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STATE OF MINNESOTA
OFFICE OF ADMINISTRATIVE HEARINGS

FOR THE PUBLIC UTILITIES COMMISSION

In the Matter of the Application of Minnesota Power for a Certificate of Need for the HVDC Modernization Project in Hermantown, Saint Louis County; In the Matter of the Application of Minnesota Power for a Route Permit for a High Voltage Transmission Line for the HVDC Modernization Project in Hermantown, Saint Louis County.	**OAH 5-2500-39600** **MPUC E-015/CN-22-607** **MPUC E-015/TL-22-611**

DIRECT TESTIMONY OF THOMAS DAGENAIS

I. INTRODUCTION AND QUALIFICATIONS

Q. Please state your name, employer, title, and business address.

A. My name is Tom Dagenais. I am employed by ATC Management, Inc., the corporate manager of American Transmission Company LLC (collectively, ATC). My job title is Director – System Planning and my business address is 2489 Rinden Road, Cottage Grove, Wisconsin.

Q. On whose behalf are you testifying in this proceeding?

A. I am testifying on behalf of ATC in support of the Arrowhead Substation Alternative that ATC has presented as an alternative to the new St. Louis County Substation Minnesota Power (MP or Applicant) is proposing to construct as part of the High Voltage Direct Current (HVDC) Modernization Project (Project).

Q. Please describe your educational and professional background as it relates to this proceeding.

A. I started working at ATC in 2004, when I was hired as a Transmission Planning Engineer, and over time have been promoted to my current position. In the last few years, my job duties have included guiding and leading ATC's System Planning teams in evaluating potential transmission system solutions for constraints on the system, coordinating cross-functional review and approval for project plans, and participating in cross-functional development discussions for future proposed projects.

Prior to working at ATC, I spent two years working at the Midwest Independent System Operator (now known as the Midcontinent Independent System Operator (MISO)) as a reliability coordinator.[1] My duties included evaluating transmission system reliability, forecasting transmission congestion, and preventing and resolving transmission system problems. Prior to MISO, I spent several years working at the Mid-America Interconnected Network (a former regional reliability organization) monitoring and analyzing bulk power system security, performing contingency analyses, and implementing line-loading relief as necessary.

I have a Bachelor of Science Degree in Electrical Engineering from the University of Illinois in Urbana-Champaign, and a Master of Business Administration Degree from the University of Wisconsin at Madison. I am registered as a Professional Engineer with the State of Wisconsin.

[1] MISO is an independent, not-for-profit regional transmission organization that is comprised of member electric utilities within its footprint and is responsible for (among other things) planning and operating the high-voltage transmission system across 15 midwestern states and Manitoba, Canada. MISO does not own any of the facilities that comprise the electric grid but acts as a sort of air traffic controller to ensure that the bulk power system is planned and operated in a manner that reliably delivers power from generators to consumers.

Q. What are your responsibilities at ATC?

A. I direct and guide the efforts of four teams of planning engineers and several specialists in support of ATC's efforts to reliably and cost-effectively plan, design, build, own, and operate the electrical transmission system. My duties include providing guidance, leadership, and direction on planning studies for projects under consideration in ATC's System Planning Department.

Q. Please describe the scope of your involvement with the Arrowhead Substation Alternative and the Project generally.

A. My involvement with the Project began in September 2022, when MP first provided ATC with an overview of the need for and scope of the Project. At that time, MP indicated that it intended to interconnect the Project to the bulk electric transmission system using ATC's 345/230 kV Arrowhead Substation—an approach that ATC supported. Just over two weeks later, MP advised ATC that rather than using the existing 345/230 kV Arrowhead Substation, MP would interconnect the Project to the transmission system through the new St. Louis County 345 kV Substation. Over the next year or so, I was involved in several discussions with MP and/or MISO concerning the Project and MISO's plans for Tranche 2 of its Long Range Transmission Plan (LRTP).[2] During these meetings, ATC consistently reiterated its support for the Project to utilize ATC's existing 345/230 kV Arrowhead Substation. Since August 2023, I have been working with a team of subject matter experts at ATC to evaluate and study utilization of the existing 345/230 kV Arrowhead Substation as an alternative to MP's proposed new St. Louis County Substation. Specifically, my focus

[2] ATC witness Robert McKee provides additional background regarding MISO's Long Range Transmission Planning process.

has been on supervising the development, implementation, and analysis of several planning studies for the Project and the Arrowhead Substation Alternative. As part of this effort, I have reviewed the Certificate of Need and Route Permit Application that MP filed for the Project and have reviewed MP's responses to various information requests that have been issued in this docket.

Q. What are some of the major transmission projects that you have worked on at ATC?

A. In my time at ATC, I have been involved in several major transmission projects. I worked on the early development of the Pleasant Prairie-Zion Energy Center 345 kV Multi-Value Project (MVP) in southern Wisconsin and the Badger Coulee 345 kV MVP in western and central Wisconsin. I also performed analysis proving the need for a rebuild of the Kenosha-Lakeview 138 kV line in southeastern Wisconsin. I was the lead planner for ATC's Cardinal-Hickory Creek 345 kV MVP, which is located in southwest and south-central Wisconsin. I have also provided secondary support on efforts such as ATC's Bay Lake Project in northeastern Wisconsin and the Upper Peninsula of Michigan. I performed an analysis to justify the cancellation of the Rockdale-Mill Road 345 kV Project and led the planning effort to propose, and then later re-evaluate and cancel the proposal for, the 345 kV Wisconsin-Illinois Reliability Project, both of which would have been located in southeastern Wisconsin. Finally, I performed an economic analysis that led to a project to improve the ratings on the Point Beach-Sheboygan 345 kV line, which is located in eastern Wisconsin. I have also performed many studies to evaluate the economic and reliability performance of projects developed for reliability purposes, and I have analyzed the economic impacts of numerous high-voltage transmission projects that ATC ultimately did not pursue.

Q. In addition to your role at ATC, do you serve on any other professional committees or in any organizations related to transmission planning or reliability?

A. While I am not currently serving actively on any industry committees related to transmission planning or reliability, I very recently completed a two-year term serving on the NERC Reliability Issues Steering Committee and multiple planning engineers who report to me actively participate on various committees, such as the MISO Planning Sub-Committee, Planning Advisory Committee, Regional Expansion Criteria and Benefits Working Group (RECB), Interconnection Process Working Group (IPWG), Loss of Load Expectation Work Group (LOLE WG), Modeling Users Group (MUG), the North American Reliability Corporation (NERC) Electro-magnetic Transient Task Force (EMTTF), Multiregional Modeling Working Group (MMWG), Inverter-Based Resource Performance Subcommittee (IRPS), the Institute for Electrical and Electronics Engineers (IEEE) P2800 Working Group (developing standards for interconnection and interoperability of inverter-based resources interconnecting with electric power transmission systems), and the Electric Power Research Institute (EPRI) Model Validation Group, among others.

Q. What is the purpose of your direct testimony?

A. The purpose of my testimony is to provide an overview of and justification for ATC's proposed Arrowhead Substation Alternative and the planning analysis that ATC has conducted for this proposed modification to the HVDC Modernization Project. As I will discuss, ATC conducted several different planning analyses in state-of-the-art power flow computer models to compare the Project as proposed by MP with the alternative proposed by ATC—namely connecting the eastern end of the Project to ATC's 345/230 kV

Arrowhead Substation. These analyses demonstrate that the Arrowhead Substation Alternative provides an as reliable or more reliable solution for interconnecting the Project to the alternating current high-voltage transmission system, relative to MP's proposal.

Q. Are you sponsoring any exhibits in support of your testimony?

A. Yes. I am sponsoring the following exhibits:

- Schedule 1: MP Responses to ATC Information Request Nos. 5, 10, 21, 19
- Schedule 2: MP Responses to Large Power Intervenor Information Request Nos. 3, 4, 5 & LPI IR 005.01 Attach
- Schedule 3: NERC TPL-001-5 (Transmission System Planning Performance Requirements)
- Schedule 4: Steady State Reliability Analysis Results (MP models)
- Schedule 5: Steady State Reliability Analysis Results (MTEP models)
- Schedule 6: Dynamic Stability Analysis Results
- Schedule 7: Voltage Stability Analysis Results
- Schedule 8: ATC Response to DOC-DER Information Request Nos. 10-11

II. THE HVDC MODERNIZATION PROJECT

Q. Please explain your understanding of the need for and scope of MP's proposed Project?

A. According to MP, the fundamental purpose of the Project is to upgrade and modernize the HVDC converter stations on either end of its approximately 465-mile long Square Butte HVDC 550-megawatt (MW) 250 kilovolt (kV) transmission line (HVDC Line). MP notes that, in recent years, it has experienced outages in the HVDC terminals due to failures of various pieces of aging equipment and components. MP states that the Project is needed to

modernize equipment in the HVDC terminals to ensure continued delivery and expansion of its renewable carbon-free energy resources.[3]

As proposed by MP, the Project involves constructing a new HVDC converter station and a new 345/230 kV St. Louis County Substation in Hermantown, Minnesota; connecting the existing HVDC Line to the new converter station and decommissioning that portion of the existing HVDC Line between the new converter station and MP's existing 230/115 kV Arrowhead Substation; constructing a new 345 kV transmission line to connect the new HVDC converter station to the new St. Louis County Substation; and constructing two new parallel 230 kV lines to connect the new St. Louis County Substation to MP's 230/115 kV Arrowhead Substation.[4]

Q. How has MP characterized the need for the proposed St. Louis County Substation?

A. MP states that this new substation—which would be located less than a mile from ATC's existing 345/230 kV Arrowhead Substation—is needed to interconnect the new HVDC converter station in Hermantown to the alternating current (AC) bulk electric transmission system. Under MP's proposed configuration of the Project, the new HVDC terminal will convert electricity carried along the HVDC Line from direct current (DC) to AC. The power will then flow from the HVDC converter station to the new St. Louis County Substation, where it will be stepped down in voltage (from 345 to 230 kV) and transmitted to MP's existing 230/115 kV Arrowhead Substation. At that point, the power will be transmitted along MP's existing system to its customers. MP also asserts that the new St. Louis County Substation is needed to accommodate potential future transmission

[3] *See* Application, § 3.0.
[4] *See* Application, at 2–4 & Map 1.

expansion and, as such, will be designed with room to accommodate a second 345/230 kV transformer and additional 345 kV lines that may be needed in the future.[5]

Q. Did MP conduct any system planning modeling or analysis for the Project?

A. Yes. MP stated that it conducted several planning and integration studies for the Project between 2020 and 2023. Broadly speaking, these studies included several reactive power analyses, analyses related to line commutated converter (LCC) HVDC technology, a power flow analysis, and a transformer energization study.[6] I will discuss certain aspects of these studies in greater detail later in my testimony.

Q. Is ATC opposed to the Minnesota Public Utilities Commission (Commission) issuing a certificate of need and route permit for the Project generally?

A. No. ATC is not contesting the need for or adequacy of the Project generally. ATC is not proposing that MP implement any systematic alternative to the Project that MP originally proposed in the Application. ATC is simply proposing that MP modify one aspect of the overall Project—the means by which it interconnects to the AC bulk electric transmission system. As I discuss in more detail below, ATC recommends that MP interconnect the Project to the transmission system through ATC's existing 345/230 kV Arrowhead Substation, rather than through the new 345 kV St. Louis County Substation, which would be located less than a mile away. ATC supports Commission approval of the Project, conditioned upon MP's implementation of the Arrowhead Substation Alternative.

[5] *See* Application, at 8, 11.
[6] *See* Schedule 1.

III.THE ARROWHEAD SUBSTATION ALTERNATIVE

Q. Please provide an overview of the Arrowhead Substation.

A. As described in the direct testimony of ATC witness Tobin Larsen, the Arrowhead Substation is located in Hermantown, Minnesota and consists of two distinct substations—a 230/115 kV Substation owned by MP and a 345/230 kV Substation owned by ATC. MP's 230/115-kV Arrowhead Substation serves several MP-owned transmission lines in the area. It is also connected and directly adjacent to ATC's 345/230 kV Arrowhead Substation, which serves as the northern end point for ATC's Arrowhead-Stone Lake-Gardner Park 345 kV transmission line (also known as the Arrowhead-Weston 345 kV Transmission Line).

Q. Please generally describe the Arrowhead Substation Alternative.

A. Fundamentally, the Arrowhead Substation Alternative is a modification to MP's proposed point-of-interconnection for the Project. Whereas MP is proposing to interconnect the Project to the AC bulk electric system through a new 345/230 kV St. Louis County Substation, ATC is proposing to interconnect the Project through its existing 345/230 kV Arrowhead Substation. This involves construction of a new, double-circuit 345 kV transmission line from the new HVDC converter station to ATC's 345/230 kV Arrowhead Substation. Within the substation, ATC would also add a new 345/230 kV transformer, remove and decommission the existing 230 kV phase shifting transformer (PST), remove and decommission the existing 345 kV capacitor banks, and perform other miscellaneous work. ATC witnesses Michael Bradley and Tobin Larsen provide additional details regarding the work associated with construction of this alternative.

Q. Can you briefly explain ATC's justification for removing the existing capacitor banks in its 345/230 kV Arrowhead Substation as part of the Arrowhead Substation Alternative?

A. Historically, these capacitor banks have helped maintain voltage stability on the nearby transmission system. Voltage stability refers to the ability of the power system to maintain appropriate voltage levels. If appropriate voltage levels are not maintained, voltage collapse can compromise reliability and lead to widespread outages. As MP notes in its Application, the technology that it will be using in the new converter stations being built as part of the Project will support voltage stability and "eliminate[] the need for additional reactive support from mechanically switched capacitors . . . ."[7] As such, it is reasonable to conclude that the capacitor banks at the ATC 345/230 kV Arrowhead Substation will no longer be needed. This is confirmed by the results of the planning analysis that ATC has conducted as part of this proceeding, which I discuss in greater detail below.

Q. What if any other alternatives to the Arrowhead Substation Alternative has ATC considered for interconnecting the Project to the AC high voltage transmission system?

A. As I noted earlier, ATC is not contesting the need for the Project generally or proposing a systematic alternative to the Project itself. ATC's focus in this proceeding is on making efficient use of existing resources regarding the means by which the Project interconnects to the AC high-voltage electric transmission system. Put differently, assuming the Project is constructed, the only question is the method of interconnection, and there are only two

[7] *See* Application, at 27.

ways to achieve that interconnection: through a new substation (such as the St. Louis County Substation that MP has proposed) or an existing substation (the Arrowhead Substation). MP has ruled out interconnecting the Project directly to its 230/115 kV Arrowhead Substation,[8] and ATC is not contesting that conclusion. Thus, as far as interconnecting the Project is concerned, the only two alternatives available are MP's new St. Louis County Substation or ATC's existing 345/230 kV Arrowhead Substation. For this reason, ATC did not consider any other alternatives aside from the one it is presenting here.

Q. What are the expected electrical losses under maximum loading and projected average loading in the transmission line and substation terminal for the Arrowhead Substation Alternative?

A. ATC obtained several power flow models from MP through discovery that MP used as part of a 2023 power flow analysis for the Project.[9] Per these models, the maximum amount of power injected into the western (North Dakota) terminal of the HVDC Line is **[BEGIN HIGHLY CONFIDENTIAL TRADE SECRET DATA]: , [END HIGHLY CONFIDENTIAL TRADE SECRET DATA]** and the maximum power received at the eastern (Minnesota) terminal of the HVDC Line is **[BEGIN HIGHLY CONFIDENTIAL TRADE SECRET DATA]: [END HIGHLY CONFIDENTIAL TRADE SECRET DATA]** Under these operating conditions, the real power losses on the two 230 kV transmission lines that MP would construct between its new St. Louis County Substation and its 230/115 kV Arrowhead Substation would be 154 kilowatts (kW). For the same operating condition with the Arrowhead Substation Alternative, the real power

[8] *See* Application, § 4.3.2
[9] This power flow analysis is confidential and is included in Schedule 1 to my direct testimony.

losses on the double-circuited 345 kV transmission line from MP's new converter station to ATC's 345/230 kV Arrowhead Substation would be 130 kW. Given the short distance of both transmission lines (approximately one mile or less in length), these transmission line losses are very small fractions of the overall amount of power received at the Minnesota terminal of the HVDC Line.[10]

To provide a more holistic understanding of the total electrical losses for the Arrowhead Substation Alternative and MP's proposal, ATC also calculated the maximum expected electrical losses on the transmission system for either alternative. Table 1, below, summarizes these calculations and provides the real power losses for all areas on the transmission system that surround MP's proposed new St. Louis County Substation and ATC's 345/230 kV Arrowhead Substation. These losses were calculated using MISO 2023 Transmission Expansion Plan (MTEP) 2028 summer peak models, with certain modifications.[11] In general, the Arrowhead Substation Alternative results in approximately 1 MW less of electrical losses compared to MP's proposal.

[10] ATC did not conduct calculations to determine electrical losses under average loading conditions, as those values will be much smaller than the losses calculated under maximum loading conditions. That said, the electrical losses for the Arrowhead Substation Alternative will always be lower than the electrical losses associated with MP's proposal because the former operates at a higher voltage than the latter. Moreover, ATC did not calculate the real power losses within the St. Louis County 345/230 kV transformer (which would be installed under MP's proposal) because the modeling data MP provided assumed **[BEGIN HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION]: [END HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION]**

[11] I provide background on MISO's MTEP process later in my testimony. The major modifications that ATC made to these models include updating the model to reflect the voltage source converter (VSC) technology MP intends to install for the Project. ATC also assumed that the HVDC Line is dispatched at 900 MW (injected at the North Dakota side of the HVDC Line). All major generation additions and significant dispatch assumptions stipulated in MP's HVDC Modernization Project Power Flow Analysis report, *see* Schedule 1, for the **[BEGIN HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION]: [END HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION]** case were also accounted for.

Table 1: Comparison of Maximum Expected System Losses

Area[1]	System Losses in MW (System Intact)[2]			
	MP's Alternative		ATC's Alternative	
	Pre-LRTP	Post-LRTP	Pre-LRTP	Post-LRTP
WEC (295)	102.2	103.3	102.3	103.4
XEL (600)	211.7	206.1	210.2	204.5
MP (608)	182	182.1	180.7	180.6
GRE (615)	108.4	108	108.1	107.8
ALTW (627)	94	92.9	94	92.8
DPC (680)	35.9	32.7	35.9	32.7
ALTE (694)	72	70.8	71.8	70.7
WPS (696)	68.2	68.1	70.8	70.5
Total	**874.4**	**864**	**873.8**	**863**

NOTES:

1. The "areas" described in this column refer to local balancing authorities (LBAs), or certain geographic areas within the MISO footprint. These areas are generally located in the states of Minnesota and Wisconsin. A map depicting the general location of these LBAs is included in Attachment VV to the MISO Tariff. *See* MISO, *Tariff: Attachment VV*, *available at* http://tinyurl.com/2s4hcars.
2. Losses in each area were calculated for each alternative, both before and after the addition of Projects 4, 5, and 6 of Tranche 1 of MISO's Long Range Transmission Plan.

Q. What is the expected average annual availability of the Arrowhead Substation Alternative?

A. Under the Arrowhead Substation Alternative, MP would use ATC's 345/230 kV Arrowhead Substation as the point-of-interconnection for the Project. Based on historical operating performance, ATC expects that its Arrowhead Substation will be available to serve the Project well more than 99 percent of any given year.

Q. Based on this, is it your opinion that the Arrowhead Substation Alternative provides a reliable means of interconnecting the Project to the transmission system?

A. Absolutely. ATC's Arrowhead Substation has historically been very reliable and ATC expects that this trend will continue if the Commission orders implementation of the Arrowhead Substation Alternative. That is because this alternative would result in the

addition of a second, parallel 345/230 kV transformer to the Arrowhead Substation. The presence of two parallel transformers to serve the Project makes ATC's proposed alternative a highly reliable means of serving the Project because, if one transformer were forced out-of-service, the other can continue to provide reliable service to the Project. This is a notable advantage compared to MP's proposal, which calls for the installation of a single 345/230 kV transformer at the new St. Louis County Substation. If that transformer were to be forced out-of-service, then the HVDC Line would be unable to transfer power.

Q. Did MP ever consider interconnecting the Project to the transmission system through ATC's 345/230-kV Arrowhead Substation, rather than through the new St. Louis County Substation?

A. Yes. As noted earlier, when MP first approached ATC about the Project in September 2022, MP indicated that it planned to interconnect the Project through ATC's 345/230 kV Arrowhead Substation. In fact, in a June 2022 presentation to MISO concerning the Project, MP presented an option for interconnecting the Project to ATC's 345/230 kV Arrowhead Substation that is similar to the design that ATC has presented in this proceeding. However, prior to this proceeding, MP did not conduct any regional planning and integration studies related to the Arrowhead Substation Alternative.[12]

Q. Generally speaking, why does ATC support utilizing its 345/230 kV Arrowhead Substation to interconnect the Project, rather than MP's proposed new St. Louis County Substation?

[12] *See* Schedules 1 & 2.

A. Simply put, the Arrowhead Substation Alternative provides a more reliable solution for interconnecting the Project to the AC high-voltage transmission system, at a lower overall cost and with fewer environmental and community impacts. As discussed in greater detail below, ATC conducted several different planning analyses in state-of-the-art power flow modeling computer simulations to compare MP's proposal for interconnecting the Project (i.e., through the new 345/230 kV St. Louis County Substation) to the Arrowhead Substation Alternative. These analyses included over 75 different modeling runs across multiple scenarios and model sets to evaluate the reliability impacts of each alternative. The results demonstrate that the Arrowhead Substation Alternative is as reliable or more reliable than MP's proposal. In fact, one of the key benefits of ATC's proposed solution is that it would ultimately result in two transformers at the 345/230 kV Arrowhead Substation to serve the Project, meaning that, if one transformer is forced out-of-service, the other can continue to serve the Project. As I noted earlier, MP's proposal for interconnecting the Project does not provide this kind of reliability benefit. Implementation of the Arrowhead Substation Alternative will also still enable MP to serve its customers with carbon-free renewable energy transferred over the HVDC Line and to upgrade the aging equipment in the converter stations at either end of the line. In addition to these benefits, utilizing ATC's existing 345/230 kV Arrowhead Substation will result in lower costs and fewer environmental impacts relative to MP's proposal to construct an entirely new 345/230 kV substation less than a mile away.[13]

A. Overview of ATC's Planning Analysis

[13] ATC witnesses Dustin Johanek, Michael Bradley, and Amy Lee discuss the Arrowhead Substation Alternative's costs and impacts in greater detail in their direct testimony.

Q. Has ATC conducted any system planning modeling or analysis of the Arrowhead Substation Alternative?

A. Yes. Since becoming involved in this proceeding, ATC has completed several planning analyses comparing the performance of the Arrowhead Substation Alternative to MP's proposed means of interconnecting the Project to the transmission system (i.e., through the new 345/230 kV St. Louis County Substation). The studies that ATC conducted include steady state reliability analysis, dynamic stability reliability analysis, and steady state voltage stability analysis.

Q. Can you describe the purpose and scope of these various studies?

A. Broadly speaking, these planning analyses are intended to evaluate how changes in the transmission system impact the ability of the overall system to reliably deliver power to consumers. Grid operators and utilities commonly conduct these studies using software that simulates how the transmission system will react to the addition or retirement of (for example) generating resources or transmission lines. Each study is conducted using a model that contains certain assumptions about how the electric system will operate under certain conditions. No simulation can perfectly predict how the transmission system will react to changes in transmission the transmission system. However, grid planners try to develop realistic assumptions within their models so they can identify any material issues and (if necessary) plan for the implementation of mitigation measures.

While there are a variety of studies that can be conducted for any given project, ATC conducted three different analyses to compare the performance of the Arrowhead Substation Alternative to MP's proposal: (1) a steady state reliability analysis; (2) a dynamic stability analysis; and (3) a steady state voltage stability analysis. The steady state

reliability analysis evaluates how the transmission system would perform in the presence of either alternative at a single point in time, under various contingencies.[14] The results of this analysis show whether the studied alternatives result in potential overloads any of the transmission facilities being monitored, as such overloads can adversely impact system reliability.

The dynamic (or transient) stability analysis evaluates how the transmission system would react in the presence of either alternative under various contingencies, but over a shorter period of time than the steady state analysis: whereas the latter is focused on the long-term performance of the system following any abrupt disturbance, the dynamic analysis covers the response of the system to electrical faults (disturbances) from fractions of a second to 20 seconds after the fault occurs.[15] The results of this study indicate whether one of the studied alternatives results in an unstable response, including (but not limited to) cascading outages of generators or uncontrolled loss of customer load.

Finally, the steady state voltage stability analysis is intended to evaluate whether and to what extent each alternative would maintain acceptable voltage levels under normal operating conditions and after a contingency. This study involves identifying the worst single contingency and limits the flow of electrical power over a pre-defined set of

[14] In this context, a "contingency" refers to the failure of a key piece of equipment (e.g., a generator, transmission line, or transformer) on the high-voltage electric system. The North American Electric Reliability Corporation (NERC) has established national standards that transmission planners and coordinators must adhere to when analyzing contingencies in their planning analyses. These standards define different types of contingencies that may need to be studied, ranging from P0 contingencies (where the system is intact) to P7 contingencies (where there is a loss of two facilities on a common structure). A list of these contingencies and the associated NERC planning standard (TPL-001) is attached to my testimony as Schedule 3.

[15] An electrical fault is simply an abnormal condition on the transmission system that can damage equipment and disrupt the flow of power. Faults can occur due to malfunctioning equipment or external factors, such as bad weather causing a tree to fall on a power line.

transmission elements (e.g., specific transmission lines or transformers) to the system operating limit (SOL) for that set of transmission elements.

Q. Why did ATC decide to conduct these specific studies?

A. Transmission planners commonly conduct these analyses to evaluate the performance and reliability of the transmission system in the face of a new transmission project. The studies provide an effective way of determining whether a particular project will satisfy relevant planning standards and what (if any) mitigation measures need to be implemented to continuously satisfy those standards. In this case, conducting these studies enabled ATC to assess the relative performance of MP's proposal and the Arrowhead Substation Alternative under the relevant planning criteria.

Q. What models and assumptions did ATC employ in conducting the steady state analysis?

A. ATC conducted the steady state contingency analysis in a commercial software program known as PowerGEM Transmission Adequacy & Reliability Assessment (TARA),[16] using two different sets of power flow models. ATC obtained the first set of power flow models through discovery from MP, which had previously used these models as part of a power flow analysis conducted for the Project in 2023.[17] ATC compared the performance of the Arrowhead Substation Alternative to MP's proposal in four different cases (i.e., scenarios), with the material assumptions for each case noted in Table 2, below. Within each case, ATC modeled the system with and without the addition of three Long-Range Transmission

[16] This software is widely used in the power industry, including by MISO and many North American utilities.
[17] Specifically, MP retained Siemens PTI to conduct a power flow analysis for the Project in 2023 to evaluate "project scope optimization, performance requirements and system impacts from the Project and an HVDC Line capacity increase of up to 900 MW." *See* Schedule 1.

Planning (LRTP) projects (LRTP Tranche 1, projects 4, 5, and 6, which are to be located in Wisconsin and Minnesota), which MISO's Board of Directors approved for inclusion in the MTEP in July 2022. ATC modeled MP's proposal as it was presented in the power flow models that were provided; when modeling the Arrowhead Substation Alternative, ATC modified the model by relocating the point-of-interconnection for the Project to ATC's Arrowhead 345/230 kV substation, adding a second 345/230 kV transformer at the Arrowhead Substation, and retiring the existing Arrowhead phase-shifting transformer (PST) and 345 kV capacitor banks at that substation. This analysis produced outputs (or results) identifying which transmission facilities would be subject to potential overloads in each scenario.

Table 2: Key Assumptions for Steady State Reliability Analysis (MP-Supplied Models)

[HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION BEGINS]:

Case (Scenario)[1]	VSC HVDC Flow Direction (MW)[2]	Additional Generation not in MTEP (MW)[3]	Wind generation (west of HVDC)[4]	J732 Injection Level (MW)[5]

[HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION ENDS]

NOTES:

1. Each scenario reflects conditions on the transmission system at a single point in time—in this case, the 2028 summer peak, summer shoulder, or winter peak.
2. This represents the direction of flow along the HVDC Line. The amount of power injected (on the North Dakota side) and received (on the Minnesota side) is different due to electrical losses on the HVDC Line.
3. This represents additional new generating capacity that was added in the MP-supplied power flow models, in excess of the generation capacity present in MISO's 2023 transmission expansion plan (MTEP) power flow models.

4. This represents the dispatch level (capacity factor) of existing wind generation located west of the HVDC Line. In this context, "dispatch" simply refers to the amount of power flowing from a particular generator onto the grid.
5. This represents the amount of power injected from the Nemadji Trail Energy Center (NTEC, which has a signed Generator Interconnection Agreement and occupies position J732 in the MISO generator interconnection queue), an approximately 560 MW natural gas plant that is being built near Superior, Wisconsin and is expected to begin operating in 2028. Given its relatively close proximity to both the Project and the Arrowhead Substation, the output from NTEC is an important variable to consider, as it could have material impacts on the results of the analysis.

Q. Why did ATC conduct the steady state analysis in multiple different scenarios?

A. As I mentioned earlier, no single modeling run can perfectly predict how the transmission system will respond to changes on that system, and the outputs of such modeling depend heavily on the inputs (or assumptions) that are utilized. As such, it is common for transmission planners to conduct studies in multiple different scenarios, as this provides a more comprehensive picture of how the project being studied (in this case, MP's and ATC's respective alternatives) perform from a reliability perspective. It is also common for transmission planners to conduct reliability analyses based on summer peak or shoulder (i.e. intermediate summer load level or peak spring/fall load levels) electric power flows in a future year, as this informs how a given project will affect reliability when demand on the system is at its highest levels.[18]

Q. Did ATC evaluate any additional sensitivities within the MP-supplied power flow models?

A. Yes. For all scenarios listed in Table 2, above, ATC conducted a steady state analysis of the Arrowhead Substation Alternative assuming a lower power transfer rate along the HVDC Line and without the addition of a second 345/230 kV transformer at the Arrowhead

[18] In the context of electric grid planning, the "peak" refers to the point in time at which consumer demand (also referred to as "load") is at its highest. Although peak demand times vary from one region to the next, utilities in the Midwest often experience peak demand during the summer, when there is a high electric demand due to (for example) increased use of air conditioning. The "shoulder" refers to intermediate demand levels during the summer or peak demand levels during the fall or spring.

Substation.[19] Specifically, ATC assumed 550 MW of power transfer along the HVDC Line, which represents the line's existing capacity.[20] ATC ran this analysis to verify whether the existing 345/230 kV transformer at its Arrowhead Substation is sufficient to meet MP's need to inject up to 550 MW of power from the HVDC Line (west-to-east), even without the addition of the second transformer that ATC would install at its Arrowhead Substation as part of its proposed alternative. With the addition of these sensitivities, ATC conducted a total of 22 distinct steady state modeling runs using MP-supplied models.

Q. Please describe the second set of models that ATC utilized in the steady state analysis.

A. Every year, MISO prepares transmission system planning and power flow models as part of its annual transmission planning process, which are referred to as the MISO Transmission Expansion Plan (MTEP) models. MISO develops these models through a collaborative process that considers feedback from a variety of stakeholders in the transmission planning process, including MISO's member utilities, independent power producers, consumer advocates, and state regulators, among others. These models serve as the foundation for the local and regional planning analyses that MISO conducts when evaluating changes to the generators or transmission lines that make up the system.

ATC conducted a second steady state reliability analysis using power flow models that MISO developed as part of the MTEP 2023. As with the initial steady state analysis, ATC compared the performance of the Arrowhead Substation Alternative to MP's proposal

[19] This analysis did assume retirement of the existing Arrowhead PST and 345 kV capacitor banks at the Arrowhead Substation.

[20] MP has noted that, while the new converter stations will be capable of transferring up to 1500 MW of power, the existing HVDC Line cannot transfer more than 550 MW of power without additional targeted upgrades to the line itself; MP notes that it is currently evaluating what permits and approvals may be needed to implement these upgrades. *See* Schedule 2.

in four different scenarios, with the material assumptions for each scenario described in Table 3, below. Within each case, ATC modeled the system with and without the addition of three of MISO's LRTP Tranche 1 projects (LRTP projects 4, 5, and 6, which are to be located in Wisconsin and Minnesota). In modeling MP's proposal, ATC updated modified the MTEP 2023 models to reflect the new voltage source converter (VSC) technology that MP intends to implement for the Project; in modeling the Arrowhead Substation Alternative, ATC relocated the eastern HVDC terminal to the Arrowhead 345/230 kV substation, added a second 345/230 kV transformer at Arrowhead, and retired the existing Arrowhead PST and 345 kV capacitor banks.

Table 3: Key Assumptions for Steady State Reliability Analysis (Based on MTEP 2023 Models)

<table>
<tr><th rowspan="2">Case (Scenario)[1]</th><th colspan="4">Key Modifications to the closest MTEP Power Flow Case</th></tr>
<tr><th>VSC HVDC Flow Direction (MW)[2]</th><th>ND Wind Generation</th><th>J732 Injection Level (MW)[3]</th><th>Other Key Dispatch Assumptions</th></tr>
<tr><td>Summer Peak High Wind (SHW)</td><td>West-to-East
900 injected
785.3 received</td><td rowspan="3">Added 350 MW of additional wind capacity

All ND wind generators scaled up to match the required increase in HVDC Line injection in ND

Scaled down the rest of MISO Classic to maintain the load plus losses to generation balance</td><td>560
(full capacity)</td><td rowspan="4">Dispatched nearby generation (e.g. Hibbard Renewable Energy Center) following MP's HVDC Modernization Project Power Flow Analysis report (issued on Aug 5, 2023)</td></tr>
<tr><td>Shoulder High Wind (SSH)</td><td>West-to-East
900 injected
785.3 received</td><td>Offline</td></tr>
<tr><td>Winter North Flow (WNF)</td><td>West-to-East
416 injected
387 received</td><td>560
(full capacity)</td></tr>
<tr><td>Summer Reverse Flow (SRF)</td><td>East-to-West
900 injected
785.3 received</td><td>Wind generation in ND turned off</td><td>560
(full capacity)</td></tr>
</table>

NOTES:

1. Each scenario reflects a snapshot of the transmission system operating point in time—in this case, the 2028 summer peak, summer shoulder, or winter peak operating points. The source MTEP models for each scenario were the 2028-SUM-TA Summer Peak (Low Wind) case (for the SHW scenario), the 2028-SHHW-TA Summer Shoulder (High Wind) case (for the SSH scenario), the 2028-WINNF-TA

Winter Peak (North Flow for MH) case (for the WNF scenario), and the 2028-SUM-TA Summer Peak (Low Wind) case (for the SRF scenario).

2. This represents the direction of flow along the HVDC Line. The amount of power injected (on the North Dakota side) and received (on the Minnesota side) is different due to electrical losses on the HVDC Line. While the default MTEP models assume significantly less power being dispatched along the HVDC Line, ATC conservatively preserved the dispatch assumptions from the MP-supplied models when analyzing either alternative in the MTEP models.
3. This represents the amount of power injected from the Nemadji Trail Energy Center (NTEC, which has a signed Generator Interconnection Agreement and occupies position J732 in the MISO generator interconnection queue) near Superior, Wisconsin. Given its relatively close proximity to both the Project and the Arrowhead Substation, the output from NTEC is an important variable to consider, as it could have material impacts on the results of the analysis.

Q. Did ATC evaluate any additional sensitivities within its steady state reliability analysis using the MTEP 2023 power flow models?

A. Yes. In reviewing the models that MP provided, ATC observed that one piece of equipment—known as the Stinson phase shifting transformer (Stinson PST)—was assumed to operate in a manner that was inconsistent with how MISO models that equipment in the MTEP 2023 power flow models; the operating parameters for the Stinson PST were also not consistent across the four scenarios included in the MP-supplied models.[21] To evaluate the impact of Stinson PST operation on either alternative, ATC ran three different sensitivities within the MTEP 2023 models: one with the Stinson PST enabled post-contingency, a second with the Stinson PST disabled post-contingency, and a third with the Stinson PST bypassed (i.e., retired). For the first and second sensitivities (i.e., both Stinson PST enabled and disabled), ATC utilized the operating parameters for that equipment that were included in the MTEP 2023 models, rather than the operating parameters from the MP-supplied models. With the addition of these sensitivities, ATC conducted a total of 48 modeling runs using the MTEP 2023 power flow models.

[21] As its name suggests, the Stinson PST is a phase-shifting transformer (like the Arrowhead PST) located in Superior, Wisconsin. ATC's understanding is that the Stinson PST has been operated to provide active power flow control over the transmission system between Minnesota and Wisconsin.

Q. How do the assumptions or variables in MP's power flow models compare to the power flow models in MISO's MTEP 2023 dataset?

A. Several of the variables in the MP-supplied power flow models were more aggressive than or inconsistent with comparable variables in the MTEP models. For example, MP's models assume **[BEGIN HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION]:**

. **[END HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION]** Some scenarios in MP's models also reflect situations that I believe have a low probability of occurring but would highly stress the system if they did occur. For example, in its **[BEGIN HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION]:**

. **[END HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION]** Finally, the MTEP 2023 models assume **[BEGIN HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION]:**

. **[END HIGHLY CONFIDENTIAL TRADE SECRET INFORMATION]** These assumptions are not necessarily flawed, as it can be reasonable to "stress test" a project under a more aggressive set of assumptions. I point this out simply to note that these different modeling assumptions can and did impact the amount and/or extent of potential

overloads present on the transmission facilities being monitored in the steady state analysis for both alternatives.

Q. What models and assumptions did ATC employ in conducting the dynamic (or transient) stability analysis?

A. ATC conducted the dynamic stability analysis for MP's proposal and the Arrowhead Substation Alternative in the Powertech Transient Security Assessment Tool (TSAT).[22] This modeling exercise used dynamic stability models from MTEP 2023 under three different scenarios (i.e. Summer Peak, Summer Shoulder, and Light Load), which resulted in six different modeling runs. For each run, ATC assumed that LRTP Tranche 1 Projects 4, 5, and 6 are in-service.[23] The material inputs for these modeling runs are described in Table 4, below. In analyzing MP's proposal, ATC modified the MTEP models by replacing the original LCC HVDC converters in the model with the VSC technology that MP is proposing for the Project, and assumed a dispatch pattern for the Project that is consistent with the dispatch assumptions from the steady state reliability analysis. In modeling the Arrowhead Substation Alternative, ATC relocated the point-of-interconnection for the Project to the Arrowhead 345/230 kV substation, added a second 345/230 kV transformer at Arrowhead, and assumed retirement of the existing Arrowhead phase-shifting transformer and 345 kV capacitor banks.

The modeling for both alternatives assumed that major generating resources around the HVDC Line (i.e., in North Dakota, Minnesota, and Wisconsin) are dispatched in a

[22] TSAT is another power flow modeling and transient analysis software that is widely used in the utility industry.
[23] ATC did not see a need to perform the dynamic analysis before and after implementation of these LRTPs, since the addition of these projects did not result in significant changes to the results of the previously conducted steady state analysis.

manner that is consistent with the power flow modeling that MP conducted in 2023 for the Project. ATC also created additional P1 and P6 contingency events to analyze the impact of either alternative on all nearby 345 kV and 161 kV transmission lines and transformers. Ultimately, ATC conducted six different modeling runs as part of its dynamic stability analysis.

Table 4: Key Assumptions for Dynamic Stability Analysis

Case (Scenario)	VSC HVDC Flow Direction (MW)	Wind generation (west of HVDC)	J732 Injection Level (MW)
2028 Summer Peak High Wind (SHW)	West-to-East 900 injected 785.3 received	350 MW of additional wind capacity All ND wind generators scaled up to match the required increase in HVDC Line injection in ND Scaled down generation in the rest of MISO Classic to maintain load plus losses to generation balance.	560 (full capacity)
2028 Shoulder High Wind (SSH)	West-to-East 900 injected 785.3 received		560 (full capacity)
2028 Light Load	West-to-East 900 injected 785.3 received		560 (full capacity)

Q. Did ATC conduct any sensitivities as part of its dynamic stability analysis?

A. Yes. ATC compared MP's proposal to the Arrowhead Substation Alternative using the same assumptions described in Table 4, above, with the following exceptions: flows on the HVDC Line were assumed to be 550 MW (rather than 900 MW), west-to-east; the Arrowhead Substation Alternative was modeled with the single existing 345/230 kV transformer; and that transformer was assumed to trip due to a fault during the dynamic simulation. The purpose of this analysis was to evaluate the security of the transmission system if the existing transformer were forced out-of-service for any reason and a second transformer was not available to serve the Project; this helped ATC understand if it could serve the Project using only the existing transformer at the Arrowhead 345/230 kV Substation. These sensitivities resulted in another six dynamic stability modeling runs (one for each alternative in each scenario described above), bringing the total number of dynamic stability modeling runs to 12.

Q. What models and assumptions did ATC employ for the voltage stability analysis?

A. ATC conducted the voltage stability analysis in the Powertech Voltage Security Assessment Tool (VSAT)[24] software using MISO's Definitive Planning Phase (DPP) Phase 1 ATC area model from the 2021 cycle. This model reflects 2026 shoulder load on the MISO system with LRTP projects 4, 5, and 6 in service. ATC modified the model by removing three future generating resources that were previously assumed to be connected to the King–Eau Claire–Arpin 345 kV line (which runs from southern Minnesota to central Wisconsin), as interconnection requests for these projects have already been withdrawn. The HVDC line was assumed to be dispatched at 900 MW at the North Dakota terminal, which resulted in a 785.3 MW injection into the Arrowhead substation. Generation associated with the Bison wind farm was increased as a proxy for any generation near the western terminal of the HVDC Line, and generation from the Boswell Generating Station in Minnesota was decreased as a proxy for any generation near the eastern terminal. ATC maximized generation from NTEC, with all generation in the MISO North region (generally, eastern Montana, the Dakotas, Minnesota, and Iowa) re-dispatched to account for this change. As with the steady state and dynamic analyses, when modeling the Arrowhead Substation Alternative, ATC added a second transformer at its Arrowhead Substation that is identical to the existing transformer, retired the existing Arrowhead PST, and retired the existing capacitor banks in the Arrowhead 345 kV Substation.

ATC selected the Stone Lake 345 kV substation as the point for voltage measurement, since the bus (i.e. electrical node) associated with this substation is the most

[24] This is a standard computer software program used by grid planners throughout the industry.

voltage sensitive on the Arrowhead–Superior–Stone Lake–Jump River–Gardner Park 345 kV path.[25] The Superior–Stone Lake 345 kV line was chosen as the flowgate on which to measure real power flow, since it is stressed by west-to-east transfers for both of the alternatives. ATC included contingencies of 345 kV facilities in an area bounded by the Arrowhead Substation, Arpin Substation (in north central Wisconsin), and Briggs Road Substation (near La Crosse, Wisconsin).

Q. Did ATC conduct any sensitivities as part of its voltage stability analysis?

A. Yes. ATC conducted a second voltage stability analysis for the Arrowhead Substation Alternative, but assuming only one 345/230 kV transformer is present at the substation. The purpose of this analysis was to evaluate whether serving the Project with a single transformer at ATC's 345/230 kV Arrowhead Substation would cause voltage stability issues.

B. Results of ATC's Planning Analysis

Q. What were the results of the steady state reliability analysis that ATC conducted?

A. Overall, the steady state reliability analysis indicates that, from a reliability perspective, the Arrowhead Substation Alternative performed as well or better than MP's proposal (i.e., through new the St. Louis County Substation) for interconnecting the Project. The detailed results of the steady state analyses that ATC conducted are included in Schedules 4 and 5. Schedule 4 reflects the results of the first set of analysis, which compared MP's proposal to the Arrowhead Substation Alternative (under both a single and double transformer configuration) across 22 different modeling runs using the MP-supplied models; it depicts

[25] As its name suggests, the Stone Lake 345 kV Substation is located near Stone Lake, Wisconsin.

each transmission facility that was monitored as part of the study, its base and emergency ratings, and the electrical loading on the facility in each scenario and for each alternative studied. As shown therein, both MP's proposal and the Arrowhead Substation Alternative result in similar performance, with potential overloads occurring on many of the same monitored transmission facilities in each scenario.

Schedule 5 reflects the results of the second set of analysis, which compared MP's proposal to the Arrowhead Substation Alternative across 48 different modeling runs using the MTEP 2023 power flow models. Again, both MP's proposal and the Arrowhead Substation Alternative result in similar impacts on many of the same monitored transmission facilities in each scenario. Notably, there are generally fewer potentially overloaded facilities (for both alternatives) in the sensitivity where the Stinson PST is enabled, versus those scenarios in which it is bypassed or disabled.

Q. What were the results of the dynamic stability analysis that ATC conducted?

A. The detailed results of this analysis are included in Schedule 6, which shows each contingency studied and whether either alternative creates a stability issue on the facilities being monitored under each scenario. As shown therein, both alternatives perform similarly, although the Arrowhead Substation Alternative performs better under certain contingencies in the 2028 Summer Peak and Shoulder scenarios. There are five P6 contingencies in which the system remains insecure with either alternative assumed in service. For either alternative, these system issues can be mitigated by re-dispatch of the

NTEC generator, as described in a recent report from MISO.[26] Finally, there is one P6 contingency—a failure of both 345/230 kV transformers at ATC's Arrowhead Substation—that applies only to the Arrowhead Substation Alternative and creates dynamic and voltage instability; again, redispatch of the NTEC can be implemented in this scenario to alleviate these instabilities.

Q. What were the results of the voltage stability analysis that ATC conducted?

A. The detailed results of this analysis are included in Schedule 7, which depicts voltage levels at the Stone Lake 345 kV Substation bus at certain levels of power flow over the Superior–Stone Lake 345 kV line. The analysis indicates that the Arrowhead Substation Alternative outperforms MP's proposal, with the planning horizon system operating limit for the Superior–Stone Lake 345 kV line equal to 1,057 MW with the Arrowhead Substation Alternative and 957 MW under MP's proposal. The Arrowhead Substation Alternative was also found to allow for an increased west-to-east transfer when compared to MP's proposal. Finally, the results of the second voltage stability analysis that ATC conducted for the Arrowhead Substation Alternative (i.e., with only one 345/230 kV transformer present at the Arrowhead Substation) demonstrates that serving the Project with only this existing transformer does not present any voltage stability concerns.

Q. What conclusions can be drawn from the results of these analysis?

A. There are several key conclusions that can be drawn from these analyses. First, while MP's proposal and the Arrowhead Substation Alternative perform similarly in the steady state

[26] *See* MISO, *DPP 2017 August Wisconsin Area Phase 3 System Impact Study Report*, at 23-24 (Aug. 20, 2019), *available at* http://tinyurl.com/yck7besp. P6 contingencies are "multiple contingency" scenarios. In other words, they reflect a situation in which there are two separate outage events on two separate elements of the transmission system in a short timeframe.

and dynamic analyses, the Arrowhead Substation Alternative is superior because it performs better in the voltage stability analysis and has an innate advantage in terms of availability and reliability due to the parallel 345/230 kV transformers that would be installed at the Arrowhead Substation. While the dynamic stability analysis indicates that a loss of both 345/230 kV transformers at the Arrowhead Substation (both the existing transformer and the new one that would be procured as part of the Project) could create dynamic and voltage stability issues, the Arrowhead Alternative is still more reliable than MP's proposal. This is because, once ATC installs the second 345/230 kV transformer at the substation, there will be two transformers available (the old and the new) to serve the Project. If one of those transformers experiences an outage, the second can serve as a backup and allow for continued operation of the HVDC Line. This is a significant advantage relative to MP's proposal, which would add a single 345/230 kV transformer to the new St. Louis County Substation; if that transformer experiences an outage, then output from the HVDC Line would drop to zero, because there is no backup transformer available to serve it.

Second, the steady state analysis demonstrates that the existing transformer in ATC's 345/230 kV Arrowhead Substation is sufficient to meet MP's immediate need to transfer up to 550 MW over the HVDC Line, from west-to-east, and to meet MP's future stated need to transfer up to 900 MW over the HVDC Line, from west-to-east. As noted earlier, ATC is aware that MP is considering implementing targeted upgrades to the HVDC Line to increase its capacity from 550 to 900 MW. However, MP has stated that the earliest potential completion date for this project is the fourth quarter of 2028; until that happens,

the HVDC Line will be limited to 550 MW of capacity.[27] Therefore, even prior to the addition of a second, parallel 345/230 kV transformer, ATC's Arrowhead Substation can adequately and reliably serve the Project up to its full current capacity.

Third, from a voltage stability standpoint, the Arrowhead Substation Alternative has superior performance compared to MP's proposal. This is evident from the voltage stability curves included in Schedule 7. These curves show that under a P0 contingency (i.e., with the system intact), the Arrowhead Substation Alternative enables larger power flows across the system; likewise, under the worst contingency (a P7 contingency), the Arrowhead Substation Alternative facilitates larger power flows before voltage instability sets in. The voltage stability analysis also demonstrates that the existing capacitor banks can be removed from ATC's 345/230 kV Arrowhead Substation without compromising system reliability, as this analysis was conducted assuming those capacitor banks are, in fact, retired.

Fourth, the Arrowhead PST is no longer needed. In all three studies that ATC modeled the Arrowhead Substation Alternative, ATC assumed that the existing Arrowhead PST would be bypassed and retired. The results of those studies show that there are no adverse reliability impacts associated with retiring the Arrowhead PST. Indeed, in all three studies, the Arrowhead Substation Alternative performs comparably to (if not better than) MP's proposal, even without the Arrowhead PST.

[27] *See* MPUC Docket No. E999/M-23-91, *2023 Biennial Transmission Projects Report*, at 63 (Nov. 1, 2023), *available at* http://tinyurl.com/54xr24u9.

Q. If the Commission were to approve the Project on the condition that MP implement the Arrowhead Substation Alternative, what further system planning studies would be needed and who would conduct them?

A. To answer this question, some background on the planning process for the MISO Transmission Expansion Plan (MTEP) may be useful. As mentioned earlier, MISO undergoes an annual process to prepare the regional MTEP, which lasts approximately 18 months, beginning in the summer of the year before the plan is released (e.g., the process for MTEP25 will commence in the summer of 2024). As part of the MTEP study cycle, transmission owners submit to MISO projects that are needed to address local reliability issues, load growth, generator interconnections, or other issues. MISO evaluates these projects through a collaborative, stakeholder driven process that includes the development of various planning models and the testing of the proposed projects within those models. At the end of the study process, MISO staff prepares a list of projects for inclusion in Appendix A of the MTEP, which is then forwarded to the MISO Board of Directors for full approval in December of the planning year. If a project is listed in Appendix A to the annual MTEP, it has either been approved as part of the current MTEP cycle or has been approved as part of a prior MTEP cycle, but is not yet fully implemented. Each MTEP report also includes an Appendix B, which consists of projects that MISO has not formally approved, but have been submitted as a possible solution to address an identified need based on current information and forecasts.

In this case, MISO has not designated the Project as proposed by MP (i.e., with construction of the St. Louis County Substation) as an approved project in Appendix A of the MISO MTEP. As of this writing (February 13, 2024), MP's HVDC Modernization

Project is currently only listed in Appendix B of the MISO MTEP, and as such, will need to undergo further evaluation and study by MISO in a future MTEP cycle. The same holds true if the Project were to be implemented with the Arrowhead Substation Alternative. In accordance with Attachment FF-ATCLLC of the MISO Tariff and ATC's Transmission Interconnection Guide, ATC would work with MISO and MP to develop and implement planning analyses for ATC's proposed configuration of the Project; ATC anticipates that these analyses would be of a similar nature to those that ATC has presented in this proceeding. Once the planning assessment is complete, ATC will submit information concerning the Project to MISO for evaluation, inclusion, and approval in the MISO MTEP, in accordance with the MISO Tariff and associated Transmission Planning Business Practices Manual (BPM). This type of project planning coordination with MISO and other neighboring utilities occurs in the normal course of business for ATC.

Q. Is there a way to expedite the MTEP review process?

A. Yes. Under Attachment FF of the MISO Tariff and MISO's Transmission Planning BPM, if a transmission owner like MP or ATC determines that system conditions warrant the urgent development of a project that will be jeopardized absent an expedited review, then MISO must use a streamlined process for reviewing and approving that project. This expedited review process can result in a decision within as little as 30 days of project submittal, unless a longer review period is mutually agreed upon.

C. <u>Response to MP Comments on Arrowhead Substation Alternative</u>

Q. Minnesota Power previously filed comments in this proceeding in opposition to the Arrowhead Substation Alternative. Did you review those comments?

A. Yes.

Q. What objections did Minnesota Power raise concerning the Arrowhead Substation Alternative?

A. MP's general position is that use of the Arrowhead Substation Alternative would pose unnecessary risk to the Project generally and would not meet the purpose and need of the Project. More specifically, MP asserted that (1) ATC would need to install a second 345/230 kV transformer at the Arrowhead 345/230 kV Substation, which could result in delays in project implementation due to the long lead time associated with procuring such a transformer; (2) it is unclear whether the Arrowhead PST can be retired or bypassed, and the need to procure an additional PST could introduce delays in Project implementation; (3) relocation of the point-of-interconnection for the Project to ATC's 345/230 kV Arrowhead Substation would cause power to flow into Wisconsin along ATC's Arrowhead-Weston 345 kV transmission line and in excess of the 800 MVA limit that the Minnesota Environmental Quality Board (EQB) imposed when it initially permitted the facility in 2001; (4) ATC and MP would need to execute a new transmission-to-transmission interconnection agreement to accommodate the new point-of-interconnection for the Project; and (5) the Arrowhead Substation Alternative provides no additional benefits for future transmission expansion and ATC is inappropriately attempting to inject issues into this proceeding that should be dealt with through MISO's regional transmission process.

Q. Generally speaking, do you find these objections to be credible?

A. No, I do not. In my opinion, none of the arguments that MP raised against the Arrowhead Substation Alternative are reasonable or persuasive.

Q. Let's discuss each of MP's arguments in more detail. How do you respond to MP's assertion that ATC will need to procure a second 345/230 kV transformer, which could delay implementation of the overall Project?

A. First, while I am not a procurement specialist, my understanding is that ATC can procure an additional 345/230 kV transformer in time to meet the Project's April 2030 in-service date. ATC witness Dustin Johanek discusses the procurement schedule for the Arrowhead Substation Alternative in his direct testimony. Second, and as I discussed earlier, ATC's existing 345/230 kV transformer can adequately and reliably serve the Project with west-to-east flows up to the HVDC Line's existing capacity (550 MW), even prior to the addition of a second 345/230 kV transformer. Thus, even if MP were able to achieve an in-service date for the Project that is earlier than April 2030, ATC can adequately serve the Project through the existing 345/230 kV transformer at the Arrowhead Substation.

Q. MP also asserted that it is unclear whether the existing Arrowhead PST can be retired. Do you agree with this assertion?

A. No. As ATC previously explained in response to an information request from DOC-DER, changes to the function and operation of the electric grid since the commissioning of the Arrowhead PST have rendered it obsolete for its original intended purpose.[28] To ATC's knowledge, while the Arrowhead PST has been operated manually for periodic testing of its phase-shifting capabilities, it has never operated automatically out of a need to prevent voltage instability. It was planned and placed into service prior to the emergence of the

[28] *See* Schedule 8.

MISO market and is now unused due to the real-time market dispatch and constraint binding process administered across MISO.

Furthermore, when ATC studied the Arrowhead Substation Alternative in the planning analyses I described earlier, it was assumed that the Arrowhead PST would be bypassed and retired. Those analyses show that the Arrowhead Substation Alternative performs as good or better than MP's proposal from a reliability perspective: the former does not produce more significant thermal overloads, insecure transmission facilities, or voltage instability than the latter. If MP considers its proposal reliable and adequate in light of these results, then the same is necessarily true of the Arrowhead Substation Alternative.

Q. How do you respond to MP's assertion that implementation of the Arrowhead Substation Alternative "would cause power flow through the Arrowhead 345 kV/230 kV Substation and on the Arrowhead–Weston 345 kV line to exceed the [Minnesota Environmental Quality Board (EQB)] 800 MVA limit established when the Arrowhead-Weston Project was originally permitted"?

A. MP is correct that implementation of the Arrowhead Substation Alternative could cause flows through the Arrowhead 345/230 kV transformer to exceed 800 MVA.[29] The existing transformer has a summer normal rating of 801 MVA, and if and when ATC procures the second transformer, it will have an identical rating, resulting in a combined summer normal rating of approximately 1600 MVA. However, there is no reasonable engineering basis for this limit to remain in place. ATC's understanding is that, when the EQB initially imposed the 800 MVA limit in 2001, it did so to mitigate potential noise impacts from the substation

[29] *See* Schedule 8.

on the surrounding community. As described in ATC witness Tobin Larsen's testimony, ATC has since installed 24-foot concrete walls around the perimeter of this substation and will be retiring the phase shifting transformer, which will help mitigate noise in the future; ATC could also conduct noise studies during detailed project engineering to evaluate whether sound from the substation will exceed applicable limits and (if so) develop mitigation measures, to the extent necessary and feasible.

Q. What is your response to Minnesota Power's assertion that relocating the point-of-interconnection for the Project to ATC's 345/230 kV Arrowhead Substation will send more power into Wisconsin, rather than to MP's customers?

A. This concern is overstated and out-of-touch with the reality of how the modern power grid functions. MP and ATC are members of MISO with interconnected transmission systems. MISO has functional control over those systems and is responsible for dispatching generation to serve load across the MISO region in a reliable and cost-effective manner. Given MISO's role in managing and coordinating the regional grid—as well as the fact that electrons don't respect the borders of a utility's transmission system—it is inevitable the power will flow from one transmission network to another.[30]

Furthermore, the steady state reliability analysis that ATC conducted demonstrates that network flows from MP's system to ATC's system would be similar under both alternatives. As shown in Schedule 5, both MP's proposal and the Arrowhead Substation Alternative result in similar levels of loading on certain Wisconsin transmission facilities, regardless of whether the Stinson PST is enabled or bypassed. However, of note, many

[30] Much like water running down a hillside during a thunderstorm, electricity will follow the path of least resistance. It is difficult to direct electricity from one specific location to another on the AC network, so it is very common for electricity generated on one utility's transmission system to flow to and through another utility's system.

potential overloads identified in the analysis are reduced or resolved with the Stinson PST enabled. Thus, the Stinson PST can be operated to control electrical flows into Wisconsin and, in any event, those flows are comparable regardless of whether MP or ATC's proposal is implemented.

Q. Do you agree with MP's assertion that negotiating a new transmission-to-transmission interconnection agreement with ATC presents a risk to implementation of the overall Project?

A. No. As mentioned in ATC witness Robert McKee's direct testimony, ATC and MP entered into a Transmission Interconnection Agreement in 2008. If the MPUC were to order implementation of the Arrowhead Substation Alternative, then ATC and MP would need to amend this agreement to reflect the implementation of that alternative, which would likely only take a few business days.

Q. How do you respond to MP's assertion that ATC is "pre-emptively and inappropriately bring[ing] issues into consideration as part of Minnesota Power's HVDC Modernization Project that should rightly be dealt with through MISO's regional transmission planning process and future project-specific regulatory filings."

A. This is simply incorrect. MP made this statement in response to ATC's claim that there is sufficient space in and around ATC's 345/230 kV Arrowhead Substation to accommodate potential future transmission expansion in the area. However, the only reason ATC made this claim is because MP asserted in its Application that its new St. Louis County Substation "will be designed with room for several future 345 kV line additions to accommodate regional transmission development in conjunction with increasing capacity

and utilization of the HVDC line."[31] ATC was not attempting to introduce into this proceeding issues that are more properly considered in MISO's planning process. It was simply pointing out that, like MP's proposed St. Louis County Substation, ATC's Arrowhead Substation also has sufficient space to accommodate future transmission development. If MP believes that it is not appropriate to address either substation's expansion capabilities as part of this proceeding, then it should not have raised that issue in its application.

Q. Finally, how do you respond to MP's assertion that the Arrowhead Substation Alternative does not meet the purpose and need of the Project?

A. This argument makes little sense. MP has stated that the fundamental purpose of the Project is to modernize aging assets associated with the HVDC Line to improve transmission system reliability and ensure continued, efficient delivery and expansion of MP's renewable carbon-free energy resources.[32] With respect to the new proposed 345 kV St. Louis County Substation, MP has stated that this facility is needed to interconnect the new converter station in Hermantown to the AC bulk electric transmission system.[33]

There is nothing about the Arrowhead Substation Alternative that would undermine these basic goals—to the contrary, use of ATC's 345/230 kV Arrowhead Substation affirmatively supports them, and even provides better capability to ensure continued, efficient delivery of MP's renewable carbon-free energy resources due to the inclusion of a second, parallel 345/230 kV transformer as part of the Arrowhead Substation Alternative. Again, ATC is not proposing an entirely new project or a systematic alternative to the

[31] *See* Application, at 11.
[32] Application, at 29.
[33] *Id.* at 3, 8.

project that MP has proposed. It has proposed a minor modification to one *aspect* of MP's overall Project—namely, the point at which it interconnects to the transmission system. In a nutshell, ATC is simply proposing that MP interconnect the Project through ATC's existing Arrowhead Substation, rather than through a new substation that would be constructed less than a mile away. Modifying MP's proposal in this way will not prevent MP from modernizing the aging assets associated with the HVDC Line, interconnecting the upgraded assets to the AC bulk electric transmission system, or continuing to serve its customers with carbon-free renewable energy from the HVDC Line; all of these goals still can and will be achieved if ATC's proposal is implemented.

Q. Does this conclude your pre-filed direct testimony?

A. Yes.

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