INTRODUCTION

Manitoba Hydro needed to remove a common point of failure in its transmission network in order to ensure reliable transmission of renewable, clean energy. To achieve this, Manitoba Hydro undertook the massive task of designing and constructing the Bipole III High-Voltage, Direct Current (HVDC) Project. During construction, Bipole III was one of the largest and most technologically complex energy projects on the continent. Requiring special expertise for this one-of-a-kind project, Manitoba Hydro assigned the role of Owner's Engineer to Teshmont and its subconsultant Stantec, henceforth referred to as "the Team".

Over the span of eight years, the Team supported Manitoba Hydro through a wide range of engineering services on this important energy project that ensures reliable energy transmission for the citizens of Manitoba for generations to come.

The Team provided engineering service to Manitoba Hydro related to five distinct project phases, namely: Preliminary Engineering; Specification Development; Bid Evaluation; Design and Manufacturing; and Construction and Commissioning. The project's Keewatinohk and Riel Converter Stations successfully came on line in July of 2018.

The breadth and complexity of this project necessitated the Team overcoming many challenging day-to-day obstacles over the course of 250,000-plus hours of service. To illustrate these challenges, the Team presents a high-level overview of each of the five phases of the project, along with"case studies" that provide snapshots of the project's complexity during each phase and the innovative solutions proposed by the Team to overcome them. Through a collaborative approach, ingenuity, and continuity of service throughout the lifespan of the project, the Team has helped Manitoba Hydro reach their project goals and, ultimately, ensure renewable energy access for Manitobans.

PHASE 1 – PRELIMINARY ENGINEERING

From the time Manitoba's second HVDC bipole went into service in 1985, Manitoba Hydro began planning for Bipole III. Although the existing bipoles had the capacity to serve Manitobans well into the future, there was a critical weakness to the system. Both existing bipoles travelled along essentially the same route and terminated in one converter station, Dorsey, in southern Manitoba. Together, Bipole I and Bipole II transmitted over 70% of the Province's power to Winnipeg and surrounding regions.

Manitoba Hydro was keenly aware that a serious weather event at any time and at any point along the 900 km long transmission line route, or a significant failure at Dorsey, could have a devastating impact on Manitoba's citizens and industries, especially in months of extreme temperature ranges, either cold or hot.

Repair of the HVDC transmission system in such scenarios could have taken significant time to complete, due to the unique nature of some of the equipment and limited access to parts of the transmisison lines in remote northern regions. Secondary power would need to be sourced through the purchase of coal and gas-fired power from neighbouring utilties, inducing significant economic and environmental costs.

While Manitoba Hydro was aware of the critical necessity of introducing a third bipole to the system, it was also aware that adding another bipole to the system would cost billions of dollars, require coordination across multiple disciplines, and involve extensive studies to properly integrate with existing controls and systems. In early 2010, 25 years after the second bipole had gone into service, the conditions to proceed aligned and Manitoba Hydro formed a plan to execute the project. The company turned to the team of Teshmont, for its global HVDC expertise, and Stantec, for its multidisciplinary capacity and northern Manitoba engineering experience. Together, Teshmont and Stantec formed the Team that would provide Owner's Engineer services to Manitoba Hydro and see the project through to completion.

Case Study 1

The Challenge

A key challenge for the Team was to capture the existing expertise spread out within Manitoba Hydro over the last 25 years and find innovative solutions that would address the diverse needs of the multiple stakeholders.

The 25-year gap between the design of the original and the new bipole systems meant that knowledge gained on the earlier projects were highly dispersed within the organization. Bipoles I and II had gone into service in 1971 and 1985, respectively, and each project represented important milestones both for Manitoba Hydro and the HVDC industry globally. Of the original Manitoba Hydro team that had worked on those bipoles, many had retired, some had moved to other companies, and those who remained had moved to a variety of different departments, distributing their expertise.

This distribution of expertise meant that the Team would need to gather each department's knowledge and preferences and find technical solutions that best optimized the needs of all stakeholders.

The Solution

The team's first step was to gain buy-in from all stakeholders on overriding project drivers. To achieve this, the team facilitated a series of important project chartering sessions for each of the core technical contracts to identify the key project drivers. These drivers would guide the Team's approach throughout the duration of the project, from tendering strategy to close-out.

After identifying the high-level goals of the project, the Team set out to determine and articulate a multitude of individual technical details. Given the complex nature of the project and the wide range of disciplines included, the Team broke down the work into over 50 separate technical memoranda covering the complete scope of the project. The Team then worked collaboratively with experts within Manitoba Hydro to gain an understanding of their work place procedures, preferences, and lessons learned in the field. The Team facilitated workshops to find commonality and propose alternatives informed by current industry practice and the Team's own technical expertise were used to supplement Manitoba Hydro's internal expertise in order to ultimately develop and document a set of technical requirements for the project. Findings were reviewed with subject matter experts and Manitoba Hydro stakeholders, and, ultimately, distilled into a single, design-basis memorandum. The Team maintained a record of the reasons for all decisions so that knowledge gained in this work would be available for future Manitoba Hydro engineers.

Engaging subject matter experts early in the process allowed the Team to streamline subsequent work. It also built the trust and understanding needed to make decisions on behalf of the various stakeholders in the

later stages of the project, when scheduling commitments would not allow for extensive consultation processes. For example, even in the last stages of the project after Bipole III had gone into service, the Team continued to provide close-out support. Manitoba Hydro at that time was considering the use of a metallic return operating mode (that utilizes the neutral line of the transmission system in the event that one pole is unavailable) under a unique set of system conditions. In response, the Team was quickly able to provide Manitoba Hydro the consensus and rationale behind the technical decisions made at the beginning of the project on that subject.

In addition to working with Manitoba Hydro to compile the technical requirements and preferences that would form the building blocks for all future technical work, the Team took on early design work to address the technical challenges of the project.

Early design work included: site selection; access study to move twenty 250-ton (12,000mm x 3,950mm x 4,950mm L/W/H) converter transformers; site drainage; risk management; and project implementation plan, to name a few examples.

One of the unique challenges that this design work needed to consider was Manitoba's northern climate.

Case Study 2

The Challenge

At the northern site, several existing climatic and geotechnical issues needed to be considered in the design of underground infrastructure. It was critical for the Team to define a common set of requirements for the underground infrastructure suitable to extreme climate conditions. This would ensure that pipes and other underground utilities could be procured and installed in a standardized manner by the multiple contractors who would be working on the project.

Air temperatures in northern Manitoba can reach as low as -50°C, and frost depth, without considering the permafrost, can be as much as 4.2m. With such cold ground conditions, technical requirements for the underground infrastructure designs needed to identify reliable freeze-prevention measures in a way that could be competitively bid by multiple contractors.

Not only did the cold need to be considered, but the northern converter station site contained discontinuous permafrost. Due to the site activities, the Team anticipated that permafrost would degrade over time, meaning that settlement could be highly variable throughout the site. The Team's geotechnical specialists determined that the ice-rich soils could result in over 1m of settlement.

To compound matters, Manitoba Hydro requires and expects its stations to be operating for many years due to *the capital outlay needed to build them and their critical importance in providing energy to Manitobans. As such, the target for any product being installed was a minimum 50-year life span.*

The Solution

The Team analyzed several freeze-prevention measures and ways to counter the potential settlement, and discussed the benefits and disadvantages of each with Manitoba Hydro. The measures analyzed include: depth of bury; pipe insulation; water circulation; heat injection at source; heat recovery; heat trace; flexible pipe systems; fittings to provide flex and expansion/contraction; and shear locations. The Team decided to move forward with a multi-faceted approach that ensured redundancy and reliability. For freeze prevention, all designers involved in the project were required to use in their designs a mitigating depth of bury, pipe insulation, and two of: heat injection at source, heat trace, redundant heat trace, and circulation. To account for settlement, the EPC teams were directed to use flexible pipe systems, provide flex at building connections, and provide expansion/contraction/ deflection fittings at all connections to piled infrastructure.

PHASE 2 – SPECIFICATION DEVELOPMENT

The second phase of the project built upon the success and stakeholder buy-in of the first phase, and was used to translate the technical details into technical specifications. Specifications were created for the HVDC converter stations, the 230 kV switchyard at the northern site, and the synchronous compensator facility, as well as for civil development of the northern converter station, and for the several auxiliary and process buildings at each station.

Each of the specifications combined the work of multiple disciplines, and each presented unique challenges of its own. For example, the synchronous condensers specification needed to encourage competitive bids, yet nowhere in the world was any company currently building the large synchronous condenser machines to the specifications Manitoba Hydro required.

Case Study 3

The Challenge

Manitoba's electrical system is unique in that 900 kms separates the bulk of Manitoba's generation in the north from its primary load in the south. The DC link between systems results in essentially two electrically separate AC systems. In the event of a fault in the southern system, the inertia created by the generation in the north is not available to stabilize the southern system.

Further, as a result of the DC to AC conversion process at the southern Bipole III Converter Station, additional reactive power is required. To counter these effects, Manitoba Hydro requires the use of synchronous condensers, which are large rotating machines, to inject reactive power and bring inertia into the southern electrical system.

As a result of the unique conditions needed to warrant their use, synchronous condensers are not common to begin with, and none are production-line built at the 250 MVAR size required by the Bipole III system. This led to a small pool of potential bidders.

The Solution

The Team carried out a technology review to ascertain if an innovative solution could increase the number of possible suppliers for competitive tendering. The review resulted in the discovery and recommendation that both salient-pole machines and turbo-generators (two-pole machines) would be appropriate for this application, allowing for a wider range of machines with similar characteristics that could then be modified to meet project requirements. Further, this allowed for both hydrogen-cooled and air-cooled machines to be bid. Moving away from a dependency on hydrogen as a cooling agent gave Manitoba Hydro additional potential benefits. For weather-protection, air-cooled machines could be installed inside a building without introducing concerns related to possible hydrogen leaks. Although the contractor who was ultimately selected provided a traditional design, the Team's innovative solution nonetheless resulted in multiple competitive bids being offered.

While the primary challenge in putting together the synchronous condenser specification was accommodating a specific set of technical requirements, in contrast one of the challenges in putting together the converter station specification was how to incorporate the vast quantity of requirements into a comprehensive, biddable package.

Case Study 4

The Challenge

The HVDC Converter Building houses critical, high-voltage power electronics and equipment and associated computer-controlled protection and control systems. This specialized facility is a 450m-long, three-storey facility, made up of seven diverse units. Developing the concept and requirements for this facility required input from the entire project team and every discipline. The goal was to determine the facility requirements in enough detail so that Manitoba Hydro's requirements would be met, while providing flexibility for the contractor to come up with its own cost-effective solution.

The Solution

The process for gathering requirements related to the building started with review of the existing Manitoba Hydro Dorsey facility and similar facilities within the industry. Options for placement of the converter transformers outside the building needed to be reviewed, as this directly impacted design elements. Options for valve hall locations, valve types, and ways to achieve redundancy (from the primary systems to the sub-systems supporting them) in case of failure were reviewed. The Team worked with Manitoba Hydro on multiple iterations to refine the concept and develop technical requirements for the facility. The Team began the process by holding chartering sessions with subject-matter experts and end-users to determine high-level requirements. The Team then developed "building blocks" which were comprised of groups of rooms related to the different uses of the facility. The Team then took these blocks and created physical representations that the stakeholders could manipulate in hands-on sessions, to allow them to physically understand and manipulate the space. From this, concept plans were developed. These concepts were further refined through the Team's process of technical memoranda development, meeting with different groups within Manitoba Hydro, review and response to formal reviews and comments, and additional detailed work. The end result was technical specifications identifying architectural, structural, mechanical, and electrical requirements, and room data sheets for every room that included all of the minimum room requirements. This critical process maximized bidder flexibility while ensuring that project needs would be met.

PHASE 3 – BID EVALUATION

The three primary contracts - converter stations, northern switchyard, and synchronous condensers - were tendered with a staggered roll out. The timing was based on expected duration of each contract to reach its in-service date and included the added benefit of allowing the Team to apply knowledge gained from each tender to subsequent tenders. Due to the complexity of the project and the number of contracts, there was an interdependent technical reliance between the contracts. By staggering the tenders, the Team was able to reduce some of that interdependency and standardize the technical approaches. This gave Manitoba Hydro the benefit of executing multiple contracts optimized to reduce overall cost, while still receiving a unified technical solution in the end. The Team's technical oversight during this and subsequent phases was essential in providing a seamless and high-performing end product.

Once again, the size and complexity of the project presented the next challenge: how to fairly evaluate the different bids and inevitable non-conformances across a wide range of disciplines and stakeholder interests. This was especially true for the converter stations, which constituted the largest portion of the work.

Case Study 5

The Challenge

The HVDC Converter Stations contract represented over $800 million worth of work alone, and via a pre-qualification process undertaken by the Team, only three bidders were considered eligible to bid. Although reliability was the overall project driver, Manitoba Hydro wanted innovative solutions that could provide substantial life cycle cost savings. With many possible design possibilities, it was important to develop a robust and transparent process that was fair to all bidders.

The Solution

The Team developed a multi-step, fully documented process that involved multiple reviewers and unified checklists and criteria. The approach allowed reviewers to focus on their areas of expertise and identify issues and impacts of decisions. Each of those areas was pre-weighted and agreed to by the stakeholders as being representative of the relative importance and impact to the project. Non-compliance within the bids was evaluated by utilizing the Team's industry knowledge to determine real-world dollar impacts that could then be translated into weighting criteria, allowing Manitoba Hydro to compare technically different offers on equal footing. This enabled a multi-discipline review team of over thirty people to efficiently score and aggregate the results into one comprehensive value that was both representative and transparent.

With the process defined, the Team took a lead role in responding to bidder inquiries. Hundreds of questions and clarifications were submitted that needed to be reviewed. Often, answers could be provided quickly due to the initial documentation done in the first phase. In some instances, the Team needed to quickly review

technical alternatives and advise Manitoba Hydro on their acceptability. The Team worked closely with Manitoba Hydro, in some instances having several meetings per day to discuss issues and develop resolutions and responses. The goal was to help bidders understand the nuances of the project and have adequate information on the existing conditions and required finished products to provide bids conforming to the requirements of the tender documents.

Once tenders closed, the evaluation work began. For each tender, the Team provided a report identifying the evaluation criterion, strengths, and weaknesses of the bids with respect to conformance to the technical requirements and a comprehensive list of negotiation items for each vendor.

As noted, there were non-conformance items within each bid that needed to be addressed so that Manitoba Hydro requirements could be met. Once the preferred bidder was selected, the Team had a limited period of time to complete negotiations on non-conformance items and proposed alternatives, and, ultimately, come up with a conformed technical specification. For the preferred HVDC proponent alone, over one hundred technical items were identified, needing further discussion and negotiation at the outset.

Case Study 6

The Challenge

It was critical for Manitoba Hydro to obtain the most *cost-effective solution possible, but, most importantly, it needed to gain a reliable system that would serve Manitobans well for the next fifty-plus years. The Team was aware that the longer the negotiation process took, the more limited Manitoba Hydro's negotiating leverage would be, due to the fact that, as in-service dates loomed closer, the ability to negotiate with alternative vendors lessened. As such, proposals and counter-proposals needed to be technically evaluated with minimum turnaround time.*

The Solution

The initial list of over one hundred negotiable items was first triaged into "non-complaint," "requiring further clarification," and "acceptable to be left to design stage" categories. Priority items were then assigned to teams via an action item list shared with the bidder. Where possible, documentation from the first phase was used to streamline decisions. Where more complex, the Team needed to write multi-page technical reports outlining the issues, possible solutions, and impact to the overall project. The reports were then reviewed with the stakeholders, modified as needed, and used to drive negotiations. Once a technical solution had been agreed to, the team then incorporated the information into a conformed technical specification for approval by Manitoba Hydro and the HVDC proponents. As a result of the Team's organizational planning, coordination across disciplines, and technical input, Manitoba Hydro was able to efficiently finalize the contract within the required timeframe to maintain the project schedule.

PHASE 4 – DESIGN AND MANUFACTURING

The design review was the most hectic time of the project and required the greatest work force to support it. As the equipment contractors developed their designs, the team was responsible for review of the submissions. The sheer volume and turnaround time presented a challenge.

Case Study 7

The Challenge

The team was responsible for providing review of the design submissions and comments back to the design teams within three weeks or less in order to maintain project schedule. Not even accounting for the multiple revisions issued of each drawing over the course of the project, over 50,000 unique drawings were submitted by the contractors, with the majority arriving within a two-year period. This, in turn, triggered Requests for Information (RFIs) from and to the contractors, which required responses within less than a week. In total, the Team sent and received over 9,000 items of correspondence in the form of RFIs over the course of the project. Given that these submissions and requests occurred largely over a two-year period and the three projects had significant overlap of submissions, the design review team was required to be large, knowledgeable, and efficient. Further, the technical interdependence of the contracts meant that decisions made in one area of the project could easily impact other contracts and disciplines. Therefore, not only did the Team need to handle the sheer volume of technical work, but also keep the entire technical team aligned around emerging decisions.

The Solution

To address this, the Team developed and implemented a standardized system to handle documents and review comments and correspondence across all contracts. Review comments were logged, responses tracked across revisions, and final resolutions recorded. Weekly in-person meetings between the Team and Manitoba Hydro's project leads were essential to maintaining awareness of all the moving pieces. In addition, the team met weekly with the contractors themselves to ensure that issues could be caught and resolved. To ensure continuity, all technical decisions were passed through the Team's core group of five project engineers. These engineers met and communicated daily and were responsible for distributing and gathering information to and from the team of reviewers while maintaining oversight.

Also essential to the ultimate success of the project was the trust and relationship built between the Team and Manitoba Hydro. Confidentiality agreements allowed the Team to work in step with Manitoba Hydro's commercial team, flagging issues early and providing advance notice to each other of potential impacts in each of their scopes. The Team's personnel embedded at Manitoba Hydro offices were often entrusted with providing responses to issues on behalf of Manitoba Hydro.

In addition to the design review process, the Team provided quality assurance services during Factory Acceptance Testing (FAT), and related international inspection work. Specialized high-voltage testing for the thyristor valves was witnessed in Germany, testing of filter bank capacitors in Brazil, application-specific tests for the purpose-built converter transformers in Germany, standardized transformer testing in Italy and Mexico, testing of high voltage measuring devices in Romania, and inspection of miscellaneous equipment in Canada and the United States. One of the more complex systems tested was the HVDC protection and control equipment, the brain and nervous system for the converter stations, which needed to interface with both the switchyards and Manitoba Hydro's existing system. The complexity of this system meant that over 600 tests needed to be performed and verified while connected to state-of-the-art, real-time digital simulators. These tests were witness by both the Team and Manitoba Hydro subject matter experts, whom worked together daily for over four months to ensure functional and performance requirements were achieved.

PHASE 5 – CONSTRUCTION AND COMMISSIONING

As the project entered its final phase, the Team provided construction and commissioning support at the sites, as well as engineering services to coordinate the design interfaces. New personnel were brought on to provide site reviews of the work to confirm conformance to the approved design documents. The design development team remained involved but shifted to review of engineering change notices brought on by conflicts, varied site conditions, or improved construction methods.

The Team dispatched personnel to site for oversight related to piling, foundation work, building erection, building mechanical and electrical system review, underground works, and steel structure review. These personnel recoded daily logs of the ongoing work, noting issues that required resolution. Some members took more senior roles at site, assisting with administration of contracts. Up to a dozen members of the team were embedded within the Manitoba Hydro site construction teams at any one time.

As a specific example of the technical interdependence of the contracts and the innovative solutions that the Team provided to assist the construction work, the proximity of work on site sometimes raised concerns of potential damage and claims between contractors.

Case Study 8

The Challenge

At the northern site, the switchyard contractor needed to drive steel piles near recently installed transformers from another contract, raising concerns that vibrations from pile driving might negatively impact or damage the transformers.

The Solution

The Team had considerable experience monitoring vibrations during pile installations and also had access to vibration monitoring equipment. Working with Manitoba Hydro to coordinate with the contractors, it was agreed that the transformers would be monitored full-time and that pile installation would cease if vibrations were observed to approach maximum acceptable limits. The monitoring equipment was transported to site and the Team's qualified geotechnical personnel monitored the vibrations near the transformers while pile installation work was completed. The monitoring results ultimately indicated that the vibrations were within acceptable limits and no transformer damage occurred.

The successful use of the monitoring equipment by the Team propogated safe installation and mitigated potential claims between contractors.

The success of the monitoring led to several other vibration monitoring events at the site, including additional monitoring of the transformers and monitoring near a fresh concrete pour for one of the fire pumphouse buildings during the installation of transmission tower foundations.

The Team provided additional technical solutions as issues arose. For example, a portion of the project required large, concrete oil-containment basins to minimize the environmental impact of oil leaks or spills.

Case Study 9

The Challenge

Environmental protection was an important project driver; therefore, the Team specified tight tolerances for hydraulic integrity of oil containment basins. During the testing of the exterior oil containment basins, seepage was observed beyond the acceptable limit.

The Solution

The Team performed an assessment and created a crack propagation map that could be used to treat the cracks with a patch sealant. The remediation was intended to bring the basins into testing compliance. In the event of an oil release, the tanks would better resist seepage and mitigate against environmental contamination. The recommended repair protocol was implemented and subsequent testing of the basins identified that their integrity exceeded specified requirements.

As design details were finalized, the gaps and interfaces between contracts needed to be coordinated. The Team coordinated multiple interface packages, which required communication between the two parties responsible for each side of the interface (often with both sides still in the midst of finalizing details), and close coordination with the construction team as shifting site conditions needed to be confirmed. The interfaces included integrating fire alarm systems, coordinating deluge piping, high voltage cables, protection and control interfaces on site, and integrating controls into Manitoba Hydro's existing network. One of the unique interfaces required for this project was a control system that would dynamically control the reactive power being supplied by the synchronous condensers.

Case Study 10

The Challenge

The synchronous condensers are four independent spinning machines that together can inject 1000 MVAR of reactive power into Manitoba Hydro's transmission network. Manitoba Hydro wanted a way to jointly control the MVAR output of each machine to balance the voltage on the southern station's 230 kV bus based on a specific set point and balance the loading across the available machines. The control system would also need to provide automatic control of the unit transformer tap changer associated with each machine.

The controls needed to interface with the synchronous condenser manufacturer's digital control system and exchange data over a fibre-optic, local-area network to control the local machines. The system would also need to communicate with Manitoba Hydro's control centers located in Winnipeg, which control the entire electrical system within Manitoba.

The Solution

As the controls represented a new design that impacted multiple stakeholders within Manitoba Hydro, the first step was to develop a concept design report to confirm direction. The design was then finalized, and the controls procured and assembled in coordination with a local panel manufacturer. The system was then brought into Manitoba Hydro's facilities and tested with a Real Time Digital Simulator (RTDS), which is highly specialized hardware used in the power industry, to confirm the integration with the system. The system controls were ultimately successfully installed and commissioned.

In addition to creating unique designs to solve specific problems, the Team was also tasked with maintaining consistency across projects.

Case Study 11

The Challenge

In late 2003, a software bug in the alarm system of a control room in Akron, Ohio, made operators unaware of unfolding system conditions, leading to the second biggest blackout in world history, taking out power in eight US states and Ontario, in total affecting over 50 million people. This ripple effect speaks to the criticality of control networks in power systems, and also to the interconnections within the entire electrical system in North America. To prevent similar disastrous events from happening, all interconnected electrical systems within North America, including Manitoba Hydro's, must adhere

to the standards of and report to the North American Electric Reliability Corporation (NERC).

Since 2003, the electrical industry has evolved rapidly with the implementation of network-based control systems becoming more and more common. Now, not only are the electrical networks tightly integrated, but the communication protocols within each station are as well. As a result, NERC issued new Critical Infrastructure Protection (CIP) standards related to cyber security. Manitoba Hydro needed to ensure that all critical assets within its stations were protected, and that security measures were tracked and implemented consistently across all contracts.

The Solution

The Team first worked with Manitoba Hydro stakeholders to confirm consensus on the proposed approach to applying the standards. Then, all critical assets were identified and inventoried, as well as all systems and support systems that impacted those assets. For example, if information on one of the many networks within the station could be falsified to imply that an asset was failing or trigger an action on a support system, it could cause a series of cascading events that would ultimately take down the asset. As the converter sites use multiple electronic networks for communications, all designs had to be extensively reviewed to ensure all possible data pathways had been considered. The Team worked with the contractors responsible for each asset to document all possible avenues of influence. From this information, the Team developed a broader set of physical and electronic security perimeters to protect the assets. The Team then monitored the recording and upkeep of all security logs and protocols needed to maintain NERC compliance.

As a result, Manitobans can be confident in the security of the Bipole III system.

As construction drew to a close, the Team's involvement switched to providing commissioning expertise to Manitoba Hydro. The Team's participation in preparing, witnessing, and reviewing commissioning test results was intense and diverse, covering the critical HVDC valves, converter transformers, specialized HVDC valve cooling systems, control and protection systems, fibre-optic communications, transformers, building envelopes, building roof construction and flood leak testing, synchronous condenser cooling systems, building HVAC systems, building electrical, fire and security systems, and underground systems connecting the facilities to site civil infrastructure.

CONCLUSION

Over the course of eight years, the Teshmont and Stantec team provided key engineering services to Manitoba Hydro on an hour-to-hour and day-to-day basis that resulted in the successful design and installation of Canada's highest-rated HVDC link. To achieve this required extensive coordination across multiple disciplines and geographic locations, unique expertise and local knowledge, dedication, and quick thinking. As a result, Manitobans now rely upon and continuously benefit from a robust and redundant HVDC system that brings and will continue to bring clean, reliable power to current and future generations of Manitobans for decades to come.

Overall, the Teshmont/Stantec team contributed to the overall success of the project, including completion of the project on schedule and under budget.