LARGE POWER INTERVENORS

Utility Information Request

Docket Numbers: E015/CN-22-607; E015/TL-22-611 Date of Request: November 7, 2023

Requested From: Minnesota Power Response Due: December 1, 2023

By: Large Power Intervenors (Andrew P. Moratzka, Amber S. Lee)

Information Request No. 3

Refer to page 11 of the Certificate of Need Application where the following is stated: "Given the long-term significance of the HVDC Line for Minnesota Power and the region, design options to accommodate future expansion are a major consideration for the Project. The new voltage source converter ("VSC") HVDC Converter Stations will be designed with a flexible, scalable approach that will enable their future expansion to accommodate bulk regional transfers of renewable energy. Minnesota Power is working with the HVDC supplier to procure the most current capacity and technology for the new VSC Converter Stations, as well as additional expandability features to enable staged development of additional HVDC capacity to meet future regional needs."

a. Please explain in detail the long-term significance associated with the HVDC Line for Minnesota Power. In your response, please expound upon the "additional expandability features," and the "staged development" referenced and include a timeline of the expansion.

b. Please explain in detail the long-term significance associated with the HVDC Line for the region. In your response, please expound upon the "additional expandability features," and the "staged development" referenced and include a timeline of the proposed expansion.

c. Please describe in detail how Minnesota Power's proposed Project will benefit bulk regional transfers of renewable energy and to meet future regional needs.

Response:

a. The Square Butte HVDC Line has served Minnesota Power customers with reliable, economic energy for over 45 years. While developing the Project, as described in Chapter

---

Response by: Peter Schommer

Title: Manager – Power Delivery & Asset Management

Department: Transmission

Telephone: 218-355-2639

LARGE POWER INTERVENORS

Utility Information Request

Docket Numbers: E015/CN-22-607; E015/TL-22-611 Date of Request: November 7, 2023

Requested From: Minnesota Power Response Due: December 1, 2023

By: Large Power Intervenors (Andrew P. Moratzka, Amber S. Lee)

2.0 of the CON/RP Application and taking into consideration the reasons described in Chapter 3.0, the HVDC Line plays a major role in continuing to deliver reliable, economic and clean energy from Minnesota Power's zero fuel cost North Dakota wind energy. With this Project, Minnesota Power has an opportunity to build for a future that consists of more clean energy as we execute the State of Minnesota's 100% carbon free by 2040 standard. This Project includes the replacement of the HVDC terminals and, due to the nature of the HVDC equipment, the Project will provide additional capacity for the converters. When the Project is complete, the new HVDC converter terminals will be capable of transferring up to 1500MW (although the HVDC Line will not be capable of this transfer without modifications to the HVDC Line). Furthermore, the layout of the HVDC converter stations will be designed such that it will be straightforward to add another converter to operate a second 1500MW HVDC pole, similar to the way the current bipole system operates, creating the potential to increase the total capacity up to 3000MW. Even after the initial converter station replacement, the existing HVDC Line itself will limit the capacity of the system to its present capacity or, with targeted transmission line upgrades, up to 900MW to serve Minnesota Power's needs. Over the next several years Minnesota Power will continue to evaluate the needs of its system and resources and be engaged with the MISO Long Range Transmission Planning effort to determine when and if the HVDC Line will be upgraded to 1500MW or more. There is no defined timeline for these decisions currently.

b. The Square Butte HVDC Line has also served the region with benefits such as dynamic response for specific fault conditions, congestion management, and frequency stabilization. The VSC technology offers several more system support benefits described in Section 3.3.2 of the CON/RP Application. Just as Minnesota Power continually evaluates the needs of our customers, the regional planning entities such as MISO continually evaluate the needs

---

Response by: Peter Schommer

Title: Manager – Power Delivery & Asset Management

Department: Transmission

Telephone: 218-355-2639

LARGE POWER INTERVENORS

Utility Information Request

Docket Numbers: E015/CN-22-607; E015/TL-22-611 Date of Request: November 7, 2023

Requested From: Minnesota Power Response Due: December 1, 2023

By: Large Power Intervenors (Andrew P. Moratzka, Amber S. Lee)

---

of the region in a changing resource environment. In its Renewable Integration Impact Assessment ("RIIA") study, MISO found that there was a long-term need for VSC HVDC projects to achieve renewable penetration levels consistent with clean energy goals. In its recent Long Range Transmission Plan ("LRTP") study, MISO has begun to identify and develop a justification for the specific projects necessary for the clean energy transition. From the beginning of the LRTP process, MISO has shown several high-capacity HVDC connections on its long-term indicative roadmap, including one that overlaps the Square Butte HVDC corridor. Since the beginning of 2023, MISO has been working with stakeholders to identify the assumptions, technologies, issues, and potential projects for its second tranche of LRTP projects. The stakeholder process has included significant discussions about HVDC technology and MISO appears to have recognized the likely need for HVDC projects to be considered in LRTP Tranche 2. Minnesota Power has made MISO aware of the expandability considerations for its planned VSC HVDC converters as detailed in the response to subpart (a) for MISO's consideration as they evaluate needs and alternatives for the LRTP Tranche 2 portfolio. At this time, MISO is still in the process of developing models for the LRTP Tranche 2 study and it is too early to say whether specific projects will be a part of the LRTP Tranche 2 portfolio or not. The LRTP Tranche 2 portfolio is expected to be approved by the MISO Board in mid to late 2024. For projects included in LRTP Tranche 2, it is expected that the in-service dates of the projects will be targeted for approximately 2035-2040.

c. The HVDC Modernization Project as proposed by Minnesota Power serves the renewable energy transfer needs of Minnesota Power's customers. The additional expandability features discussed in the response to subpart (a) have been included by Minnesota Power to position the HVDC facility to also meet future regional needs for bulk renewable energy transfers, in much the same way as an AC transmission line may be intentionally designed

---

Response by: Peter Schommer

Title: Manager – Power Delivery & Asset Management

Department: Transmission

Telephone: 218-355-2639

LARGE POWER INTERVENORS

Utility Information Request

Docket Numbers: E015/CN-22-607; E015/TL-22-611 Date of Request: November 7, 2023

Requested From: Minnesota Power Response Due: December 1, 2023

By: Large Power Intervenors (Andrew P. Moratzka, Amber S. Lee)

---

with the capability to add a second circuit for future use. The MISO Generation Interconnection Queue as of 11/07/2023 shows 28 projects consisting of 6,723MW of wind when filtering for North Dakota active projects. Furthermore, the MISO West region has 200 active projects adding up to 35.27GW. If those projects are to come to fruition to support clean energy and carbon reduction goals, more transmission must be built to get the energy delivered to the loads across the system. Increasing the capacity of the existing HVDC Line is one potential solution to do just that but is one part of the larger picture, as the MISO LRTP indicative roadmap illustrates. With future upgrades, the HVDC Line could help transport up to 3000MW of renewable energy from Central and Western North Dakota to Minnesota, Wisconsin, and beyond. Several of the states in the region have renewable or carbon free goals and the HVDC Line can help reach those goals.

Response by: Peter Schommer

Title: Manager – Power Delivery & Asset Management

Department: Transmission

Telephone: 218-355-2639

LARGE POWER INTERVENORS

Utility Information Request

Docket Numbers: E015/CN-22-607; E015/TL-22-611 Date of Request: November 7, 2023

Requested From: Minnesota Power Response Due: November 17, 2023

By: Large Power Intervenors (Andrew P. Moratzka, Amber S. Lee)

Information Request No. 4

Does Minnesota Power's current proposal contemplate increasing the capacity of the HVDC line itself? If so, please provide the following associated with expanding the capacity of the line.

a. Cost estimates;

b. Timeline;

c. All approvals and permits required; and

d. Whether the expansion stages will be competitively bid.

Response:

For clarification, the existing HVDC converter terminals limit the overall system to 550 MW, not the HVDC transmission line. The upgrade of the HVDC line to 900 MW is described in the 2023 Biennial Transmission Projects Report filed, and available publicly, in Docket No. E999/M-23-91 as MPUC tracking number 2013-NE-N17. The analysis of 2013-NE-N17 is provided in the 2023 Biennial Transmission Project Report. The Company is evaluating what approvals and permits may be necessary for project 2013-NE-N17. Minnesota Power will follow its standard procurement process as required for the project, if it proceeds.

The project identified with this Certificate of Need does not require additional time, permits, or upgrade of the HVDC transmission line beyond what is described in the Application.

Response by: Peter Schommer

Title: Manager - Power Delivery and Asset Management

Department: Power Delivery Engineering

Telephone: 218-355-2639

LARGE POWER INTERVENORS

Utility Information Request

Docket Numbers: E015/CN-22-607; E015/TL-22-611 Date of Request: November 7, 2023

Requested From: Minnesota Power Response Due: November 17, 2023
Extension Granted to: December 8, 2023

By: Large Power Intervenors (Andrew P. Moratzka, Amber S. Lee)

Information Request No. 5

Please provide all Company communications with MISO regarding this Project.

Objection:

Minnesota Power objects to this information request as overly broad and unduly burdensome. Notwithstanding and without waiving this objection, Minnesota Power is providing all presentations or reports delivered to MISO related to the HVDC Project prior to the filing of the Application with the Minnesota Public Utilities Commission.

Response:

Please see the attached documents:

- LPI IR 005.01 Attach: *2022.06.09 MP-MISO HVDC Discussion.pdf,* Minnesota Power update to MISO on planning for the HVDC Modernization Project.
- LPI IR 005.02 Attach: *2022.10.17 MP Response to MISO Concepts.pdf,* Minnesota Power presentation during a meeting of MISO and Minnesota-Dakotas-Wisconsin Transmission Owners on the scope of LRTP Tranche 2.
- LPI IR 005.03 Attach: *2023.01.17 MP-MISO Meeting*, Minnesota Power meeting with MISO to provide an update on planning for the HVDC Modernization Project and discuss the status of the LRTP Tranche 2 study. Please note that information discussing a project that is not the HVDC Modernization project has been redacted due to relevance.

Response by: Christian Winter
Title: Manager-Regional Transmission Planning
Department: Delivery Support Operations
Telephone: 218-355-2908

As to Objection: David Moeller
Title: Senior Regulatory Counsel
Department: Legal
Telephone: (218) 723-3963

LARGE POWER INTERVENORS

Utility Information Request

Docket Number: E015/CN-22-607; E015/TL-22-611 Date of Request: November 7, 2023

Requested From: Minnesota Power Response Due: November 17, 2023
Extension Granted to: December 8, 2023

By: Large Power Intervenors (Andrew P. Moratzka, Amber S. Lee)

- LPI IR 005.04 Attach: *2023.03.09 VSC HVDC vs 765kV AC_Draft Summary.pptx,* Minnesota Power, American Transmission Company, and MISO discussion on HVDC modeling and technology considerations for LRTP Tranche 2.
- LPI IR 005.05 Attach: *Square_Butte_HVDC_Upgrade_Facilities_Study_F118.pdf,* Minnesota Power Facilities Study Report for MISO Transmission Service Requests on the HVDC Line.
- LPI IR 005.06 Attach: *2023.05.31 MP-RBJ VSC-HVDC,* Minnesota Power and RBJ Engineering presentation during MISO Planning Advisory Committee stakeholder workshop on technology considerations for LRTP Tranche 2.

Response by: Christian Winter
Title: Manager-Regional Transmission Planning
Department: Delivery Support Operations
Telephone: 218-355-2908

As to Objection: David Moeller
Title: Senior Regulatory Counsel
Department: Legal
Telephone: (218) 723-3963

minnesota power
AN ALLETE COMPANY

Square Butte HVDC

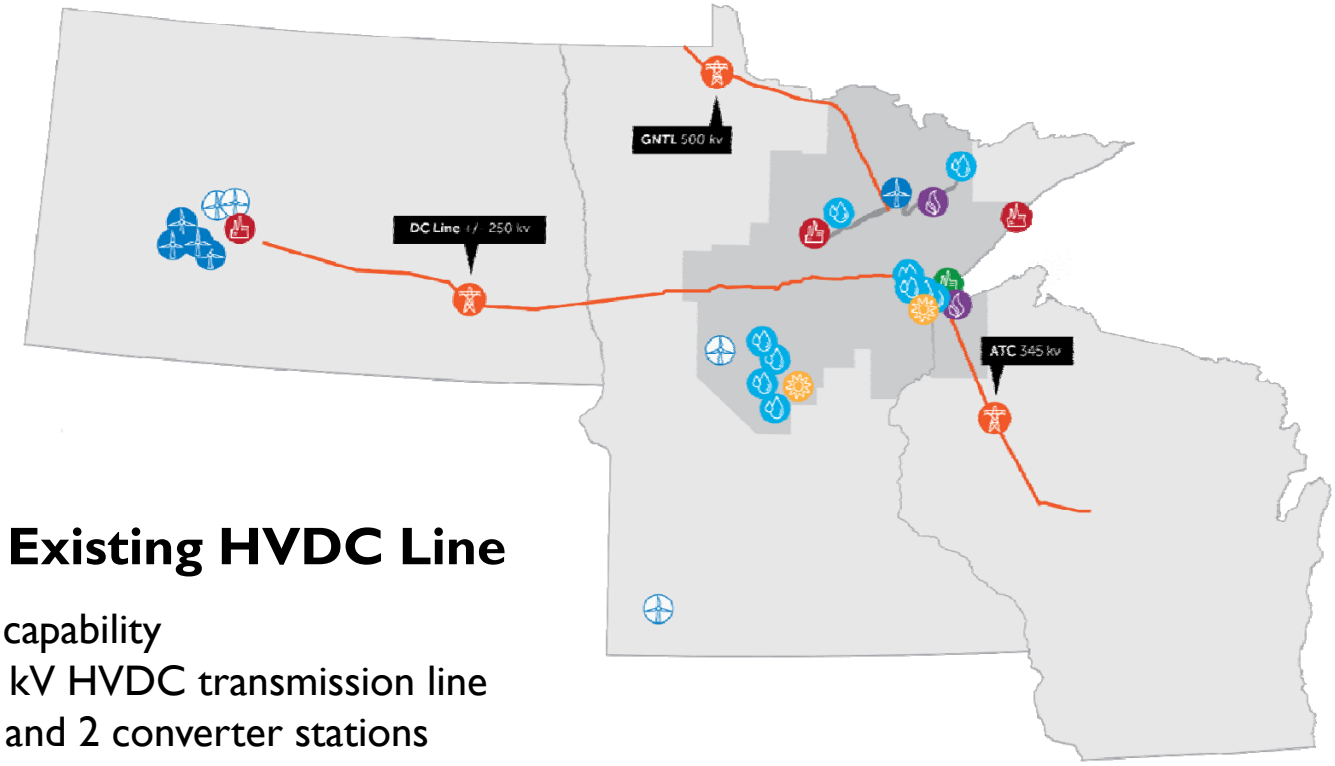
Upgrade & Modernization Planning Update

MP-MISO DISCUSSION
June 9, 2022

CONFIDENTIAL: FOR MP & MISO DISCUSSION PURPOSES ONLY

minnesota power
AN ALLETE COMPANY

The Square Butte HVDC Corridor:
A Foundation for the Clean Energy Future



By the numbers: Existing HVDC Line

- 550 MW of existing capability
- 465 miles of +/- 250 kV HVDC transmission line
- 3200 line structures and 2 converter stations
- Put in service in 1977 to deliver "coal by wire" from ND coal fields to MP customers in NE Minnesota
- Acquired by MP in 2009 and repurposed to deliver wind and valuable energy to MP customers
- It is in need of modernization and has multiple potential opportunities to upgrade

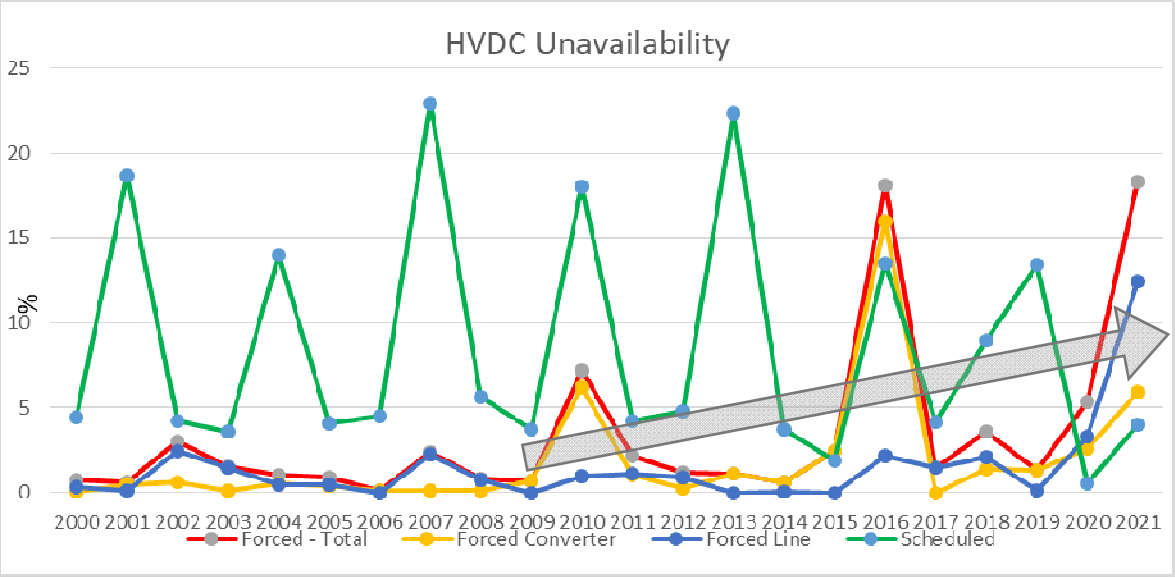
When it was originally commissioned, Square Butte was the first long-distance project in North America to implement 12-pulse thyristor technology

minnesota power
AN ALLETE COMPANY

HVDC Modernization Urgency

Converter Station Modernization & Asset Renewal Needs

- **Control System:** Last upgrade was 2004, and those computer systems and components are now failing. Could result in an extended single pole outage, cutting HVDC capacity in half.
- **Power Modules:** Original pulse transformers no longer produced or supported by any manufacturer. Design specs destroyed/lost when GE originally exited from HVDC business. Limited spares available, and when we run out we will be in extended single pole outage.
- **Converter Transformers:** Three failures in last seven years, often associated with wear and tear caused by LTC operations. Limited refurbishment options. Failures more likely to be catastrophic and cause collateral damage. Could result in loss of one or both poles for an extended period of time depending on failure mode.



Forced outage rates are generally increasing, even as MP continues to diligently maintain the Square Butte HVDC system

minnesota power
AN ALLETE COMPANY

HVDC Upgrade Project Goals

1. **Modernization:** Address asset renewal needs by replacing existing converter stations ASAP

2. **Optimize Capacity:** Design converters to optimize capacity of existing HVDC transmission line. Max capacity for existing conductor on majority of line (2839 ACSR) is 900 MW

3. **Long-Term Technology:** Implement converter technology that does not become obsolete or un-upgradeable prior to normal end-of-life (35-40 years)

4. **Future Proof:** Robust to navigate changes in the surrounding transmission system, particularly for weaker transmission systems with high penetration of inverter-based resources

5. **Performance Features:** Self-sufficient in reactive power requirements, bi-directional dispatch capability, smooth & continuous control range, sub-hourly dispatchability, blackstart capable

6. **Expandability:** Designed to meet present maximum capacity (900 MW) with staged or modular expansion to meet future regional needs (3000 MW)

How to Develop a Solution?

Minnesota Power brought in RBJ Engineering to develop a robust HVDC Technology Assessment and recommendations on optimal near/term long-term solutions

RBJ RBJ Engineering Corporation

HVDC Technology Assessment

1. **Development of Configurations:** Four basic configurations were developed by RBJ Engineering for investigation in the tech assessment:
   A. Initial 1500 MW Symmetric Monopole VSC with Future Expansion to 3000 MW Bipole
   B. Initial 1500 MW Bipole VSC with Future Expansion to 3000 MW Bipole
   C. Initial 900 MW Non-Expandable Bipole VSC with Future 3000 MW Bipole #2 Addition
   D. Initial 1500 MW Bipole LCC with Future Expansion to 3000 MW Bipole
   More information on each configuration is provided in Appendices

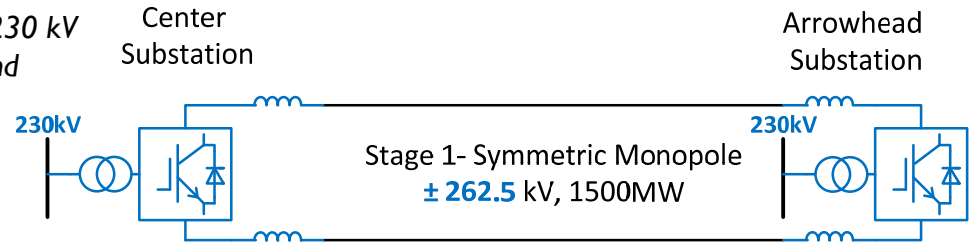
2. **Supplier Workshops:** A questionnaire with 40 specific questions was developed to accompany the configurations and three major suppliers – Siemens, Hitachi, and GE – were invited to join MP & RBJ for individual one-day technical workshops to discuss the questionnaire and configurations. Suppliers were also asked to respond in writing to the questionnaire, propose modifications or alternatives to the basic configurations, and provide indicative pricing for the initial and future stages of each configuration.

3. **Technology Assessment Report:** Following the supplier workshops, RBJ Engineering produced a detailed evaluation of technology options, configurations, performance and cost considerations, including recommendations for a preferred configuration.

Preferred Expandable Solution
Expandable Symmetric Monopole

Relocate & replace existing converter stations with one 525 kV half-bridge VSC converter on each end, operated as a +/- 250 kV symmetric monopole using the existing HVDC line. Converter designed for 1500 MW capacity, operated initially at 900 MW or less based on line capacity limit. At this stage, Square Butte is converted to a single 900 MW HVDC line.

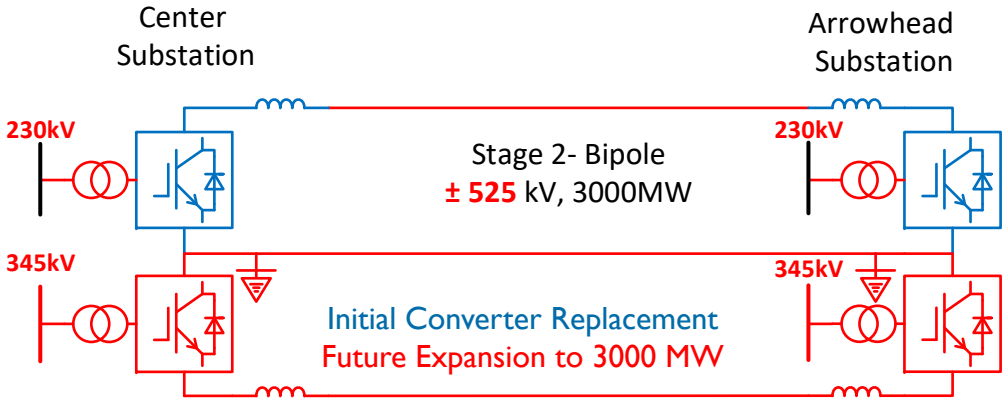
Initial AC interconnection voltage can be either 230 kV or 345 kV and can be different for each end



Expandability Options

I. Rebuild & reconductor existing HVDC line (465 miles) for 3000 MW capacity and +/- 525 kV bipole operation. Operate initially as a 1500 MW symmetric monopole (as shown above)

II. Add a second set of 525 kV converters on each end and modify existing 525 kV converter to operate as +/- 525 kV bipole HVDC with total capacity of 3000 MW (1500 MW per pole)



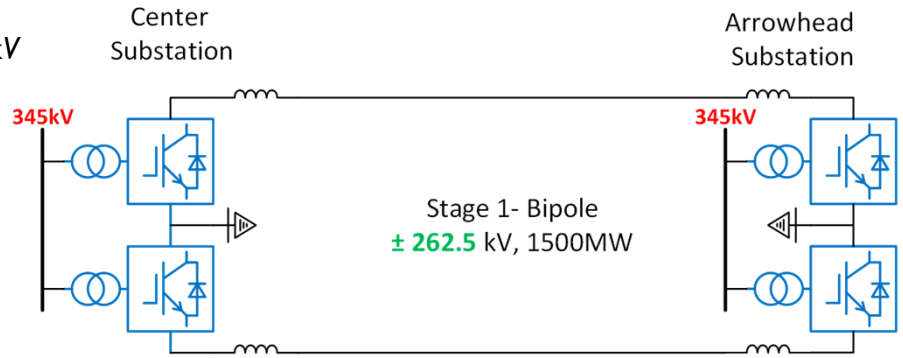
Initial converter preferably stays connected to same AC bus (230 kV or 345 kV) Future converter interconnects at 345 kV to tie in with complementary regional transmission.

HVDC control system and transmission line can be designed with future multi-terminal operation in mind, but HVDC suppliers generally discouraged multi-terminal

Alternative Expandable Solution
Expandable Bipole

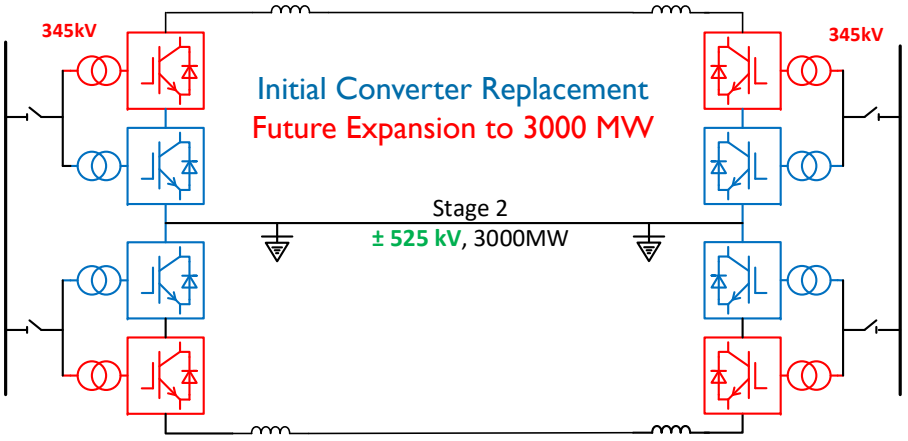
Relocate & replace existing converter stations with two 262.5 kV converters on each end, operated as a +/- 250 kV bipole similar to today's configuration. Initial bipole designed for 1500 MW capacity, operated initially at 900 MW or less based on line capacity limit.

Initial AC interconnection voltage can be either 230 kV or 345 kV and can be different for each end



Expandability

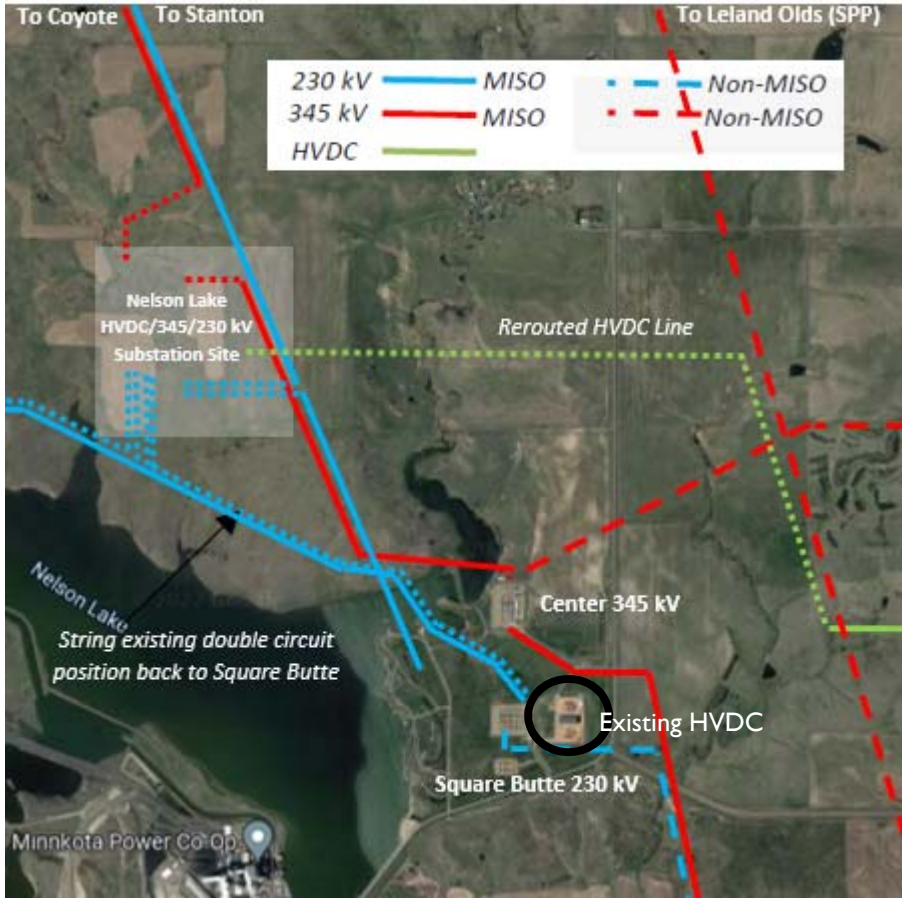
The most straightforward way to expand the bipole configuration is to add a second set of series-connected converters in each pole, located in adjacent buildings, to extend it to +/- 525 kV and 3000 MW total. This configuration may drive a preference for full-bridge converters.



Additional buildings, transformers, control system equipment, and potentially full bridge converters all drive up the cost and complexity of this configuration significantly

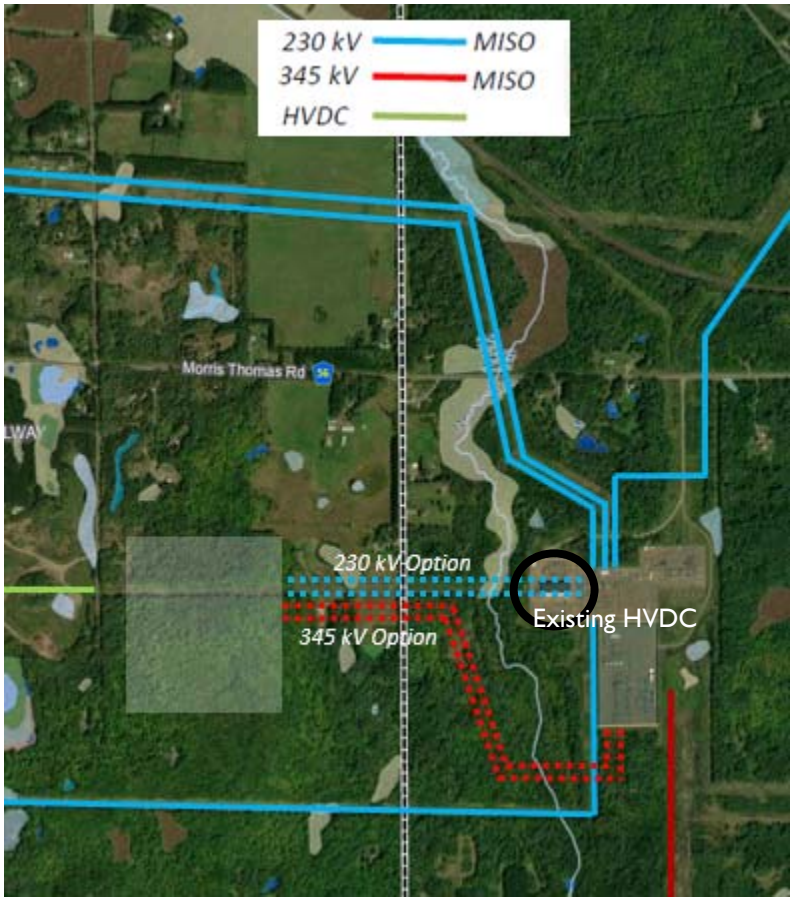
minnesota power
AN ALLETE COMPANY

Converter Station Relocations



North Dakota: Nelson Lake Substation

Relocate converter & HVDC line to north side of Nelson Lake, tie in existing 230 kV system. Opportunity to bridge MPC seams that cause issues for MP, GRE, and OTP. Space for future 345 kV expansion to facilitate regional transmission network development.



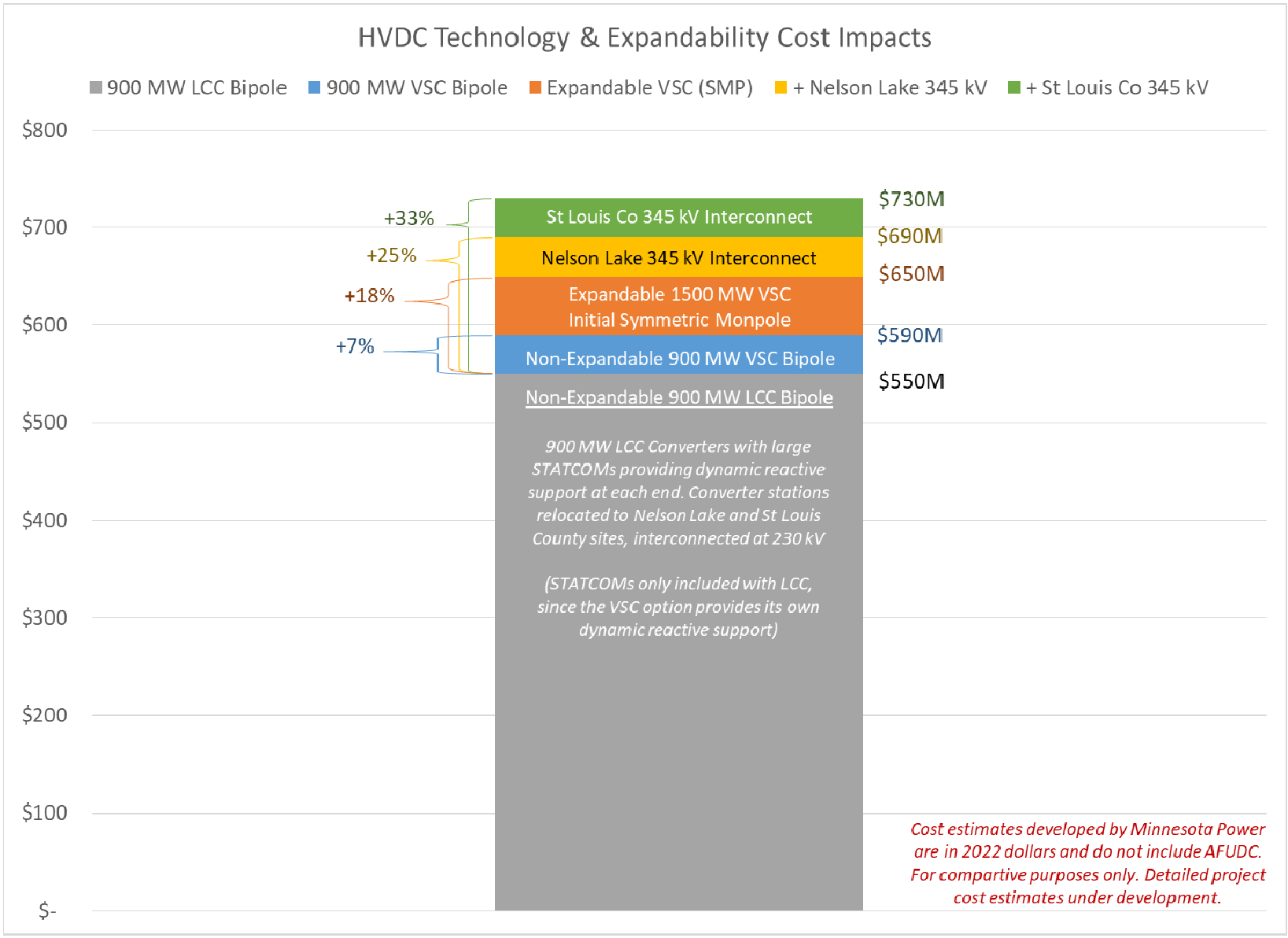
Minnesota: St Louis County Substation

Relocate converter just west of Arrowhead Substation, tie in to existing Arrowhead 230 kV or 345 kV bus. Space for future 345 kV expansion to facilitate regional transmission network development. (Existing Arrowhead Substation has limited expandability)

minnesota power
AN ALLETE COMPANY

Cost Implications of Expandability

Confidential: For MP & MISO Discussion Purposes Only



UMEX & LRTP Coordination

Moving Forward

MP has an urgent need to modernize the existing HVDC converters and is making plans to move forward with the converter station upgrades later in 2022. The project is being branded "Upper Midwest Express" (UMEX) and will be developed to meet MP's near-term needs, incorporating expandability only to the extent the incremental costs can be justified or offset. Anticipated best possible in-service date is 2027 based on HVDC supplier leadtimes.

How Should MP Coordinate with MISO Going Forward?

- Several near-term decisions about the scope of UMEX are critical to building expansion capability into the existing Square Butte HVDC corridor:
  - Technology Selection: VSC vs LCC
  - Configuration: Expandable Symmetric Monopole vs Non-Expandable Bipole
  - AC Interconnection Voltage: 345 kV vs 230 kV
- Does MISO wish to evaluate an incremental upgrade of the Square Butte HVDC as part of LRTP Tranche 2? Which increments are of interest (900 MW / 1500 MW / 3000 MW)? What is the timing for this evaluation and when will there be more certainty around whether or not the project can be justified for inclusion in LRTP Tranche 2? What can MP do to assist MISO's evaluation of the project? Can MISO assist MP with replicating the LRTP business justification metrics so that we can evaluate the project for ourselves?
- What other HVDC-related issues need to be resolved? How do we make progress on those?