Prioritizing HVDC Integration:

Recommendations for Integrating HVDC into MISO's Energy, Auxiliary Services, and Capacity Markets

Executive Summary

The Midcontinent Independent System Operator (MISO) is in a position to create industry leading standards with its upcoming whitepaper and workshop on High-Voltage Direct Current (HVDC) transmission. This working group of energy non-profits partnering with HVDC developers and owners offers this document to help MISO align these efforts with the practical needs of developers, ensuring HVDC's transformative potential is fully enabled. The working group consists of representatives from Grid United, Minnesota Power, Pattern Energy, Invenergy, National Grid Ventures, Clean Grid Alliance, Southern Renewable Energy Association, and Telos Energy. We view MISO's initiative as a critical opportunity to shape the integration of HVDC to enhance grid reliability and improve market efficiency. For HVDC to succeed, MISO must prioritize clear market participation rules, streamlined interconnection processes, and recognition of HVDC's unique capabilities and development timelines. We appreciate MISO dedicating time and resources to enabling HVDC benefits and are eager to collaborate as a partner with MISO in this forward-looking effort.

Key Points

- HVDC integration offers MISO an opportunity to enhance grid reliability and resiliency and improve market efficiency.
- MISO's upcoming whitepaper and workshop are important for setting the stage to incorporate HVDC effectively into the day-ahead and real-time energy markets as well as the capacity auction and other ancillary services markets.
- Capacity accreditation for HVDC, especially for interregional ties, ensures reliability and supports resource adequacy planning.
- Clear market participation rules are essential to unlock HVDC's potential and encourage investment.
- Streamlined interconnection processes must accommodate HVDC's long development timelines and technical uniqueness.
- Recognizing HVDC's full value (including voltage stability, reactive power support, frequency support, black-start capabilities, enhanced transfer capability, etc.) requires updated market mechanisms and compensation models.

- Integrating HVDC lines into MISO's scheduling and dispatch systems is essential for efficient operations and real-time grid management. However, full dispatch control may not be needed for all lines, especially those connecting to external markets.
- Collaboration between MISO and HVDC developers and owners, supported by this working group, will drive practical solutions and long-term grid benefits.

Introduction / Background

The grid is undergoing significant change, with rising demand and an evolving generation fleet creating new reliability challenges. HVDC transmission offers an effective solution, excelling at long-distance and/or asynchronous grid energy delivery with lower transmission losses, enabling better resource management, and bolstering grid stability. These attributes make HVDC a vital tool for addressing reliability risks, optimizing market operations, and controlling costs -- goals central to MISO's mission as a leader in grid management.

This document provides constructive input for MISO's upcoming whitepaper and workshop. Our objective is to ensure these efforts prioritize reliability and efficiency, aligning with MISO's focus on maintaining a robust grid amid current pressures. Drawing from recent working group discussions of an ad-hoc HVDC stakeholder group, we offer a prioritized list of objectives for MISO's upcoming HVDC workshop and actionable recommendations to integrate HVDC effectively, supporting MISO in managing the grid of the future.

HVDC Developer Challenges

A. Resource Adequacy and Capacity Accreditation

- **Challenge**: Ambiguous capacity accreditation for HVDC, particularly interregional ties, creates uncertainty for reliability planning and investment, a top concern for developers and utilities given current market demand for HVDC manufacturing capacity globally.
- **Recommendation(s)**: Fairly accredit HVDC lines independently of source-side resources, drawing on UK and European models for possible solutions (not necessarily as best practice), while leveraging existing MISO frameworks (e.g., seasonal constructs, external assistance methodology) and external studies like NREL's interregional transmission analysis (Barriers and Opportunities to Realize the System Value of Interregional Transmission)
    - **Detail**: Calculate a MW accreditation value to reflect HVDC's resource adequacy value, mirroring generator-like accreditation with performance-based mechanisms during observed MISO RA hours.
    - **Accreditation Recommendations**:
        - **Accreditation for Resources Enabled by HVDC**:
            - **Recommendation**: MISO should adopt a hybrid accreditation approach that accounts for both capacity contracted to the HVDC line and resource-agnostic capacity enabled by the line's increased transfer capability between MISO zones or neighboring regions with differing risk profiles.

        - **Contracted Capacity**: Resources directly contracted to the HVDC line should be treated as firm internal resources, counted toward the sinking zone's Planning Reserve Margin Requirement (PRMR), and accredited based on the exporting zone's capacity accreditation. For example:
            - **Ex. 1)** Wind from Southwest Kansas with high resource potential would reflect its locational performance when sinking into Illinois.
            - **Ex. 2)** Solar from Illinois, benefiting from a different time zone, would reflect its availability when sinking into Indiana.
        - **Accreditation Process**: Simulate these contracted resources in MISO's Deliverability Loss of Load (DLOL) model to determine their accreditation value, integrating seamlessly into existing methodologies.
    - **Justification**: This approach captures the location and time differences of HVDC-enabled resources to ensure that contributions to reliability are accurately reflected in MISO's planning process.
- **HVDC-Enabled Pool Capacity Accreditation**:
    - **Recommendation**: Capacity imported via HVDC from a pool of resources in an External Resource Zone should receive an accreditation value based on expected availability of resources deliverable by way of the HVDC Resource.
        - **Pool Capacity**: For capacity not directly contracted but deliverable through an HVDC resource, assign a deliverable Pool Capacity up to the limit of the HVDC line carrying capacity will receive an accreditation value.
        - **Accreditation Process**: Use the MISO DLOL model to simulate the availability of pool resources deliverable via HVDC.
        - **Benefits**: Recognizes load and resource diversity not specifically tied to the HVDC line but enabled by the HVDC line.
- **Hybrid Accreditation Approach**: Includes both contracted capacity and Pool Capacity and will be a combination of accreditation approaches:
    - **Net Pool Capacity Accreditation = Pool Capacity – Contracted Capacity**
    - **Hybrid Capacity Accreditation = Pool Capacity + Contracted Capacity**
    - **Contracted Capacity**: Resources will be treated as firm internal resources, and counted towards sinking Zone(s) PRMR but will reflect capacity accreditation of exporting zone.
    - **Pool Capacity:** Account for accreditation value for deliverable resources by way of HVDC from Internal or External Resource zones.
    - **Justification**: MISO does not acknowledge differences in resource potential external to, and within the vast MISO footprint for which HVDC

has the unique capability to provide firm imports into MISO LRZ's. This is depriving market participants of value during emergency events, as well as in day-to-day operations. A hybrid approach acknowledges differences in both contracted capacity, and resource agnostic models of HVDC projects.

- **Needs**: Clarity of valuation to incent investment.
- **Clearing Prices for HVDC-Enabled Generation**:
  - **Recommendation**: MISO should apply clearing prices for HVDC-enabled generation based on the zone where the capacity sinks into, rather than treating it solely as an external resource. To facilitate this, a new resource class in Module A, termed "HVDC Enabled Capacity," should be defined.
    - Internal or External HVDC Enabled Capacity that: (i) has direct interconnection facilities to a substation that contains the terminal of a transmission line under the Transmission Provider's functional control; (ii) will schedule in response to notification by the Transmission Provider during a declared Energy Emergency solely from unit(s) connected to such substation; and, (iii) whose Unforced Capacity offered into MISO may be accommodated on those transmission line(s) under the Transmission Provider's functional control.
  - **Granular Clearing Price Accountability**: When HVDC injections result in imports to multiple MISO zones, clearing prices for capacity should align with Local Clearing Requirements and reflect the sinking zone's price.
  - **Justification**: HVDC provides deliverable capacity comparable to Border External Resources or Coordinating Member Resource types, yet it is currently treated as an external resource. This adjustment ensures fair pricing and recognizes HVDC's role in enhancing zonal reliability.

- **HVDC Methods and MISO Benefit**:
  - **Local Capacity Transferability**: HVDC has exceptional transfer over long distances as shown by Minnesota Power's Square Butte and Manitoba Hydro's Nelson River DC transmission systems. Leveraging HVDC efficiency and controllability to connect generation-rich regions to distant load centers with minimal losses (3.5% losses per 1000km at 800 kV vs 6.7% of similar AC transmission). Prioritize firm transmission agreements, enabling receiving zones to count HVDC-delivered power as dependable capacity.
  - **MISO Benefit**: Creates a signal to incent participant-funding of new interregional transmission. Consistency with existing treatment of external connections. Improved reliability by fairly accounting for HVDC's resource adequacy value during peak demand and emergencies. Increase in capacity market competition, clearing of lower cost resources relative to market with less resources.

B. Recognition of HVDC's Full System Value

- **Challenge**: MISO's market only compensates HVDC for energy transfer, ignoring its ability, or potential ability, to provide attributes contributing to system adequacy, flexibility, and system stability as outlined in MISO's 2023 Attributes Roadmap.

- **Recommendation**: Assess how existing market mechanisms can be adapted to recognize additional capabilities HVDC can provide (such as spinning reserves or demand response), drawing on studies like "Improvement of Power System Stability by Using VSC-HVDC." (Improvement of power system stability by using a VSC-HVdc)
    - **Detail**: Identify applicable mechanisms (e.g., spinning reserves, black-start payments) and quantify HVDC's contributions through targeted studies, ensuring no double-counting of benefits across services, including capacity.
    - **Short-Term or Long-Term Recommendation**:
        - **Short-term**: Evaluate HVDC's ancillary service benefits, aligning with MISO's current frameworks.
        - **Long-term**: Establish permanent market mechanisms over 2-3 years for HVDC ancillary services; Explore tailored mechanisms only where gaps persist building on MISO's established processes.
    - **Needs**: Incentives to deploy HVDC with advanced capabilities.
- **HVDC Methods and MISO Benefit**:
    - **MISO Benefit**: Enhances reliability and reduces reliance on expensive ancillary services. Compensating HVDC for services like voltage stability and black start capabilities incentivizes investment in these technologies, bolstering grid resilience to better accommodate variability from renewable sources. HVDC benefits align with MISO's reliability imperative and ensures economic viability, making it a strategic investment in long-term grid reliability.

C. Efficient Scheduling

- **Challenge**: MISO's current scheduling processes lack flexibility for real-time and day-ahead adjustments, limiting HVDC's ability to optimize its fast-response capabilities.
- **Recommendation**: Explore scheduling options that allow HVDC to operate similarly to generators, enhancing its flexibility within MISO's market framework.
    - **Detail**: Evaluate how real-time and day-ahead scheduling can leverage HVDC's controllability.
    - **Short-Term or Long-Term Recommendation**:
        - **Short-term**: Identify existing gaps in MISO's scheduling processes and propose adjustments.
        - **Long-term**: Over 2-3 years, integrate HVDC-specific scheduling rules into market operations, refining based on operational data.
    - **Needs**: Predictable valuation to secure financing.
- **HVDC Methods and MISO Benefit**:
    - **MISO Benefit**: Enhances grid efficiency and reliability by optimizing HVDC's responsiveness during fluctuating demand or supply conditions.

D. MISO's Need for Functional Control

- **Challenge**: Without systems to integrate HVDC lines into MISO's market systems and operational frameworks, MISO cannot fully leverage them for real-time grid management.
- **Recommendation**: Identify systems and protocols, including HVDC OEM control and SCADA-based dispatch technologies, needed for MISO to integrate HVDC lines.

    - **Detail**: Define operational data and control points that are needed to determine flows and rights control interfaces and operating procedures, building on real-time load management insights.
    - **Short-Term or Long-Term Recommendation**:
        - **Short-term**: Identify key control parameters (e.g., data points, interfaces), using Minnesota Power's HVDC line as a case study; Develop interim operating protocols for HVDC.
        - **Long-term**: Build a comprehensive control system over 2-3 years, fully integrating HVDC into MISO's grid operations; Define permanent protocols by year 3, aligning with real-time load management needs.
    - **Needs**: Clear operational frameworks for integration.
- **HVDC Methods and MISO Benefit**:
    - **MISO Benefit**: Enhances grid reliability, aligns with LMR discussions for real-time load management, and supports operational efficiency. Functional control is essential for leveraging HVDC's full potential, especially during emergencies or peak demand. Improves reliability and efficiency, especially during peak demand or outages, see section 3.3.4 of Barriers and Opportunities to Realize the System Value of Interregional Transmission.

E. Project Development Challenges Under MISO's No-Change Policy

- **Challenge**: MISO's work on Attachment GGG at the IPWG, which addresses related transmission service coordination, is important and appreciated. However, MISO should build on this effort and reconsider the no-change policy post-submission as it is impractical for HVDC. The existing policy forces costly resubmissions for adjustments like shifting from 1,500 MW to 1,800 MW for a single study.
- **Recommendation**: Consider options to allow flexibility for making changes and enhance coordination with transmission services, building on MISO's ongoing work like Attachment GGG and Module B updates.
    - **Detail**: Assess updates to Module B for permissible modifications and evaluate how HVDC can align with transmission service frameworks and MISO's attribute discussions (e.g., ramping, quick-start potential).
    - **Withdrawal Rights**: MISO should revise Attachment GGG to explicitly include energy withdrawal rights from the MISO market. This update should apply to both future projects and those currently in the queue under Attachment X. Additionally, MISO should integrate transmission service to be used in addition to, or as a replacement for, injection and/or withdrawal rights.
    - **Module B**: MISO should prioritize and expedite updates to Module B to better support MHVDC projects, providing a detailed scope for the changes that MISO is contemplating tied to Module B. As part of this effort, MISO should establish a mechanism within Module B and related tariffs, such as Attachment GGG, to accrue transmission credits under a TCA for upgrades constructed through the transmission service process.
    - **Site Control**: MISO should be careful in developing site control requirements for HVDC projects entering the interconnection queue. These requirements need to be tailored to

balance the "first ready, first served" principle with the long lead times in HVDC development.
    - **Needs**: Lower costs and delays for project adjustments.
- **HVDC Methods and MISO Benefit**:
    - **MISO Benefit**: Speeds HVDC deployment, boosting reliability and queue efficiency.

F. Parallel Intra- and Inter-Regional HVDC Planning

- **Challenge**: MISO prioritizes intra-regional HVDC integration first, delaying inter-regional planning despite HVDC's strength in long-distance transmission.
- **Recommendation**: Shift to a holistic HVDC optimization strategy by studying intra- and inter-regional applications in parallel, treating them as complementary components of a unified, technology-agnostic transmission framework.
    - **Needs**: Clear market signals to support investment in HVDC projects, regardless of regional scope.
- **HVDC Methods and MISO Benefit**:
    - **MISO Benefit**: Enhances reliability through resource diversity and improves efficiency with reduced transmission losses.

G. Import / Export Charges

- **Challenge**: Potential import/export charges on HVDC lines crossing MISO boundaries, without clear cost recovery mechanisms, creates financial uncertainty.
- **Recommendation**: Evaluate options to import/export charges for HVDC, aligning with MISO's transmission cost allocation practices and considering differentiated treatment of imports, firm exports, and non-firm exports.
    - **Detail**: Review current tariff structures and assess exemptions or adjustments for HVDC, distinguishing between import charges (e.g., limited to HVDC link usage) and export charges (e.g., including system usage costs). Explore a tiered approach where firm exports incur higher costs due to reserved capacity, while non-firm exports leverage excess capability at little to no additional charge
    - **Needs**: Predictable valuation to secure financing, with clear differentiation between import and export cost structures to reflect system usage and capacity commitments.
- **HVDC Methods and MISO Benefit**:
    - **MISO Benefit**: Encourages HVDC development by aligning charges with system benefits, enhancing regional reliability and resource sharing (e.g., leveraging excess generation via non-firm exports) without undue cost burdens.

Key Priorities for MISO's Whitepaper and Workshop

Below are recommendations for 1) what needs to be included in MISO's whitepaper and 2) a recommended workshop discussion areas to address the HVDC integration concerns.

Content for MISO's Whitepaper

The whitepaper should provide a comprehensive roadmap for integrating HVDC into MISO's grid, addressing key challenges and outlining actionable steps and timelines. The following elements are recommended for inclusion:

- **Framework for HVDC Interconnection and Project Adjustment:** Updates to Module B allowing immaterial changes (e.g., MW tweaks) without resubmission, drawing on developer examples like 1,500 MW to 1,800 MW shifts. Include interim tariff provisions aligned with FERC regulations to enhance coordination and flexibility. Outline a policy to streamline interconnection.

- **Valuation of HVDC's Full Capabilities:** A study outline to quantify benefits like voltage stability, spinning reserve replacement, and black-start capabilities, referencing sources like "Improvement of Power System Stability by Using VSC-HVDC." Propose pilot market products to compensate these services. (Improvement of power system stability by using a VSC-HVdc)

- **Guidelines for HVDC Capacity Accreditation:** Accreditation guidelines for weather-diverse and interregional systems, supported by NREL's interregional transmission analysis.

- **Systems for MISO Integration of HVDC Lines and Control of Intra-Market HVDC Lines:** Identification of key control parameters (e.g., data points, interfaces) and interim operating protocols, using Minnesota Power's HVDC as a case study. Detail steps to integrate HVDC into real-time grid management.

- **Parallel Approach for Intra- and Inter-Regional HVDC:** A study of inter-regional HVDC benefits, emphasizing low-loss, long-distance transmission. Propose a unified approach to HVDC that considers both intra- and inter-regional applications as a single technology.

- **Implementation Timeline and Milestones:** A schedule of short-term (6-18 months) and long-term (2-4 years) actions for each area, ensuring phased progress toward full HVDC integration.

Workshop Recommended Discussion Areas

MISO has planned two workshops in 2025 to advance HVDC integration: a Q2 session (April/May) for information gathering and stakeholder presentations on challenges and opportunities, and a Q4 session to review whitepaper findings. To support these efforts, we offer the following topics as a starting point, based on working group discussions. These are intended as flexible suggestions to facilitate MISO's planning, not a fixed agenda. We look forward to assisting with speakers or additional input as needed.

Brief Overview of MISO's HVDC Work

- **Need**: Stakeholders benefit from understanding MISO's current and past HVDC efforts.
- **Suggestion**: Invite MISO to present an overview of ongoing work (Attachment GGG updates) and prior studies (Matt Tackett's 2021 technical presentation).
- **Value**: Provides context, aligns stakeholder input with MISO's progress, and identifies collaboration opportunities.

Resource Adequacy and Capacity Accreditation

- **Need**: Fair accreditation is critical for HVDC investment and reliability planning.
- **Suggestion**: Discuss accrediting HVDC lines independently, using UK/EU models and NREL's analysis (Barriers and Opportunities to Realize the System Value of Interregional Transmission), with stakeholder presentations. Additionally, workshops should explore the application of clearing prices based on sinking zones.
- **Value**: Provide least cost capacity resources to meet demand.
- **External Presentation**: Suggest MISO invite Derek Stenclik (Telos Energy) to present and moderate a discussion. Derek is a trusted expert and has been leading an ESIG working group on this topic.

Valuing HVDC Capabilities and Integration

- **Need**: Valuation gaps and lack of integration limit HVDC's deployment and real-time management potential.
- **Suggestion**: Explore adapting existing market mechanisms (e.g., spinning reserves) to value services like voltage stability and black-start, and assess control parameters.
- **Value**: Strengthens reliability and efficiency by leveraging HVDC's capabilities within MISO's systems.

Transmission Integration and Project Flexibility

- **Need**: Rigid processes, limited transmission integration, and inflexible scheduling delay HVDC projects.
- **Suggestion**: Review flexibility options for Module B, Attachment GGG coordination, and generator-like scheduling, building on MISO's IPWG efforts and examples.
- **Value**: Faster development timelines to support reliability goals.

Intra- and Inter-Regional Approach to Grid Planning

- **Need**: A unified approach maximizes HVDC's benefits across local and distant resources.
- **Suggestion**: Evaluate HVDC's role in both scopes, drawing on regional examples like UK Interconnection.
- **Value**: Enhances resource diversity aligning with reliability objectives.

Addressing Potential MISO Concerns

Resource Adequacy Value: MISO has expressed concern that HVDC lines, without firm generation commitments, may not reliably meet capacity needs during peak demand. But accrediting HVDC lines independently, as practiced in the UK (e.g., interconnectors with NRIS injection rights), can address capacity needs directly. Studies like NREL's Barriers and Opportunities to Realize the System Value of Interregional Transmission and ongoing Telos work showing near-full capacity credit for ERCOT-Southeast lines demonstrate HVDC's reliability contribution, even without source-side commitments, using performance mechanisms to ensure accountability.

Cost: Revising tariffs and systems requires investment, but long-term savings through lower transmission losses, reduced ancillary service costs, and avoided outages justify the expense. The cost of grid disruptions far outweighs proactive integration.

Complexity: MISO might view aligning HVDC with market rules, scheduling, and interregional seams as complex, but phased implementation (e.g., pilot programs through Minnesota Power Square Butte HVDC Transmission line) mitigates risks. Leveraging existing stakeholder input simplifies the process.

Reliability: Far from threatening stability, HVDC enhances it with proper integration. Its black-start capabilities are effective tools for managing outages and peak loads.

Conclusion

HVDC transmission offers MISO a powerful solution to strengthen grid reliability, provide more capabilities to market operations, and manage costs for future energy challenges. By prioritizing practical market rules, streamlined interconnection processes, and recognition of HVDC's unique strengths in its whitepaper and workshop, MISO can enable these benefits and be a leader amongst their peers.

We urge MISO to adopt these recommendations as HVDC integration supports its core mission of a reliable and efficient grid. Our working group is eager to partner with MISO, bringing technical expertise and insights from projects like the Southern Spirit Transmission, Grain Belt Express, and Minnesota Power's Square Butte line. We commend MISO and look forward to active collaboration to build a stronger grid for the future.