties, the study team presents their findings (outlet capability achieved, dollars, timing) in terms of ranges.

D. Legislation

The state of Minnesota has legislative and regulatory requirements that mandate Minnesota's load serving utilities take significant actions to enable substantial growth in the development and use of renewable electricity. Minnesota's Next Generation Energy Act of 2007 enacted the Renewable Energy Standard (RES). The RES requires that 25 percent of the electricity consumed in Minnesota be generated by renewable resources by 2025. This enabling legislation provides

interim milestones beginning in 2010 through 2025 with specific renewable energy goals for utilities to use to set a plan in place to meet these objectives. Additionally, the RES requirements hold Xcel Energy to a higher standard, requiring 30 percent of its customers' electricity needs with renewable sources by 2020. Table 1 below shows the renewable energy requirements for each milestone year. The full text of the Next Generation Energy act can be found at https://www.revisor.leg.state.mn.us/bin/bldbill.php?bill=H0436.0.html&session=ls85

Table 1 - Renewable Energy Standards - Percent of Annual Minnesota Retail Sales to be Met with Renewable Generation

Year	Utility Requirement	Xcel Energy
2010	7%[12]	15%
2012	12%	18%
2016	17%	25%
2020	20%	30% - 25% must be wind
2025	25%	30% - 25% must be wind

Another part of Minnesota's Next Generation Energy Act of 2007 requires Transmission Owning (MTO) utilities to analyze and identify specific transmission solutions for serving the renewable energy resources necessary for the load serving utilities to comply with the expanded and accelerated renewable energy standards. The MTO responded with a well-thought-out strategy sponsoring a series of studies that describe the planning steps necessary to meet the transmission needs of the expanded renewable energy standard objectives. The MTO must examine how the complex interconnected electric grid needs to be built in order to support these ambitious milestones and continue to provide a robust, reliable and cost-effective transmission system that will allow load serving entities to continue providing reliable and cost effective electric service. The Corridor and RES Update studies are two of the studies that are intended in part to meet these goals.

E. Stakeholder Involvement

While the enabling legislation did not require specific outside input for the Corridor and RES Update Studies, the Minnesota Transmission Owners (MTO) recognized the value of augmenting the process by seeking ideas from additional technical experts, Minnesota Department of Commerce staff, Office of Energy Security (OES) staff, wind developers and other interested parties.

At regular intervals throughout the study process, the Technical Review Committee (TRC) provided input to the study team on the sink alternatives, study

[12] The 7% milestone in 2010 represents a good faith objective for those utilities that do not own a nuclear generation facility in the state of Minnesota.

approach and scoping of the analytical work. The TRC is an OES appointed group assigned to oversee other legislated studies assigned to the MTO utilities, in particular the Dispersed Renewable Generation (DRG) Transmission Studies (Phase I, Phase II). Since this group met regularly and possessed the applicable technical skills needed, it was prudent to leverage their knowledge to enrich the Corridor and RES Update Studies. The individuals have experience and expertise in electric transmission system engineering and renewable energy generation technology. Their varied backgrounds made them valuable for providing input on all aspects of the study's technical methods and assumptions.

Utility transmission planning engineers were consulted to gather information on new generation data and transmission topology changes that may occur prior to 2016. These planning engineers represent transmission owners in Minnesota, South Dakota, Wisconsin, North Dakota, Manitoba and Iowa.

Regional transmission system planning needs are coordinated with Midwest ISO through the Regional Generator Outlet Study (RGOS) process. RGOS is a study being performed by the Midwest ISO in coordination with its member utilities, state regulatory agencies, and interested non-utility stakeholders seeking to design an appropriate high voltage transmission system to efficiently meet the renewable energy standards of the various states in the upper Midwest.

The Corridor and RES Update study teams made sure that the transmission lines are consistent with the preliminary work on the RGOS. The Corridor Upgrade is represented in every one of the scenarios studied in the RGOS study. In addition, many of the concepts explored and recommended in the RES Update Study are also included in the various RGOS study scenarios. While in some cases the precise facilities may differ, the need for transmission system performance enhancements is conceptually similar. To ensure coordination in both studies, the engineers from all the MTO members are working closely with the Midwest ISO on the RGOS study.

Presentations were given to the Northern MAPP-Missouri Basin Subregional Planning Group (SPG) to provide the opportunity for the study team to incorporate feedback from this group of utility transmission planners into the study scope, assumptions and analysis.

F. Regulatory Context

Electric generation and transmission service is a regulated industry. Care was taken during this study to follow all appropriate regulations. For example, commercially sensitive, non-public market information was handled correctly as related to U.S. Federal Energy Regulatory Commission (FERC) Order 2004 regulations concerning the separation of transmission and resource planning efforts. These standards of conduct are in place to prevent anticompetitive practices between electric transmission providers and their marketing affiliates.

To ensure FERC regulations were enforced and to encourage an open discussion about topics that included potentially market-sensitive information, all members of the OES's Technical Review Committee (TRC) completed a non-disclosure agreement allowing them access to the process and preliminary results.

Transmission-owning utilities that are subject to an OATT like the Midwest ISO tariff are required to provide transmission service on an open-access and non-discriminatory basis. Thus, the MTO does not prejudge and cannot preclude any particular generation source from transmission access within the Midwest ISO's or any other regional transmission organization's footprint. The transmission facilities contemplated by these studies will be available to all generation sources; however, based on generator interest and the Midwest ISO interconnection queue, it appears likely that wind-energy generators make up the substantial majority of likely generators who will use the transmission capability enabled by these facilities.

The study was undertaken in accordance with the North American Electric Reliability Corporation (NERC) Planning Standards. NERC is certified by FERC to be the organization to develop and enforce reliability standards for the bulk power system. The United States electricity industry operates under mandatory, enforceable reliability standards. Utilities and other bulk power industry participants must follow these standards or face fines and other sanctions. The standards describe how reliable systems need to be developed to meet specific performance requirements under normal conditions (TPL-001 or Category A); following the loss of a single bulk electric system element (TPL-002 or Category B); and following the loss of two or more bulk electric system elements (TPL-003 or Category C). The Corridor and RES Update Studies; modeling and analysis followed the standard requirements. Details on NERC standards can be found at http://www.nerc.com/page.php?cid=2|20.

State regulatory review and approval are required in order to construct transmission lines. In Minnesota, two permits are required: a Certificate of Need and a Route Permit. Similar review is required in North Dakota, South Dakota, and Wisconsin. These regulatory timelines are not insignificant, as the process of application preparation, contested cases, and ultimate decision can take as much as two to three years.

G. Schedule

The Corridor and RES Update Studies began their scoping phase in August 2007. Rigorous analytics began in December 2007 and final study results were completed in March 2009.

- From August through November 2007, the MTO comprising the Minnesota Transmission Owners organized a RES Update Study and Corridor Study

project team with a core group of engineers who began identifying roles and responsibilities as well as the initial scope of these studies. The team is composed of engineers that are transmission planning experts.

- The study team began the challenging, three-month initial model building process in January 2008. This public process allowed for significant input to define generation sinks and transmission system model choices. Study concepts were adjusted and transmission options chosen based on the ideas brought to the study team from all stakeholders.
- The public meetings were held in the first and second quarter of 2008 and were attended by members of the TRC, Publics Utilities Commission, and members of the public.
- In March 2008, the study team met to discuss high-level ideas for the Certificate of Need expected to be filed in 2009. Given the significant permitting timeline necessary for bulk transmission upgrade projects, the study team thought it was necessary to start laying the groundwork early. Many recent transmission projects have experienced study and permitting timelines of nearly a decade before ultimately being energized.
- The project team worked with the Midwest ISO to perform the PROMOD analyses with the Corridor Study and RES Update Study new transmission facilities envisioned. This process began in August 2008; initial results were available in late October. Additional PROMOD runs were performed in January and February 2009. For more information regarding PROMOD, refer to Chapter V Section B of this report.
- The preliminary study results of the initial scope were complete in early September 2008 and provided to stakeholders for review and feedback.
- Presentations were made to the area Northern MAPP Subregional Planning Group (SPG) in September and December of 2008, incorporating feedback from interested stakeholders as the study analysis moved forward.
- Upon review of these preliminary results, the decision was made to expand the Corridor study scope in two significant ways to provide more complete information. The first scope change was to conduct a sensitivity to the analysis without the Big Stone II generation and transmission facilities in place. The second modification was to add an examination of the sink to Twin Cities area generation rather than just the Midwest ISO generation market footprint. The transmission system models needed to be modified to support this scope addition. Also, the analysis processes needed to be altered to accommodate the changes. The team conducted this rework from November through February 2009.
- The stability analysis was conducted February through March 2009.
- Sensitivity analysis was run against CapX2020 Group I "upsize" plan between January and March 2009. Loss analysis and constructability issues assessment ran from February through March 2009.

The Corridor and RES Update Studies spanned a nineteen-month timeframe during which adjustments were made as new and better information became

available with regard to generation development, related transmission projects and load forecasting.

III. Models and Assumptions

One of the most vital steps to ensure meaningful output from the study process is to develop an accurate model of the Minnesota transmission system and the greater integrated electric transmission grid for the study timeframe. Great care was also taken to define accurate assumptions of how the system may be built and operated. The TRC and the study team spent a significant amount of time and effort in defining the study assumptions and the transmission modeling process.

The transmission system in Minnesota and the upper Midwest is a complex network of high voltage bulk transmission lines that transfer generation to load centers, lower voltage lines that distribute power among the load centers, and still lower voltage lines that deliver power within cities and to end-use customers. Utilities in Minnesota have a long history of developing projects jointly for mutual benefit. This extends to the study process and the models that are used as inputs to the development of any projects in the state. A concerted effort to produce a model that accurately represented each of the utilities in the state was necessary in order to ensure the integrity of the study work being performed. An example of the complexity of the transmission system model in Minnesota is shown in Table 2, which gives the number of miles of transmission line currently in service in Minnesota.

Table 2 - Miles of Transmission Line in Minnesota[13]

	<100 kV	100-199 kV	200-299 kV	>300 kV	DC	Total
Miles	8,604	4,728	1,895	1,193	436	16,856

The study team examined both load serving ability and transfer capability because the transmission system is in place to carry power transfers across the greater interconnected power grid as well as provide a feeder system for regional power delivery. The transmission system is primarily needed for load-serving ability during summer peak loads and transfer capability during summer off-peak load conditions. To this end, the decision was made to analyze system performance under both summer peak and summer off-peak load conditions.

A. Transmission and Substation Data Collection and Mapping

Below is a discussion of the discrete steps the study team performed to achieve the transmission and transmission substation modeling effort.

[13] Approximate mileage as reported in the MTO's 2007 Biennial Transmission Projects Report filed with the Minnesota Public Utilities Commission on November 1, 2007. For the full text of the report, see the MTO website at http://www.minnelectrans.com.

2016 Transmission System – Base Model Development

2016 was chosen as the year to study and model the transmission system. The in-service date planned for the conversion of the Southwest Twin Cities – Granite Falls Transmission Corridor is currently the end of year 2015. This provides the added transfer capability currently anticipated to be necessary to support generation projects in that time frame. It also is anticipated to be sufficient for Minnesota's utilities to enter into generation projects that satisfy the State of Minnesota's Renewable Energy Standard goal through 2016.

Steady State Transmission System Model

The first step to build the steady state transmission system model was to take data from a known and widely accepted model from Midwest ISO Transmission Expansion Plan 2007 (MTEP07). MTEP07 is a model series encompassing the entire Midwest region's transmission system as well as future transmission expansion plans. It was released in 2007 and provides a series of models that include models for years 2013 and 2018 years. This 2013 model from MTEP07 is the best topology available for Midwest ISO members and is the model employed in other RES Update Studies and the DRG Studies. The model is suitably documented and well understood. In addition, any PROMOD analysis related to this study will be done with the MTEP07 year 2013 PROMOD model, as that PROMOD model is the best available. So there is good compatibility between the steady-state transmission (Power System Simulator for Engineers – "PSS/E") model chosen and the models to be used for PROMOD work.

MTEP07 created 2013 and 2018 peak and off-peak models. Since the study team needed to look at a 2016 timeframe, the team chose to average the loads of the 2013 and 2018 models to create a 2015 ½ load level for study of the year 2016. In this manner, half a year of load growth was built in as a proxy for the impact of the Minnesota Energy Conservation Improvement Plan (CIP) energy conservation assumptions. In the off-peak case, the study team chose a 61% load level that is more recently used to model a typical off-peak summer load.

One limitation of the MTEP 07 model series is the fact that it includes only the Midwest ISO member utility data. There are utilities in this region (and members of the MTO) that are not Midwest ISO members. To ensure the model was inclusive of Midwest ISO member utility information as well as non-Midwest ISO member utility information, the study team took on the challenging task of aggregating the two sets of data. The non-Midwest ISO member data was obtained from the Midwest Reliability Organization (MRO). The MRO is one of eight regional entities in North America that operate under authority from the US and Canada whose focus is ensuring transmission reliability compliance. The MRO builds the models of the utility facilities in this region, including those utilities that are not members of Midwest ISO. The MRO models were available

in 2012 and 2017 versions. A 2015 ½ load level was also created from this initial data set.

The reason the Midwest ISO MTEP 07 model series was chosen as the initial model to build upon was because the study team needed the eastern part of the Midwest ISO footprint to be included in the models for the analysis scenarios in which generation was sunk to the Midwest ISO-wide market. The eastern part of the Midwest ISO footprint is not in the MRO region and therefore is not included in the MRO model.

The next step, transplanting this non-Midwest ISO (MRO) data into the Corridor and 2016 transmission system model, also proved to be quite challenging. Since the study team was using a simulator program called the PSS/E (Power Systems Simulator for Engineering) inputting accurate phase angles was key since they help set the power transfers across lines and transformers. If there is too much difference between a non-transplanted bus and its adjacent transplanted bus, the case will not solve. A bus is a physical electrical interface where many transmission devices share the same electric connection. Each time an MRO area is transplanted into the Midwest ISO model, the model then has to be "nursed" into solving. There is also a possibility that during this process, duplicate or fictitious facilities can be created since bus numbers between models can be inconsistent. Therefore, the model with transplanted information was extensively reviewed for accuracy.

Another detail that complicated the task of transplanting the MRO data was the varying way three-winding transformers are treated in PSS/E. In some instances the three-winding transformers have a PSS/E's built-in construct for such transformers. In other models, the three-winding transformers are depicted the historic way with three explicit branches. Still other three-winding transformers omit the third winding entirely and use PSS/E's construct for two-winding transformers. Therefore, the transformers had to be reviewed for correctness.

Dynamic Models

The base model used for the dynamic stability analysis came from the NORDAGS (Midwest ISO's North Dakota Group Study) Group 1 models. The reasons for choosing this model were that it aligns well with the study timeframe of the year 2015 and is compatible with the NMORWG (Northern Mid-Continent Area Power Pool (MAPP) Operating Review Working Group) stability package. The NMORWG stability package is widely used for MRO and MAPP studies in the upper Midwest area. The NORDAGS model was built from the same base operating model used in the 2006 NMORWG package and updated for the recent System Impact Studies for NORDAGS. The validity of the stability model is also of particular importance because these models have been reviewed and documented quite extensively and their accuracy has been confirmed by utilities throughout the region. After the appropriate model from NORDAGS was

selected, the topology had to be updated along with the corresponding files in the package to make the model used in the steady-state analysis. These changes include updates for the CapX2020 Group 1, BRIGO[14], and RIGO[15] facilities.

Generation Modeling for Base Case

Next, generation source additions needed to be added to depict an accurate 2016 generation picture. The study team used the Midwest ISO Generation Interconnection Queue and other legal requirements to identify reasonably anticipated generation projects that would be online by 2016. The Midwest ISO queue is the process where generation developers' interconnection requests move through a series of studies and tests to achieve interconnection rights with the Midwest ISO transmission system. Because of the significant amount of wind generation projects that maintain favorable queue positions, generation selected for the base case was assumed to be wind-energy generation.

The known transmission projects which will be completed by 2016 and their approximate outlet capabilities are listed in the following table:

[15] The RIGO (Regional Incremental Generation Outlet Study) focused on increasing wind outlet capacity of the transmission system in areas outside the Buffalo Ridge area. This transmission study looked at west-central Minnesota and southeastern Minnesota 115 kV or 161 kV line improvements with an in-service goal of 2011. Since the time models were developed, the number has decreased slightly and is a factor in the range of generation deliverability that will exist by 2016.

Table 3 - Base Case Transmission Projects and Wind Generation Levels

Prior Amount of Renewable Generation	*Project*	*Addition*	*New Total*
265 MW	425 upgrade project	160 MW	425 MW
425 MW	825 upgrade project	400 MW	825 MW
825 MW	BRIGO	375 MW	1200 MW
1200 MW	Twin Cities – Brookings CapX2020 project	700 MW	1900 MW
1900 MW	RIGO	922 MW[16]	2822 MW

B. Assumptions

Since the performance of any bulk electric system is significantly affected by the power transfers across it, the study team recognized that the model would have to reflect existing firm transfers, new energy transfers, and possibly some non-firm transfers (to allow for the growth of future firm transfers).

As a starting point, the team decided to model only firm transfers in the on-peak models. This choice reflects the realistic way the system operates since often non-firm transfers are not available during on-peak load periods since each utility's generation must serve its native load.

The impact on the Minnesota transmission system imports and exports were assumed to be just as important as the flows from new generation sources. Therefore, another assumption the study team agreed upon to realistically depict off-peak models was to model the highest transfers able to be simultaneously supported on three vital interfaces: the North Dakota Export (NDEX) and the Manitoba Hydro Export (MHEX) and the Minnesota-Wisconsin Export (MWEX).

The transmission models have generation units with power outputs that when combined exactly match the load in the model plus the system power losses. This balance between generation and load plus losses must always be maintained in models as well as in the real electric system. Thus, when new generation is added to the model, either the load must be increased to compensate for the new generation or existing generation must be turned down. The new generation is called the 'source' or the location point of the new generation and the existing generation to be simultaneously turned down to keep

[16] At the time the project models were being developed, the RIGO study was underway and outlet was assumed to be approximately 922 MW. Since this time the RIGO project has been refined, and this outlet level has since been reduced as project financing decisions were finalized. This adjustment is reflected in the final range of deliverability expected with the Corridor upgrade.

the system balanced is the 'sink'. The magnitude of the 'source' is equal to that of the 'sink' plus the losses in the electrical system.

The study team decided to look at two different sink assumptions to assess future transmission needs. One view was to assume the power would be delivered only to greater Twin Cities Metro Area. The other view was to look at a dispatch option for the entire Midwest ISO footprint based on merit order of generation. Merit order of generation is the operational methodology of turning down more expensive generation when the newer (typically less expensive) generation is ramped up on the system.

Since it is currently unknown whether or not the Big Stone II generating plant[17] will be built, the study team needed to determine how to treat this area with respect to model building. The assumption is that the capacity reflected in the Big Stone II's generation plant's Midwest ISO queue position was assumed to be used by either the Big Stone II generating plant or an equivalent amount (MW) of other generation. Regardless of the status of the Big Stone II project, a large amount of generation is proposed to be built in the immediate vicinity of the Big Stone plant. The Midwest ISO queue showed more than 1000 MW of wind generation requests in a close proximity to Big Stone substation.

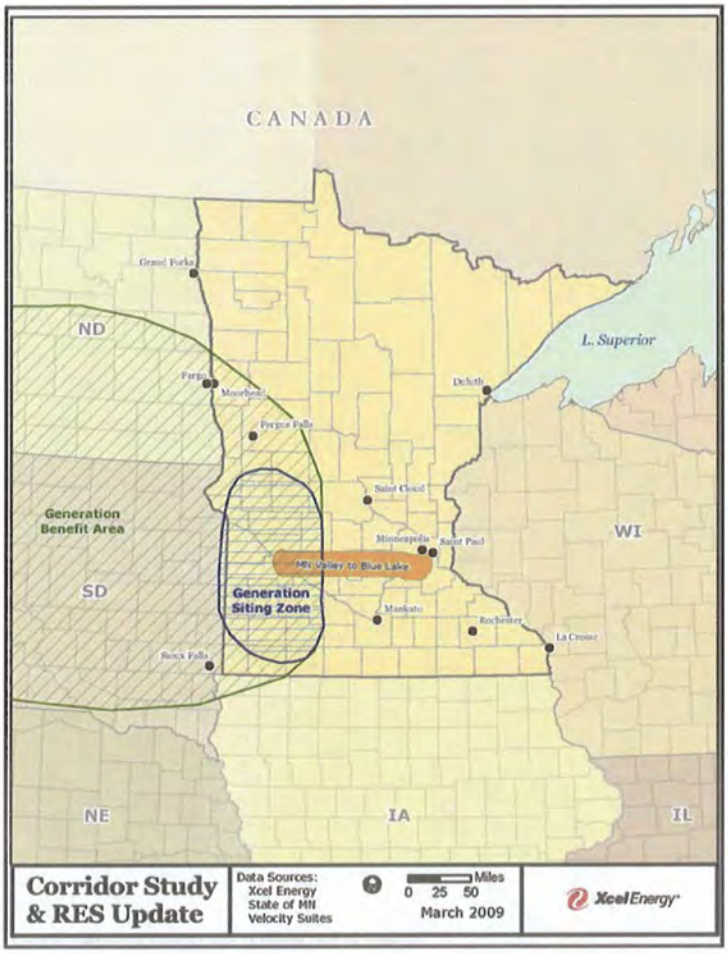
Any type of significant generation near Big Stone II will require a 345 kV connection to Hazel Creek Substation, north of Marshall, Minnesota to tie into the corridor facility and deliver the generation customers in Minnesota. This has been shown with the Big Stone II studies, and a 345 kV line from Big Stone to Hazel Creek is one of the facilities proposed for outlet of the plant.

The study team conducted the analysis without Big Stone II generation and transmission facilities in place to test sensitivities and maintained an end goal of recommending a facility which will provide transmission capability to assist utilities in meeting the Minnesota 2016 milestone regardless of the status of Big Stone II generation or transmission facilities.

Figure 2 shows the area in which generation was sited for the Corridor Study. The area in which generation will benefit from the Corridor Upgrade is overlaid.

[17] Big Stone II is a power plant proposed to be built in South Dakota.

Figure 2 - Corridor Study Generation Siting vs. Generation Benefit Area



At this point the two study teams conducted separate analyses to achieve their different objectives.

IV Corridor Study Details

A. Corridor Study Purpose

The Corridor Study purpose was to verify the status as a key "next limiter" and determine the most effective use of the existing 230 kV transmission corridor from Granite Falls, Minnesota to the southwest Twin Cities to maximize generation delivery from the area shown in Figure 2 above to the Twin Cities. By resolving this limiter, additional transmission capacity would be available for generation from the west, including generation needed by utilities to meet the RES obligations.

B. Corridor Study Analysis

The Corridor Study team began with the common base model and assumptions developed for both the Corridor Study and RES Update Study. The study team analyzed system performance for both summer peak and off-peak load conditions. The newly proposed facilities were tested to carry existing firm transfers, new energy transfers, and non-firm transfers (to allow room for growth of future firm transfers and non-firm transfers to better allow the best economic use of the generation in the area).

The study team worked with the Midwest ISO to perform the PROMOD (production cost model) analyses to determine two primary results –

(1) the transmission plans studied would be sufficient to allow the Minnesota load-serving entities to meet the applicable milestones in the Renewable Energy Standard legislation and

(2) the economic benefit of the new transmission would reduce average generation costs to end-use customers.

Steady State Simulations

The primary method of analysis for the steady-state (power-flow) simulations was the use of AC contingency analysis in PSS/E (PSS/E is a computer program capable of simulating the steady-state [power-flow] and dynamic performance of the electric system [loads and transmission lines and generators and transformers]. It is used to simulate the system response after outage of transmission or generation facilities).

Power flow analysis under system-intact and outage conditions was done to determine the effect on the electric system of adding the Corridor Study options, one at a time. The analysis simulated approximately 7,000 contingencies. This type of analysis determines the criteria violations caused by the generation additions and transmission options studied.

Dynamic Simulations

The primary method of analysis of the dynamic performance of the Corridor Study options was the use of PSS/E's dynamic simulation routines.

PROMOD Simulations

The study team worked with the Midwest ISO to perform analyses that tested the performance of the proposed facilities within the market dispatch. Short for PROduction MODeling, PROMOD is a software package developed by Ventyx that is capable of modeling the performance of the generation market. It can factor in transmission constraints, manipulate generation dispatch to avoid

overloading constrained transmission interfaces, and minimizes the generation cost to do so.

PROMOD is a highly data-intensive program. A small selection of the type of information that is necessary to conduct an effective PROMOD study is data such as fuel charges, fuel consumption rates for individual generators, possible generation increments for individual generators, and the startup time, shutdown time, and individual unit ramp rates for any generators that participate in a given market dispatch.

In addition, PROMOD is also a highly processor-intensive program. Given the amount of confidential, market-sensitive information that is used in a PROMOD run, Midwest ISO engineers are widely regarded as having some of the best-available production modeling information in the Midwest. For this reason, their assistance was sought to ensure the PROMOD study was conducted with the best information available.

The PROMOD analysis for the RES Update Study facilities was conducted with the preferred Corridor facilities in service to ensure the most accurate post-project simulations occurred.

The results of this PROMOD analysis can be found with detailed project information in this report, as well as in the Corridor and RES Update Study Technical Reports.

C. Corridor Study Key Findings

Corridor Upgrade Transmission Capacity

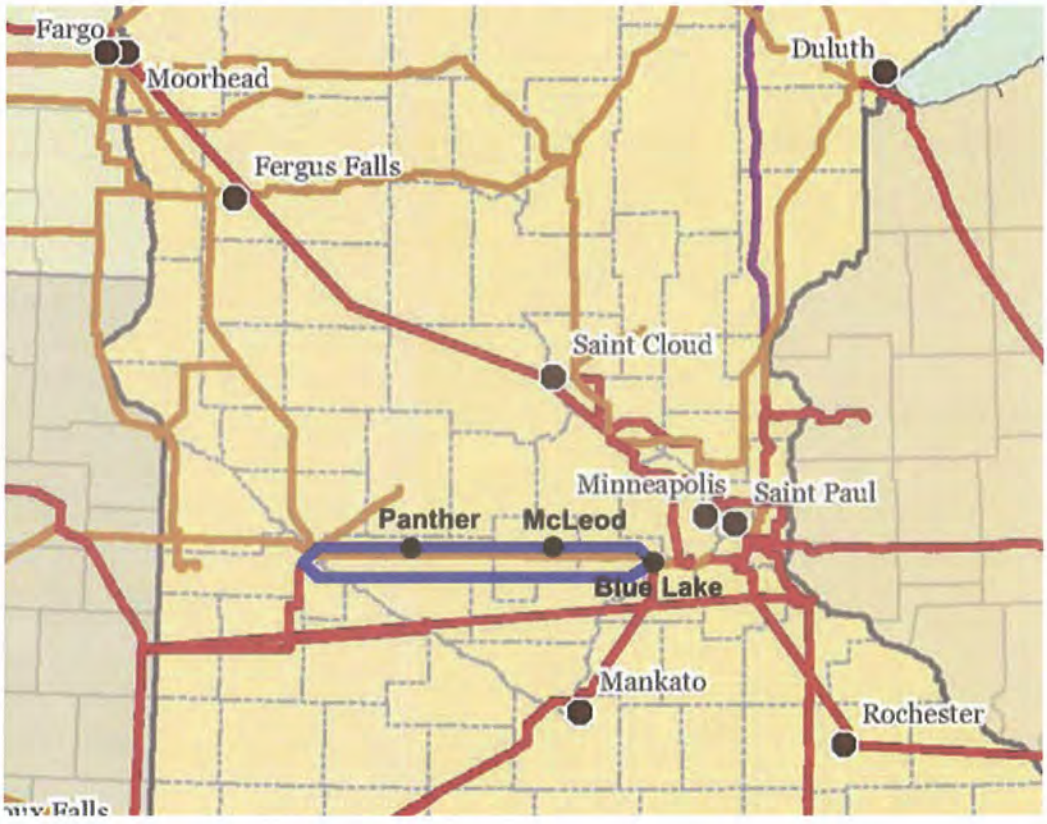
One key finding of the Corridor study is that upgrading the existing transmission corridor to double-circuit 345 kV from Granite Falls, Minnesota to the southwest Twin Cities will provide the necessary transmission capacity to provide additional transmission capacity from the west to the Twin Cities and should be sufficient for utilities to acquire generation projects to satisfy the 2016 Minnesota RES milestones. This upgrade works well to facilitate serving Minnesota load with generation located west of Marshall in southwest Minnesota, as well as to the north, into the eastern Dakotas.

The transmission system upgrade endpoints were clarified through study findings and verified by the RES Update Study results. The two termination end points are the Hazel Creek Substation near Granite Falls, Minnesota to the west and the Blue Lake Substation in Shakopee, Minnesota to the east. The Hazel Creek substation is a proposed substation that is being built in conjunction with the BRIGO facilities and will also be utilized by the Twin Cities – Brookings 345 kV transmission project that is currently being permitted.

In addition, the analysis showed that this upgrade of the Hazel Creek to Blue Lake 230 kV line to a 345 kV double circuit is a pre-requisite to utilizing additional capacity for two CapX2020 lines. Study results showed the existing Minnesota Valley – Blue Lake 230 kV line limits the ability to transfer energy along the Twin Cities – Brookings line and the Twin Cities – Fargo line. Therefore, whether or not the CapX2020 Group I lines are upsized, these lines cannot make use of their full energy carrying capability without the Corridor Upgrade.

The Corridor study team also assessed the necessary supporting projects to enable full realization of the upgrade benefits. The study results determined the approximate range of capacity or energy carrying capability likely created through installation of the corridor upgrade and supporting project. This assessment is expressed as a range since many outside influences can affect the actual results.

Figure 3 - Core 345 kV Corridor Project Map



Corridor Upgrade Project Description

The blue lines in Figure 3 represent the recommended new facilities to upgrade the 230 kV transmission line to a double-circuit 345 kV line from Hazel Creek Substation, near Granite Falls, Minnesota, to Blue Lake Substation, in Shakopee, Minnesota.

- One of these circuits is an "express" line from Hazel Creek – Blue Lake, which means the transmission line does not have any interconnections at substations along the way and does not serve any other load along the way.
- The other circuit of the double circuit upgrade has interconnections going in and out at both the Panther Substation in Renville County, Minnesota and McLeod Substation near Hutchinson, Minnesota to replace the interconnections to the existing 230 kV line.
- A supporting project necessary to fully realize the Corridor Upgrade's benefits is replacing the existing Hazel Creek – Minnesota Valley 230 kV line. This project is proposed to be completed as part of the Twin Cities – Brookings 345 kV line project.
- Another supporting project is removing existing 230 kV facilities at McLeod and Panther.

D. Corridor Study Associated Observations

As generation in the green benefit area displayed in Figure 2 is delivered to load centers to the east, including the Twin Cities metro area, the existing 230 kV line from Minnesota Valley to Blue Lake is overloaded, therefore limiting the deliverability of the generation. This overload is an issue for both meeting the 2016 RES milestone and to reliably utilizing the entire Midwest ISO operational footprint.

Transmission Grid in Western Wisconsin

One observation is that the transmission grid in western Wisconsin, along with interface loading levels along the Minnesota-Wisconsin border, limits the ability to deliver more generation from Minnesota and points further west.

Currently there is a joint transmission planning study underway to determine the need for a new transmission line from La Crosse, Wisconsin to an endpoint in the Madison area. The study is addressing the long-term load serving support for the western portion of Wisconsin. This study is being led by American Transmission Company (ATC) with participation from other area utilities, including MTO members Xcel Energy, Great River Energy, ITC Midwest, Southern Minnesota Municipal Power Agency, and Dairyland Power Cooperative. Completion of the study is expected in 2010.

Generation Siting

Another observation is that the actual amount of generation delivery capability gained by the Corridor upgrade will be determined by the actual location of future generation development. To the extent that actual generation development differs from that which was studied, the actual outlet capacity achieved by this system addition may either increase or decrease. The study team selected likely

generation development sites based on the best resources available, such as the Midwest ISO generation interconnection queue[18] and utility resource planners in order to provide a reasonable range of results.

The study team met with transmission utility resource planners to gather information about future generation locations and generation capacity amounts. The resource planners provided maps and helped the study team choose new generation sources and placement. The Distributed Renewable Generation (DRG) Transmission Study Phase I[19] team also provided information for potential generation site selection. The study team reviewed the DRG Phase I site scan in combination with the Midwest ISO and WAPA (Western Area Power Administration) generation interconnection queues to decide where to place the generation. The net result is a list of potential generation locations that represent conceptual future locations as reasonably as possible.[20]

[18] The Midwest ISO (Midwest Interconnected Transmission System Operator) queue is the process where generation developers' interconnection requests move through a series of studies and tests to achieve generator interconnection rights with the Midwest ISO transmission system.
[19] The DRG Study can be found at http://www.state.mn.us/portal/mn/jsp/content.do?subchannel=-536881736&programid=536916477&sc3=null&sc2=-536887792&id=-536881351&agency=Commerce
[20] It is important to note that siting generation locations on high voltage buses has the same net effect to the system as spreading the generation around numerous lower voltage buses. Generation sited at higher voltage buses will offset flows through the transmission grid to the local lower voltage system. In addition, the DRG Study verified that power generated on the lower voltage system makes its way to the high voltage system and impacts the higher voltage transmission grid.